March 27, 2013

Technical Data Report
Diablo Canyon Power Plant (DCCP)
San Simeon
LiDAR & Orthoimagery Survey

Prepared for:

Scot Wilson, PLS
PG&E Land Surveying &
Engineering Support
2730 Gateway Oaks Dr., Ste 220
Sacramento, CA 95833

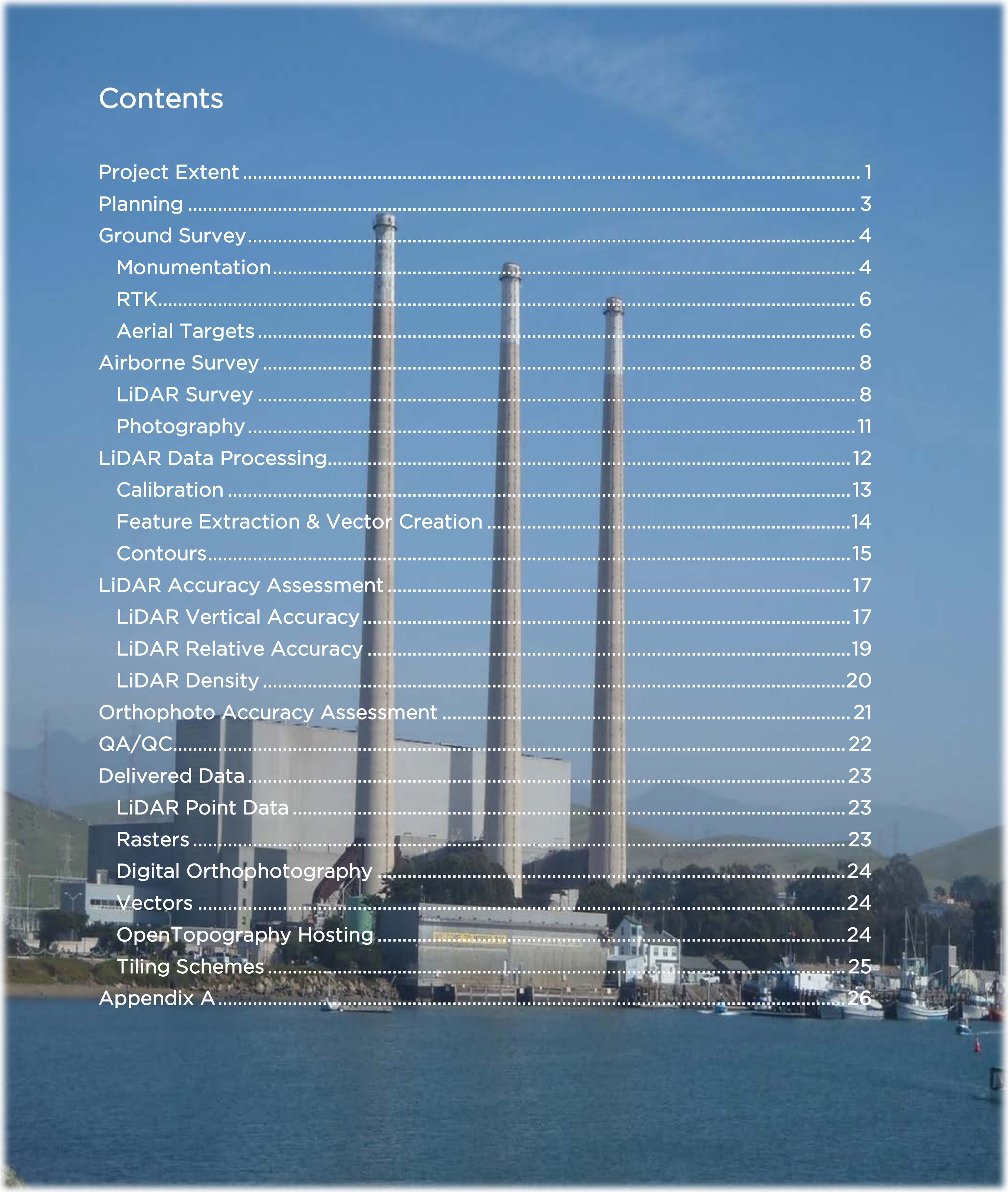
Scott Steinberg
Pacific Gas & Electric
Geosciences Department
245 Market St. Room 422 B
San Francisco, CA 94105

Prepared by:

WSI Portland Office
421 SW 6th Ave., Suite 800
Portland, OR 97204
PH: 503-505-5100
FX: 503-546-6801

Pacific Gas and Electric Company®

WSI Applied Remote Sensing and Analysis



Contents

Introduction

Beached Elephant Seals within the project study area. ➡

WSI is pleased to report that data collection, processing, and reporting are complete for the PG&E DCCP San Simeon LiDAR and Imagery Survey. Schedules, specifications, and resolution and accuracy statistics are presented within.

For optimal capture of the intertidal zone, WSI acquired LiDAR data of the coastline during seasonal low tides.

Project Extent

The DCCP San Simeon project study area is located primarily in San Luis Obispo County, California, and extends approximately 75 miles north to Monterey County. Overall LiDAR and orthophotography acquisition of the DCCP San Simeon survey area occurred between January 29 and February 25, 2013, and encompasses approximately 198,000 acres (801 square kilometers). For optimal capture of the intertidal zone, WSI acquired LiDAR data of the coastline during seasonal low tides between, February 7 and February 10, 2013. This survey was flown in conjuction with the DCCP Senior Seismic Hazard Analysis Committee (SSHAC) Level Three process and as part of the DCCP Long-Term Seismic Program (LTSP). Deliverables include LiDAR point data, digital orthophotos, rasters, and vectors of the study area.

LiDAR data, rasters, and orthophotos from the DCCP San Simeon survey will be simultaneously delivered to PG&E and OpenTopography, a public data domain. OpenTopography will have data uploaded and available for public consumption by March 29, 2013, thus fulfilling regulatory requirements. Survey data from 2010 and 2011 are currently available on OpenTopography.

Projection:

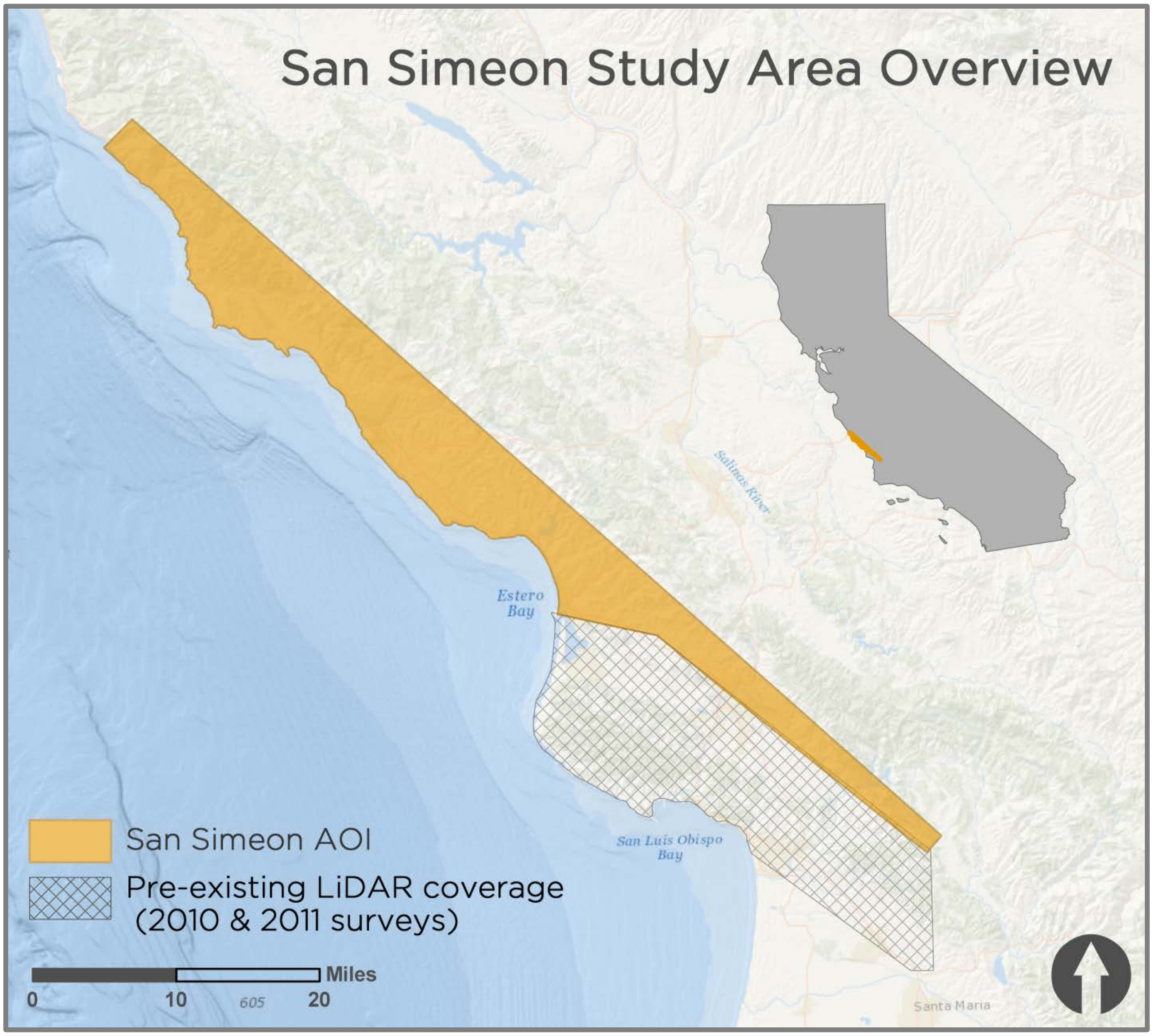
Universal Transverse Mercator Coordinate System, NAD83 (2011), Zone 10N

Datum:

North American Vertical Datum 1988 (NAVD88), GEOID 12A

Units:

Meters



PG&E DCCP San Simeon LiDAR & Imagery Survey			
	AOI (Acres)	Acquisition Dates*	Delivery Date**
LiDAR	198,529	2/7/2013 - 2/25/2013	3/21/2013
Orthophotos		1/29/2013 - 2/2/2013	

*See Aerial Survey section of report for detailed LiDAR acquisition dates regarding intertidal zone of survey area

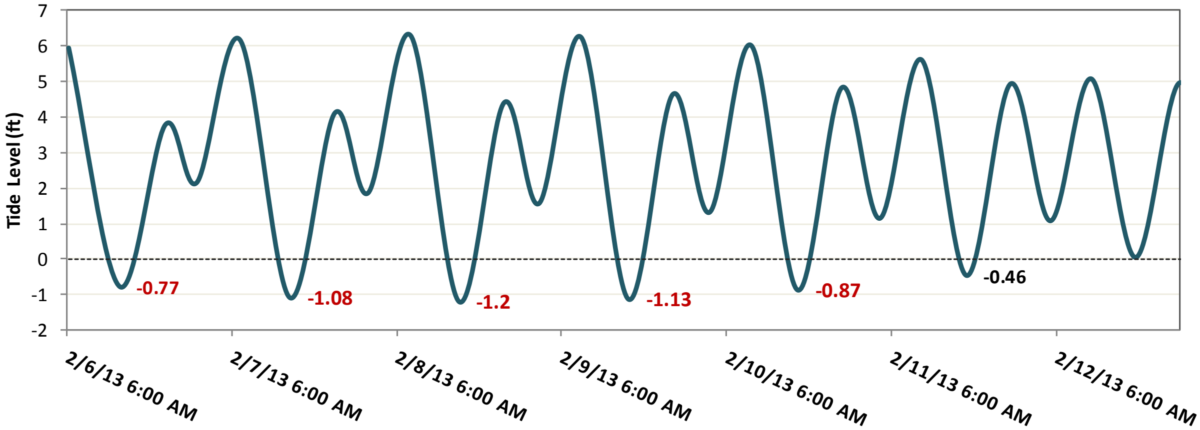
**Data will be simultaneously delivered to PG&E and Open Topography for public consumption on their website

Base station set up over monument "NERC_34" and radio unit within the San Simeon study area.

Planning

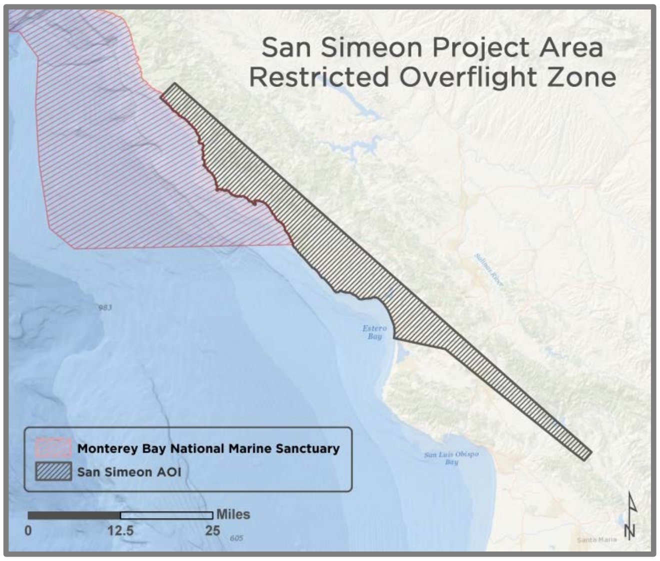
Flightlines were developed using ALTM-NAV Planner (v.3.0) software. Careful planning of the pulse rate, flight altitude, and ground speed ensured that data quality and coverage conditions were met while optimizing flight paths for minimal flight times.

The mission planning conducted at WSI was designed to optimize flight efficiency while meeting or exceeding project accuracy and resolution specifications. In this process, known factors were prepared for, such as GPS constellation availability, photography and acquisition windows, and resource allocation. To optimize LiDAR acquisition of the intertidal zone, National Oceanic and Atmospheric Administration (NOAA) tide tables (San Simeon Station, CA, ID: 9412553) were examined; acquisition was targeted for February 6-10th during seasonal low tides.



San Simeon area seasonal tide levels (NOAA). Red text indicates targeted acquisition dates.

In addition, a variety of logistical barriers were anticipated, namely, private property access, air space restrictions and acquisition personnel logistics. Within the Monterey Bay National Marine Sanctuary, a minimum overflight altitude of 2,000 ft (610 m) AGL is requested of pilots. Over designated areas within the sanctuary, flight below 1,000ft AGL violates NOAA regulations. Finally, weather hazards and conditions affecting flight were continuously monitored due to their impact on the daily success of airborne and ground operations.



Map of restricted overflight zone abutting study area

Ground Survey

Monumentation

Ground data was collected for every mission, which included establishing and occupying survey control, collecting static positional data, collecting ground check points (GCPs) using GPS real-time kinematic (RTK) survey with a narrow band roving radio relayed unit, and installing air targets.

Using the High Accuracy Reference Network (HARN) and the Continuous Operation Reference System (CORS), WSI tied to a network of points with orthometric heights determined by differential leveling. Where available, First Order National Geodetic Survey (NGS)-published monuments with NAVD88 are used. In the absence of NGS benchmarks, WSI produces our own monuments. For this project, three monuments were established by WSI (SANSIM_01, SANSIM_02, and SANSIM_03- see table on following page). Monuments established within or near the AOI for other PG&E projects were also utilized for this project (e.g., NERC_128). Monuments were spaced at a minimum of one mile apart and every effort was made to keep these monuments within the public right of way or on public lands. If monuments are required on private property, consent from the owner is required. All monumentation is done with 5/8" x 30" rebar topped with a two inch diameter aluminum cap stamped "Watershed Sciences, Inc. Control."

WSI owns and operates multiple sets of Trimble GPS and Global Navigation Satellite System (GNSS[1]) dual-frequency L1-L2 receivers, which were used in both static and RTK surveys (listed in the table on following page). During each LiDAR mission, a ground-based technician was deployed, outfitted with two Trimble Base Stations (R7) and one RTK Rover (R8 or R10).

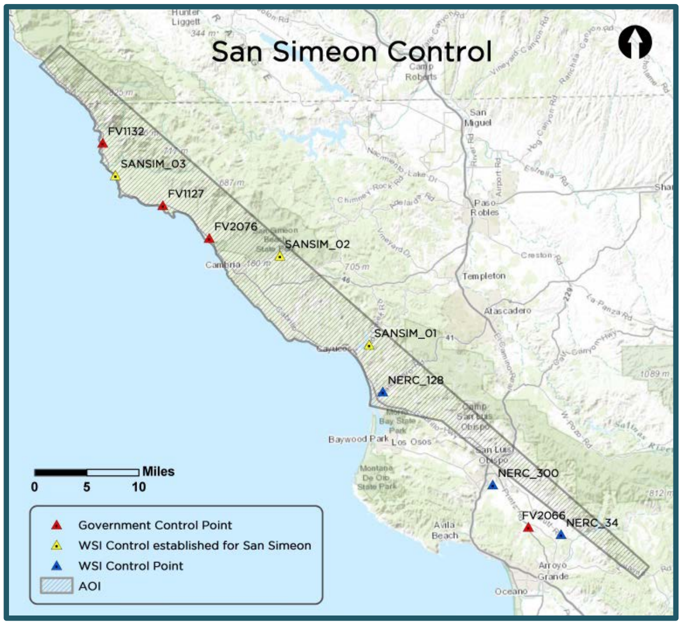
Base station over monument "NERC_128" and radio unit. Inset: Close-up of "NERC_128" monument.

[1] GNSS consists of the U.S. GPS constellation, British Galileo, and Soviet GLONASS constellation.

Final Monument Positions

All static control points were observed for a minimum of one two-hour session and one four-hour session. At the beginning of every session the tripod and antenna were reset, resulting in two independent instrument heights and data files. Fixed height tripods were used when available. Data were collected at a recording frequency of one Hertz using a 10 degree mask on the antenna.

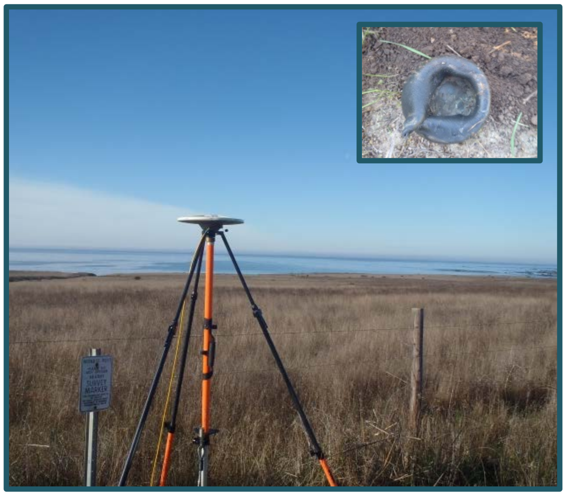
GPS data was uploaded to WSI servers daily for WSI PLS QA/QC and oversight. OPUS processing triangulated the monument position using three CORS stations resulting in a fully adjusted position. After multiple sessions of data collection at each monument, accuracy was calculated. Blue Marble Geographics Desktop v. 2.5.0 software was used to convert the geodetic positions from the OPUS reports. A total of 10 control monuments were surveyed for this project. Upon completion of the project, a total network adjustment was performed. All established monuments were certified by a California PLS (see Appendix A). The final monument positions are presented in the table below.



Monument Accuracy FGDC-STD-007.2-1998 Rating	
St Dev Northing, Easting	0.050 m
St Dev Z	0.050 m

PID	UTM	Latitude	Longitude	Ellipsoid
NERC_300		35 15 14.71682	-120 39 42.40098	6.833
FV2076		35 36 18.58907	-121 08 04.15469	-8.694
NERC_34		35 10 57.59392	-120 32 52.79575	76.685
NERC_128		35 23 11.94421	-120 50 40.83135	-6.328
FV1127	UTM	35 39 07.03101	-121 12 44.75320	-9.989
FV1132	10N	35 44 25.02834	-121 18 46.40081	-8.363
FV2066		35 11 38.77873	-120 36 11.35866	55.405
SANSIM_01		35 27 08.39270	-120 51 58.19595	87.049
SANSIM_02		35 34 43.89046	-121 00 53.30101	40.391
SANSIM_03		35 41 40.90670	-121 17 31.77729	-25.296

Monuments established for San Simeon survey. Coordinates are on the NAD83 (2011) datum, epoch 2010.00



Base station over monument "FV1127" Inset: Close-up of monument "FV1127"

Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2	TRM55972.00	Static
Trimble R8	Integrated Antenna R8 Model 2	TRM_R8_Model 2	Static & RTK
Trimble R10	Integrated Antenna R10	N/A	RTK

RTK

A Trimble R7 base unit was set up over an appropriate monument to broadcast a kinematic correction to a roving R8 or R10 unit. This RTK survey allows for precise location measurement ($\sigma \leq 2.0$ cm). All RTK measurements were made during periods with a Position Dilution of Precision (PDOP) of less than, or equal to, 3.0 and in view of at least six satellites by the stationary reference and roving receiver. For RTK data, the collector began recording after remaining stationary for five seconds, then calculated the pseudo range position from at least three one-second epochs with the relative error less than 1.5 cm horizontal and 2.0 cm vertical. RTK positions were collected on bare earth locations such as paved, gravel, or stable dirt roads, and other locations where the ground was clearly visible (and was likely to remain visible) from the sky during the data acquisition and RTK measurement periods. In order to facilitate comparisons with LiDAR data, RTK measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads.

"NERC_128" monument and associated RTK points

For each control monument, at least 50 RTK points were taken within five nautical miles of the base. The planned locations for these control points were determined prior to field deployment, and the suitability of these locations was verified on-site. Clusters of RTK were made up of no less than 25 points and were separated by no more than 20 miles. However, the distribution of RTK points depended on ground access constraints, and may not be equitably distributed throughout the study area.

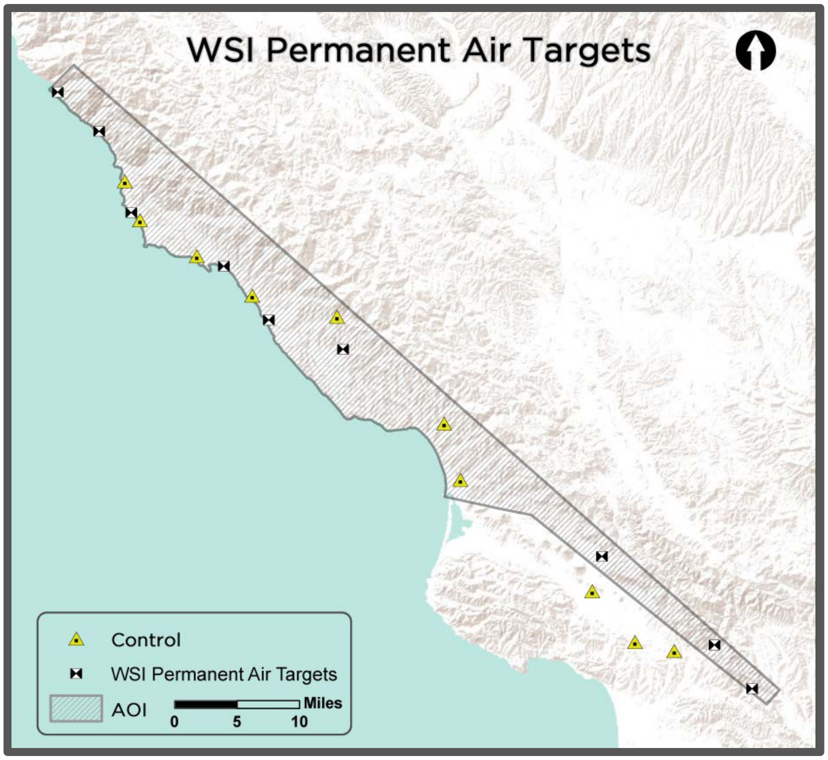
Aerial Targets

Prior to photo acquisition, aerial photo targets were installed throughout the study area. RTK Target Control Points (TCPs) were collected over each target for utilization in the processing and QC of the orthophoto deliverable. Several air targets were placed within radio range to each survey monument. Permanent TCPs are utilized in the processing and QC of the orthophoto deliverable.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

Permanent Targets

Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include painted lines on the pavement, existing aerial targets, arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. In addition to identified permanent air targets, a total of nine permanent air targets were painted prior to acquisition for the DCCP San Simeon survey by WSI.



Map of permanent air targets painted by WSI in the San Simeon project area. In addition to permanent air targets painted by WSI, other permanent targets were identified in the field and used for rectification of orthophotos during processing.

Specifications for Ground Level Data Collection	Survey Control Monuments	Ground Check Points (GCPs)	Target Check Points (TCPs)
Accuracy	$RMSE_{XY}$ ≤ 1.5 cm (0.6 in)	$RMSE_{XYZ}$ ≤ 1.5 cm (0.6 in)	$RMSE_{XYZ}$ ≤ 1.5 cm (0.6 in)
	$RMSE_{Z}$ ≤ 2.0 cm (0.8 in)	(Deviation from monument coordinates)	(Deviation from monument coordinates)
Resolution	Minimum of one per 13 nautical mile spacing	≥50 per surveyed monument	1-5 points per Air Target
	Minimum independent occupation of 4 hrs. & 2 hrs.	1181 Total	273 Total
Equipment	Trimble R7	Trimble R7	Trimble R7
	R8 GNSS	R8 GNSS or R10 GNSS	R8 GNSS or R10 GNSS
	GLONASS	GLONASS	GLONASS

Airborne Survey

Orthophoto acquisition was conducted between 10:00 AM and 2:30 PM each day. The table below is a summary of airborne acquisition for the DCCP San Simeon study area.

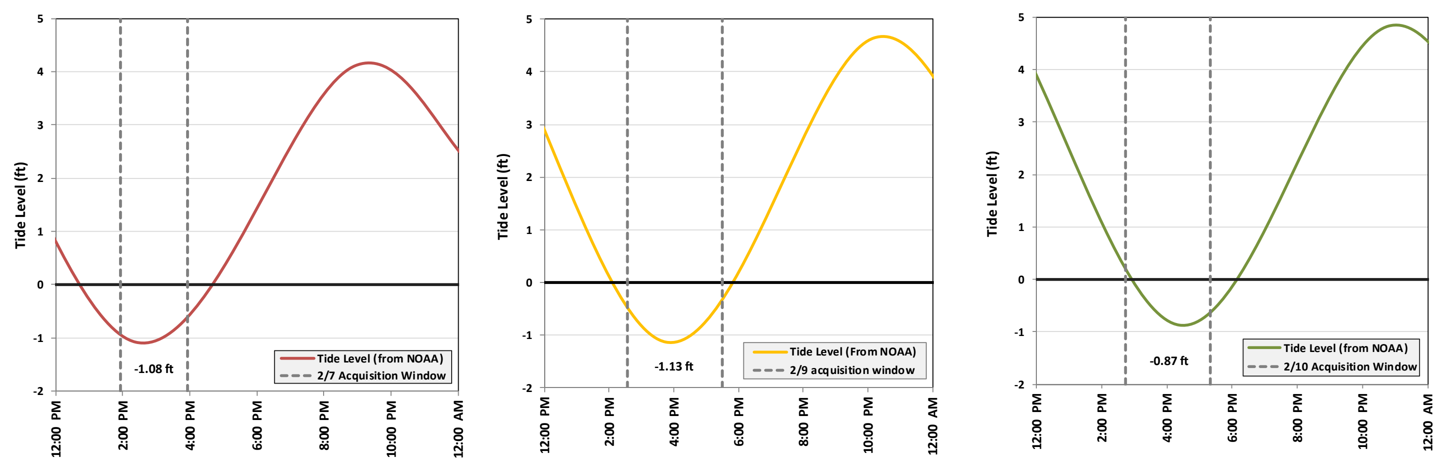
Data Collected	Equipment	Date Range	Aircraft	Elevation
LiDAR	Leica ALS70	2/9/2013-2/17/2013	Cessna Caravan	1100 m
	Optech Orion	2/7/2013, 2/9/2013 & 2/10/2013*	Bell Long Ranger	650 m
Orthophotos	UltraCam Eagle	1/29-2/2/2013	Cessna Caravan	760-1220 m

*In addition to intertidal LiDAR acquisition (2/7, 2/9 & 2/10/2013), the Optech Orion was also used to refly a small inland section of the AOI on 2/25/2013.

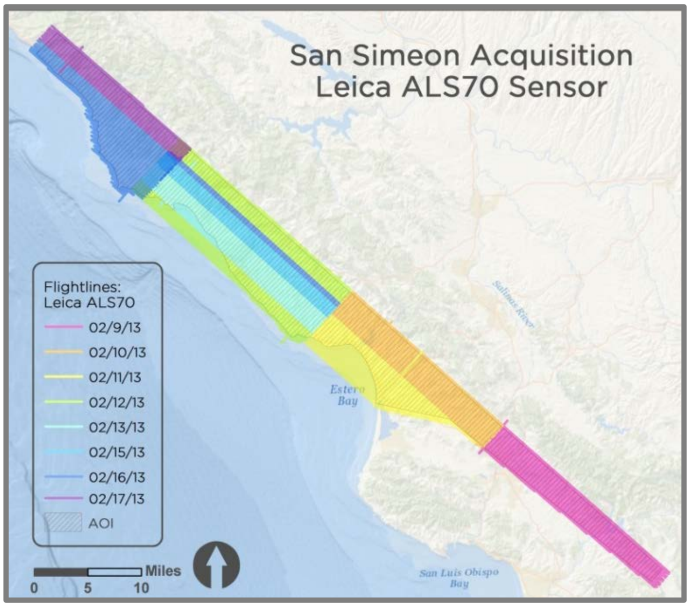
LiDAR Survey

The LiDAR survey utilized the Optech Orion sensor mounted to a Bell Long Ranger for acquisition of the intertidal portion of the study area. The system was set to acquire ≥175,000 laser pulses per second and flown at 650 meters Above Ground Level (AGL), capturing a scan angle of 13° from nadir. All intertidal LiDAR acquisition was conducted during negative low tides (see figure below for tide levels corresponding to acquisition).

February 7, 2013 | February 9, 2013 | February 10, 2013

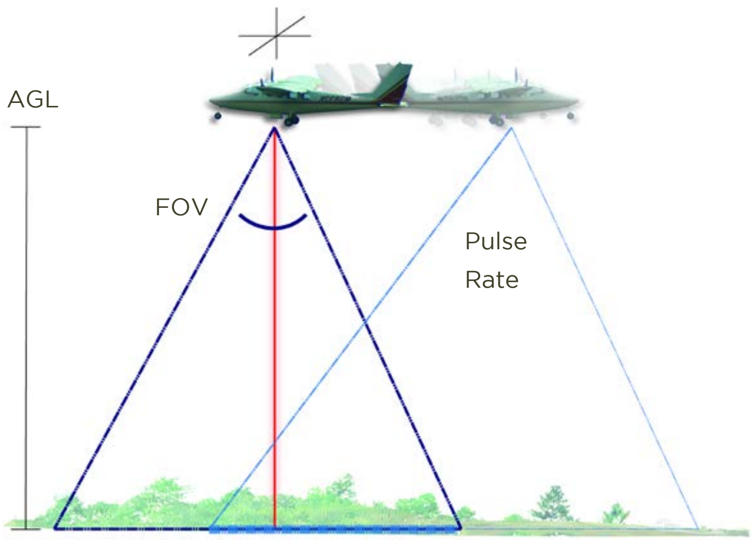


For the remainder of the study area, a Leica ALS70 sensor mounted in a Cessna Grand Caravan was employed. The system was set to acquire ≥240,000 laser pulses per second and flown at 1100 meters above ground level (AGL), capturing a scan angle of 15° from nadir.



The LiDAR system settings and flight parameters of both sensors were designed to yield high-resolution data of >15 pulses per square meter over terrestrial surfaces. To solve for laser point position, an accurate description of aircraft position and attitude is vital. Aircraft position is described as x, y, and z and was measured twice per second (2 Hz) by an onboard differential GPS unit. Aircraft attitude is described as pitch, roll, and yaw (heading), and was measured 200 times per second (200 Hz) from an onboard inertial measurement unit (IMU).

The LiDAR sensor operators constantly monitored the data collection settings during acquisition of the data, including pulse rate, power setting, scan rate, gain, field of view, and pulse mode. For each flight, the crew performed airborne calibration maneuvers designed to improve the calibration results during the data processing stage. They were also in constant communication with the ground crew to ensure proper ground GPS coverage for data quality. The LiDAR coverage was completed with no data gaps or voids, barring non-reflective surfaces (e.g. open water, wet asphalt). All necessary measures were taken to acquire data under conditions (i.e. minimum cloud decks) and in a manner (i.e. adherence to flight plans) that prevented the possibility of data gaps. Moreover, terrain following to maintain consistent aircraft altitudes eliminated the potential for data gaps related to both acquisition and laser shadowing of targets. All WSI LiDAR systems are calibrated per the manufacturer and our own specifications, and tested by WSI for internal consistency for every mission using proprietary methods.



The acquisition occurred at maximum solar zenith angles given latitude and time of year, under clear conditions with no cloud cover and less than 10% cloud shadow. Weather conditions were constantly assessed in flight, as adverse conditions not only affect data quality, but can prove unsafe for flying.

The study area was surveyed with opposing flight line side-lap of ≥60% (≥100% overlap) to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernible laser returns were processed for the output dataset.

LiDAR Survey Specifications		
Sensor	**Leica ALS70**	**Optech Orion**
Aircraft	Cessna Grand Caravan 604MD	Bell 206-L Long Ranger
Survey Altitude (AGL)	1,100 m	650 m
Laser Pulse Rate	≥240,000 Hz	≥175,000 Hz
Pulse Mode	Dual	Single
Mirror Scan Rate	52 Hz	62 Hz
Field of View	30˚	26˚
Percent Side-lap	60%	60%
Resolution/Density	> 15 pulses/m²	> 15 pulses/m²
Targeted Swath Width	191 m	300 m
GPS Baselines	≤13 nm	≤13 nm
GPS PDOP	≤3.0	N/A
GPS Satellite Constellation	≥6	≥6

Bell Long Ranger used for intertidal LiDAR acquisition

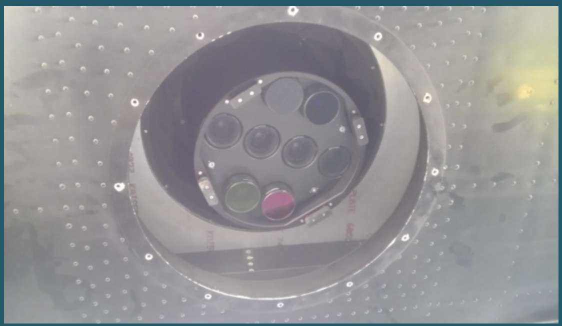
Cessna Caravan used for the remainder of acquisition

Photography

The photography survey utilized an UltraCam Eagle 260 megapixel camera mounted in a Cessna Grand Caravan.

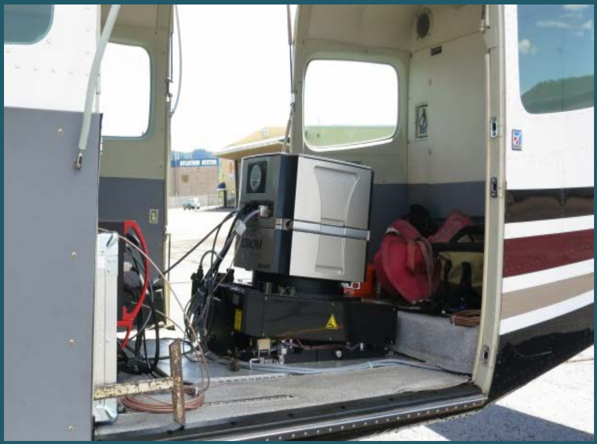
The UltraCam-Eagle is a large format digital aerial camera manufactured by the Microsoft Corporation. The system is gyro-stabilized and simultaneously collects panchromatic and multispectral (RGB, NIR) imagery. Panchromatic lenses collect high resolution imagery by illuminating nine CCD (charged coupled device) arrays, writing nine raw image files. RGB and NIR lenses collect lower resolution imagery, written as four individual raw image files. Level two images are created by stitching together raw image data from the 9 panchromatic CCDs, and ultimately combined with the multispectral image data to yield level three pan-sharpened tiffs.

UltraCam Eagle Manufacturer Specifications	
Focal Length	80mm
Data format	RGBNIR
Pixel size	5.2 µm
Image size	20,010 x 13,080 pixels
Frame rate	>1.8 seconds
FOV	66 x 46 deg.
GSD at 1000m	6.5 cm
Image Width at 800m	1,040 m
FOV	66 x 46 deg.



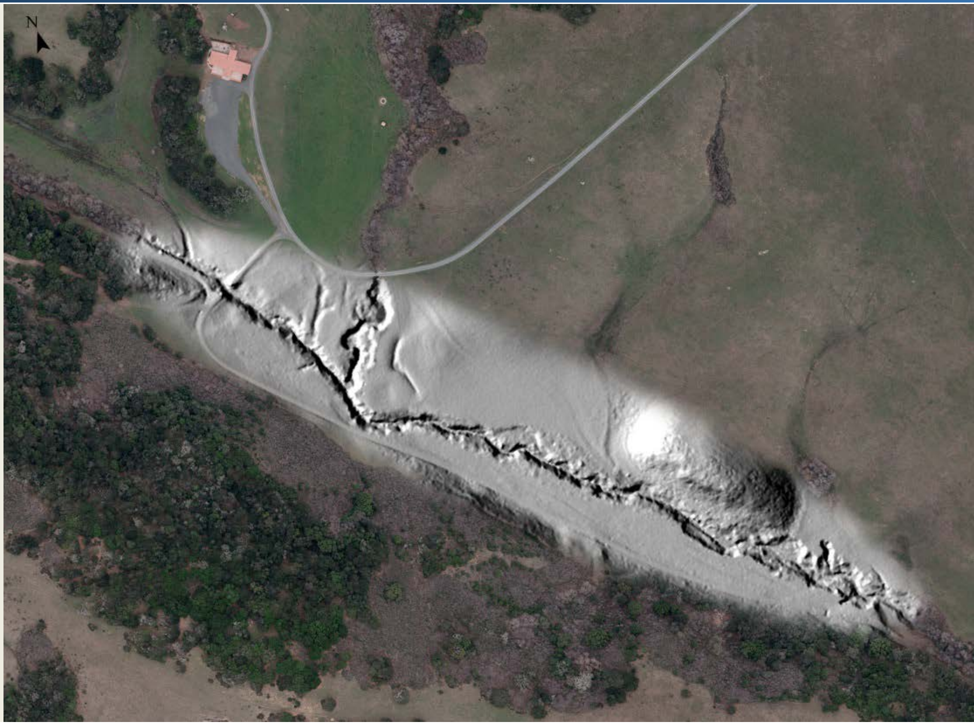
UltraCam Eagle lens configuration as viewed from the Cessna Caravan.

Above: A Cessna Grand Caravan 208B was employed in the collection of all orthoimagery. **Below:** UltraCam Eagle installed in the aircraft.



Digital Orthophotography Survey Specifications	
Sensor	UltraCam Eagle
Aircraft	Cessna Grand Caravan 208B
Height	760-1220 m AGL
GPS Satellite Constellation	≥6
GPS PDOP	≤3.0
GPS Baselines	≤16 nm
Image	8-bit GeoTIFF
Along Track Overlap	≥60%
Spectral Bands	Red, Green, Blue, NIR
Resolution	3-inch pixel size

Screenshot of custom hillshade showing the San Simeon Fault with a 3" orthophoto laid over.

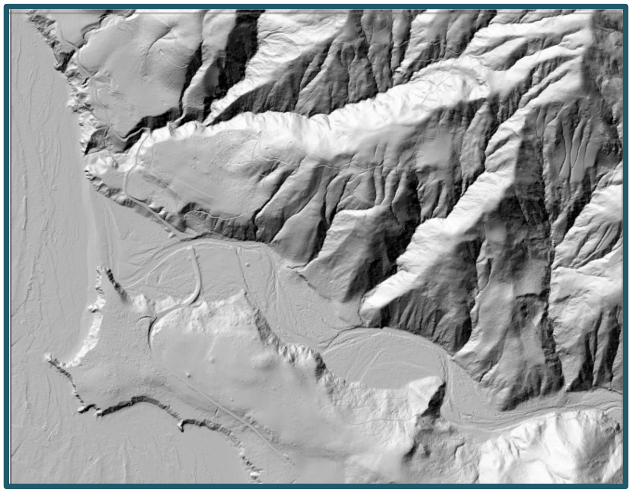


This section describes the processing methodologies for all data acquired by WSI for the DCCP San Simeon project, including LiDAR and orthophotography. All of our methodologies and deliverables are compliant with federal and industry specifications and guidelines (USGS v.13, FGDC NSSDA, and ASPRS).

LiDAR Data Processing

Once the LiDAR data arrived in the laboratory, WSI employed a suite of automated and manual techniques for processing tasks. Processing tasks included: GPS, kinematic corrections, calculation of laser point position, relative accuracy testing and calibrations, classification of ground and non-ground points, creation of contours and vegetation polygons, and assessments of statistical absolute accuracy.

LiDAR bare earth hillshade of San Carpòforo Creek entering the Pacific Ocean.



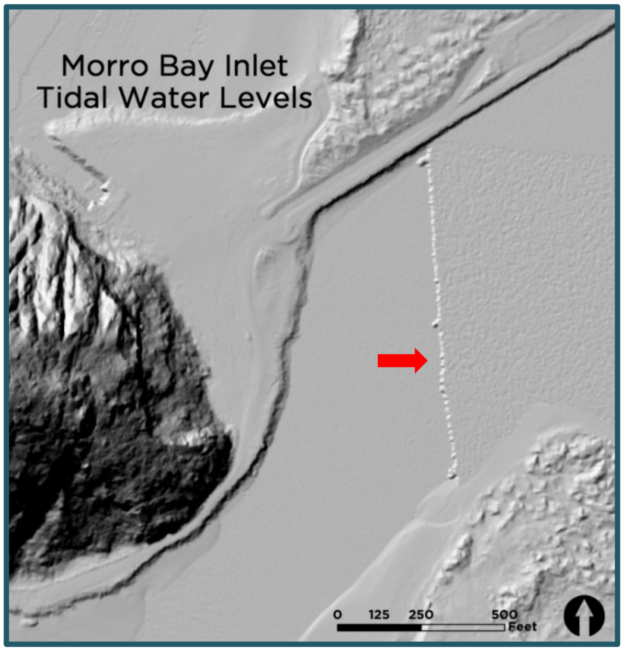
Calibration

The general workflow for calibration of the LiDAR data was as follows:

LiDAR Calibration Steps	Software Used
Resolve GPS kinematic corrections for aircraft position data using kinematic aircraft GPS (Collected at 2 Hz) and static ground GPS (1 Hz) data collected over geodetic controls.	POSGNSS v. 5.3, Trimble Business Center v. 2.81, PosPacMMS v 5.4
Develop a smoothed best estimate of trajectory (SBET) file that blends post-processed aircraft position with attitude data. Sensor heading, position, and attitude are calculated throughout the survey.	POSGNSS v. 5.3, PosPacMMS v5.4
Calculate laser point position by associating SBET information to each laser point return time, with offsets relative to scan angle, intensity, etc. included. This process creates the raw laser point cloud data for the entire survey in *.las (ASPRS v1.2) format, in which each point maintains the corresponding scan angle, return number (echo), intensity, and x, y, z information. These data are converted to orthometric elevation (NAVD88) by applying a Geoid 12A correction.	OPTECH LiDAR Mapping Suite (LMS) v. 2.1
Import raw laser points into subset bins (less than 500 MB, to accommodate file size constraints in processing software). Filter for noise and perform manual relative accuracy calibration. Ground points are then classified for individual flight lines to be used for relative accuracy testing and calibration.	TerraScan v.12, Custom Watershed Sciences software
Test relative accuracy using ground classified points per each flight line. Perform automated line-to-line calibrations for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Calibrations are performed on ground-classified points from paired flight lines. Every flight line is used for relative accuracy calibration.	TerraMatch v.13, TerraScan v.13, Custom WSI software
Assess Fundamental vertical accuracy via direct comparisons of ground-classified points to ground RTK survey data.	TerraScan v.13

Water surfaces that are rapidly changing through the influence of tides, wave action, or reservoir release can result in edge or shelf artifacts in digital elevation surfaces generated from LiDAR data. As a general practice, the LIDAR industry response to these conditions is typically to leave the artifacts in the data, without any effort to smooth or alter them. One guideline for LiDAR data (USGS LiDAR Base Specification v.1.0) states: "*Tidal variations over the course of collection or between different collections, will result in lateral and vertical discontinuities along shorelines. This is considered normal and these anomolies should be retained. The final DEM is required to represent as much ground as the collected data permits. Water surface is to be flat and level, to the degree allowed by the irregularities noted above.*" (Note: this project is not contractually bound to meet the details of the USGS LiDAR Base Specifications v.1.0).

Water surface discontinuities were observed within the Morro Bay inlet (see image to right) due to inland LiDAR acquisition occuring on a different day than coastal acquisition. To preserve geomorphologic integrity, no hydro-flattening was performed on this data.

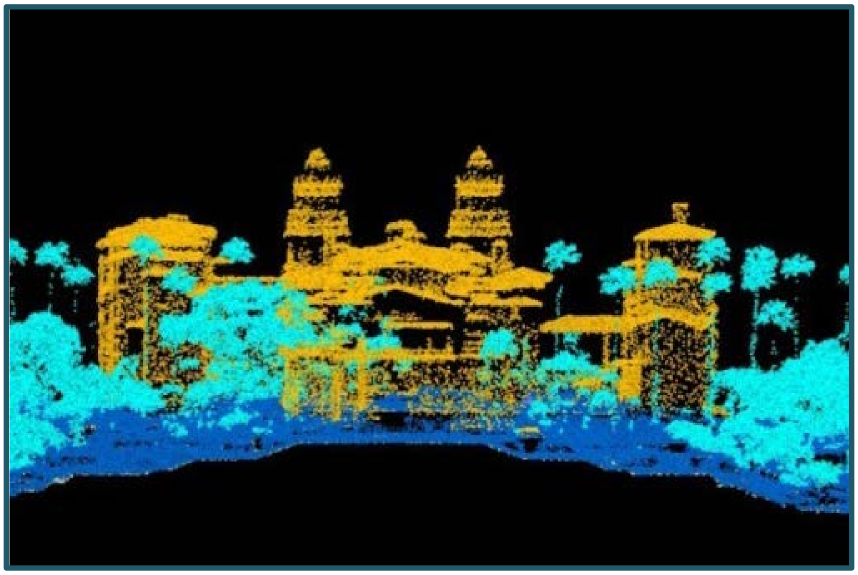


Discontinuities along the water surface within the inlet to Morro Bay can be observed in the above image (see red arrow). To preserve adjacent bank geomorphology, no hydro-flattening was performed.

Feature Extraction & Vector Creation

WSI employed in-house methods for LiDAR feature extraction, focusing on vegetation and ground. Accurate feature coding of the point cloud is essential for an accurate feature extraction analysis. Visual verification of correctness was conducted through a random sampling method that compares classifications to known areas identified in orthophotography. The general workflow for feature extraction was as follows:

LiDAR Point Classification and Vector Creation Workflow
Classify ground-level features and create the ground model.
After the ground model has been created and examined for correctness, vegetation points above 8 feet are then classified using a combination of automated and manual techniques.
Once vegetation is classified in the LiDAR point cloud, automated techniques are used to delineate individual units of vegetation. These automated techniques utilize the unique point geometry of vegetation to segment the individual units of vegetation and create crown polygons representing them.
The polygons representing individual units of vegetation (crown) are then aggregated with adjacent polygons to produce polygons representing stands.
Classify remaining points as default and check for accuracy before finalizing the point classification portion of the project.



Screenshot of classified LiDAR point cloud of the Hearst Castle. ⬆

LiDAR Point Classifications

- Ground
- Vegetation (above 8 ft)
- Default

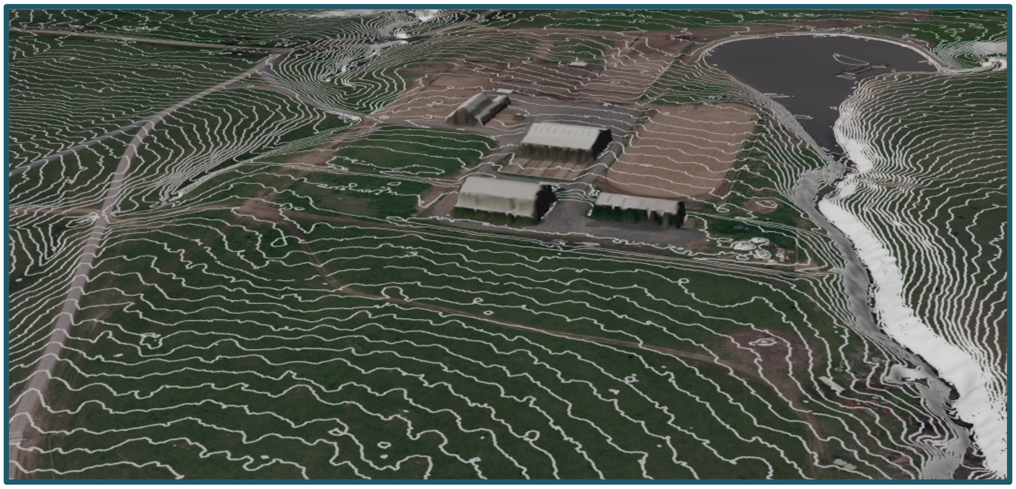
Planimetric Vectors

- Vegetation Crowns
- Vegetation Stands

Contours

Using automated processes, 1' (30.48 cm) contours were created for the entire DCCP San Simeon study area. Contour lines were clipped to cliff edges per PG&E request. The workflow for contour generation is as follows:

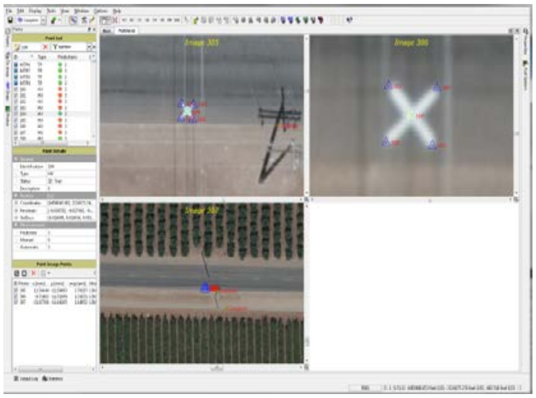
Contour Creation Workflow
Contour sinuosity was minimized through a smoothing operation based on elevation bounds and a thinning operation contstrained by elevation bounds within a sampling window.
Contour lines (1-foot intervals) were derived from ground-classified LiDAR point data using MicroStation v.8.01 and TerraModelor contour derivation tools.
Ground point density rasters were created within Microstation. Areas with less than 0.02 ground-classified points per square foot were considered as "sparse" and areas with higher densities were considered as "covered". Building vectors were generated and areas of intersect between point density rasters and building vectors were identified; building vector rasters were used instead of point density rasters for sparse contour generation.
Contour lines were intersected with ground point density rasters and a confidence field was added to the contour line shapefile. Contour lines over "sparse" areas have a low confidence, while contour lines over "covered" areas have a high confidence. Areas with low ground point density are commonly beneath buildings and bridges, in locations with extraordinarily dense vegetation, over water, and in other areas where the LiDAR laser is unable to sufficiently penetrate the ground surface.



LiDAR point cloud with RGB extraction from orthophotos and 1-foot contours overlaid. Contour lines in areas with sparse ground-classified LiDAR points, such as beneath buildings, are given a low confidence value (0,1) while contour lines in areas with high ground-classified LiDAR point density are given a high confidence value (255).

Orthophoto Processing

Digital orthophotos were collected using a 260 megapixel ultra large format digital aerial camera. Image radiometric values were calibrated to specific gain and exposure settings associated with each capture using Microsoft's UltraMap software suite. The calibrated images were saved in TIFF format for input to subsequent processes. Photo position and orientation were calculated by linking the time of image capture, the corresponding aircraft position and attitude, and the smoothed best estimate of trajectory (SBET) data in POSPAC. Within the Inpho software suite, automated aerial triangulation was performed to tie images together and adjust block to align with ground control. Adjusted images were then draped upon a ground model and orthorectified. Individual orthorectified tiffs were blended together to remove seams and corrected for any remaining radiometric differences between images using Inpho's OrthoVista. The processing workflow for orthophotos is as follows:



Inpho's MultiPhoto measured tool. Air target RTK is measured for use as orthophoto ground control.

Orthophoto Processing Step	Software
Resolve GPS kinematic corrections for aircraft position data using kinematic aircraft GPS (collected at one hertz) and static ground GPS (one hertz) data collected over geodetic controls.	Pos Pac MMS v. 6.1
Develop a smoothed best estimate of trajectory (SBET) file that blends post-processed aircraft position with attitude data. Sensor heading, position, and attitude will be calculated throughout the survey.	Pos Pac MMS v. 6.1
Create an exterior orientation file (EO) for each photo image with omega, phi, and kappa.	POS-EO and Pos Pac MMS v. 6.1.
Convert Level 00 raw imagery into geometrically corrected Level 02 image files,	UltraMap Raw Data Center v. 3.0
Apply radiometric adjustments to level two image files to create level three Pan-sharpened tiffs.	Ultra Map Radiometry v. 3.0
Apply EO to photos, measure ground control points and perform aerial triangulation.	Inpho Match-AT v. 5.5
Import DEM, orthorectify and clip triangulated photos to specified area of interest.	Inpho OrthoMaster v. 5.5
Mosaic orthorectified imagery, blending seams between individual photos and correcting for radiometric differences between photos.	Inpho OrthoVista v. 5.5

LiDAR point cloud of Morro Rock with extracted RGB values from Orthophotos.

WSI is committed to meeting or exceeding all contract specifications in order to provide PG&E with the highest quality LiDAR data, rasters and orthoimagery. This section presents the accuracy statistics for each area surveyed. Additionally, the project's cumulative statistics are presented.

WSI proposed an RMSE of <6cm for LiDAR Vertical Accuracy; an RMSE value of 2.6 cm was achieved for the San Simeon survey.

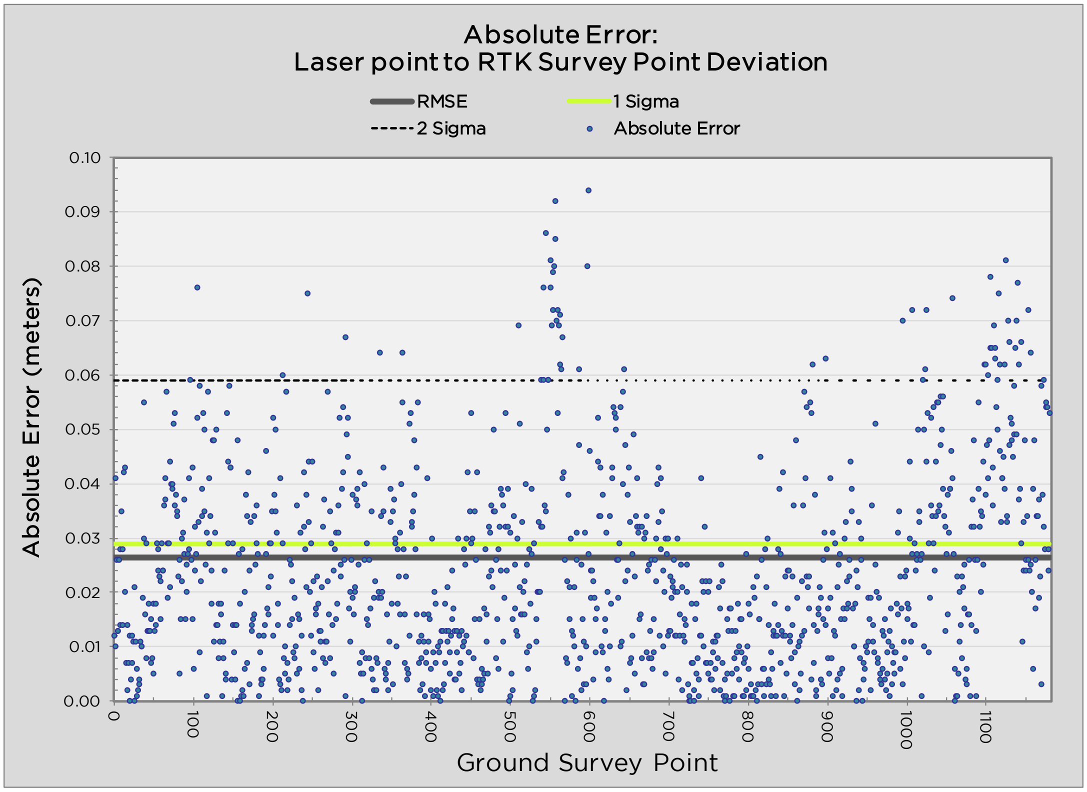
LiDAR Accuracy Assessment

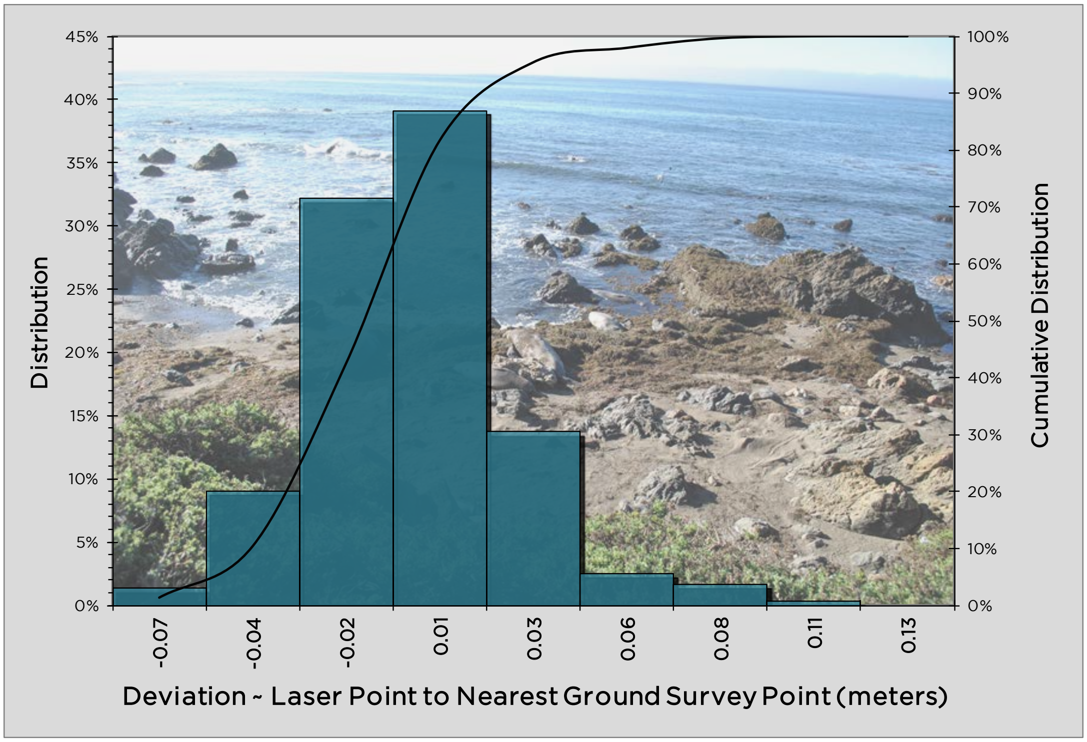
LiDAR Vertical Accuracy

Vertical absolute accuracy was primarily assessed from ground check points on open, bare earth surfaces with level slope. These check points enabled an effective assessment of swath-to-swath reproducibility and fundamental vertical accuracy. For the DCCP San Simeon LiDAR survery, 1,181 RTK points were collected in total. For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet," in accordance with the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004).

Absolute Vertical Accuracy Statistics	Meters	Feet
Sample Size	1,181 RTK points	
RMSE	0.026	0.086
1 Sigma	0.029	0.095
2 Sigma	0.059	0.194
Average Magnitude of Deviation	0.024	0.078

The absolute vertical accuracy (RMSE) for the DCCP San Simeon survey is 2.6 cm and was calculated with an RTK sample sixe of 1,181 GCPs spread throughout the study area.



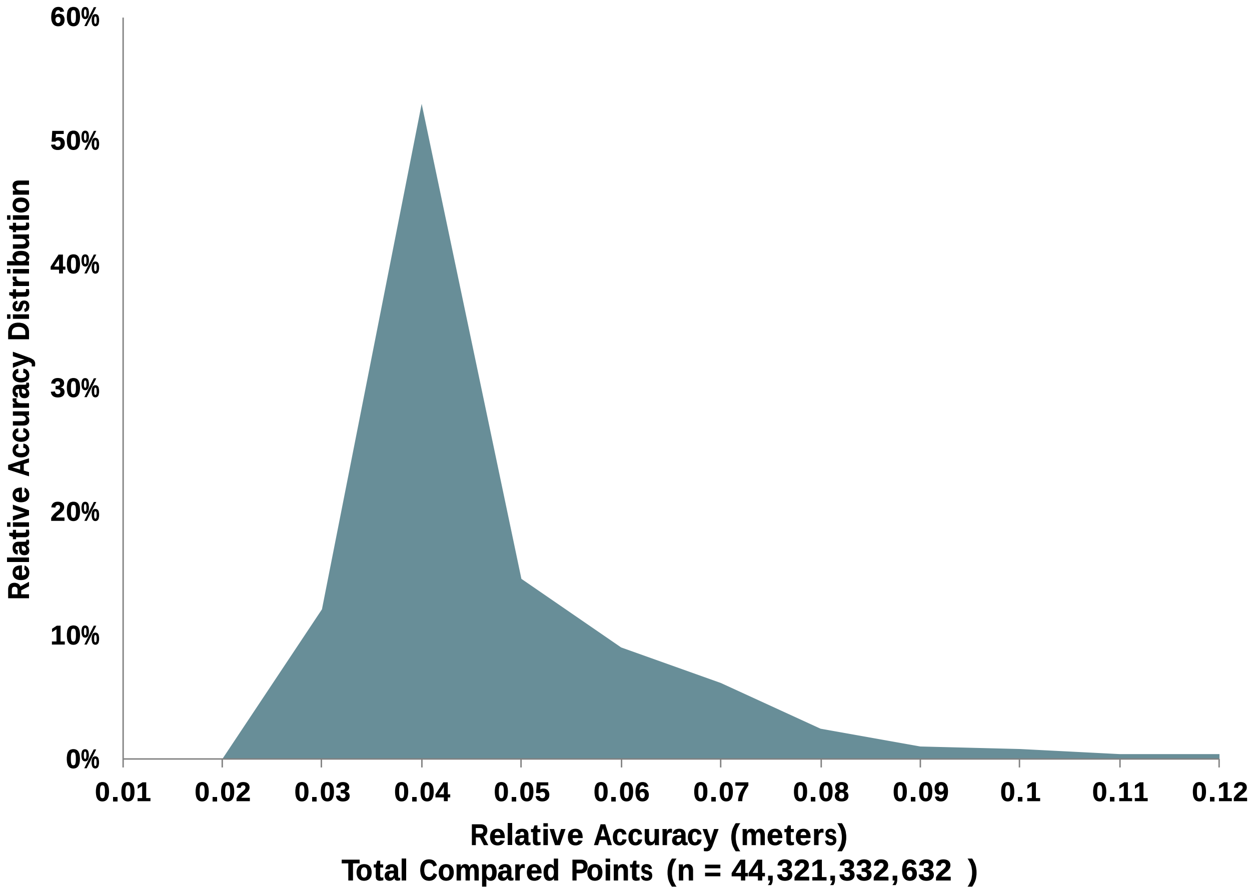


LiDAR Relative Accuracy

Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping area. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence is low (less than 10 centimeters). Internal consistency is affected by system attitude offsets (pitch, roll, and heading), mirror flex (scale), and GPS/IMU drift.

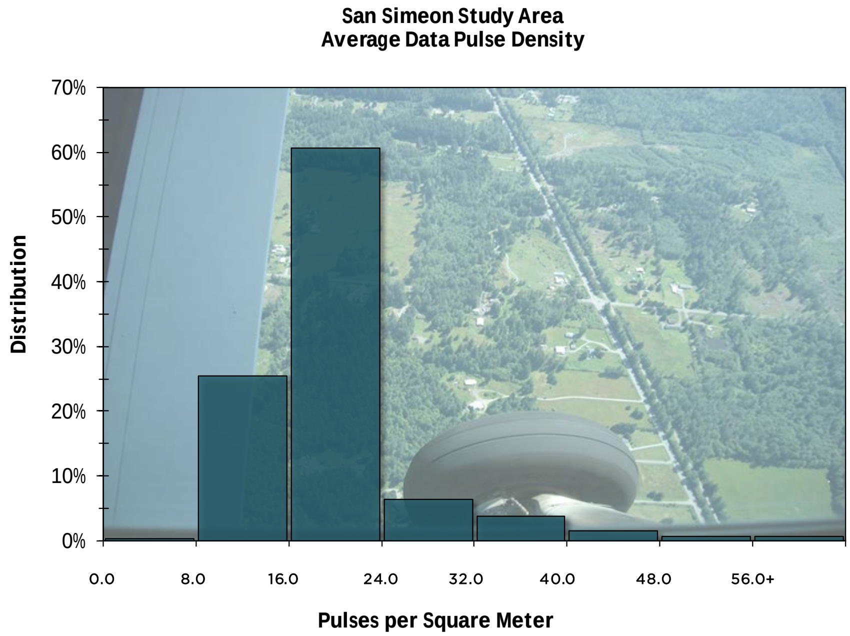
Relative accuracy statistics are based on the comparison of 940 flightlines and over 44 billion points. Relative accuracy is reported for the entire study area.

Relative Accuracy Statistics	Meters	Feet
Average	0.050	0.165
Median	0.041	0.135
1 Sigma	0.049	0.160
2 Sigma	0.095	0.313
Survey Points: 44,321,332,632		
Flightlines: 940		

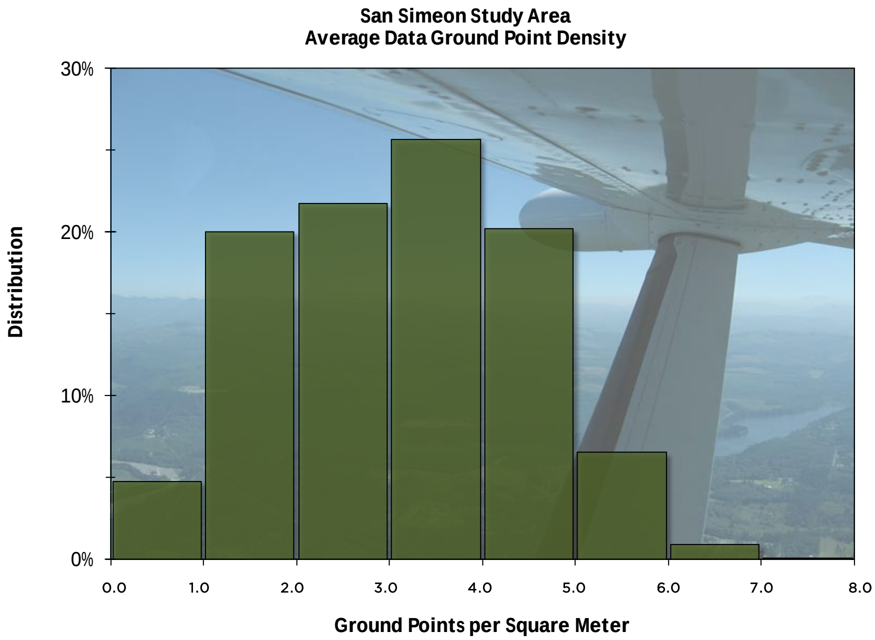


LiDAR Density

The native pulse density is the number of pulses emitted by the LiDAR system. The pulse density resolution specification for the DCCP San Simeon survey area is a minimum of 15 pulses per square meter (ppsm); WSI achieved 20.1 ppsm. Some types of surfaces (e.g. dense vegetation or water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover, and water bodies.



Average Data Pulse Density	
(pulses/m^2)	(pulses/ft^2)
20.1	1.6



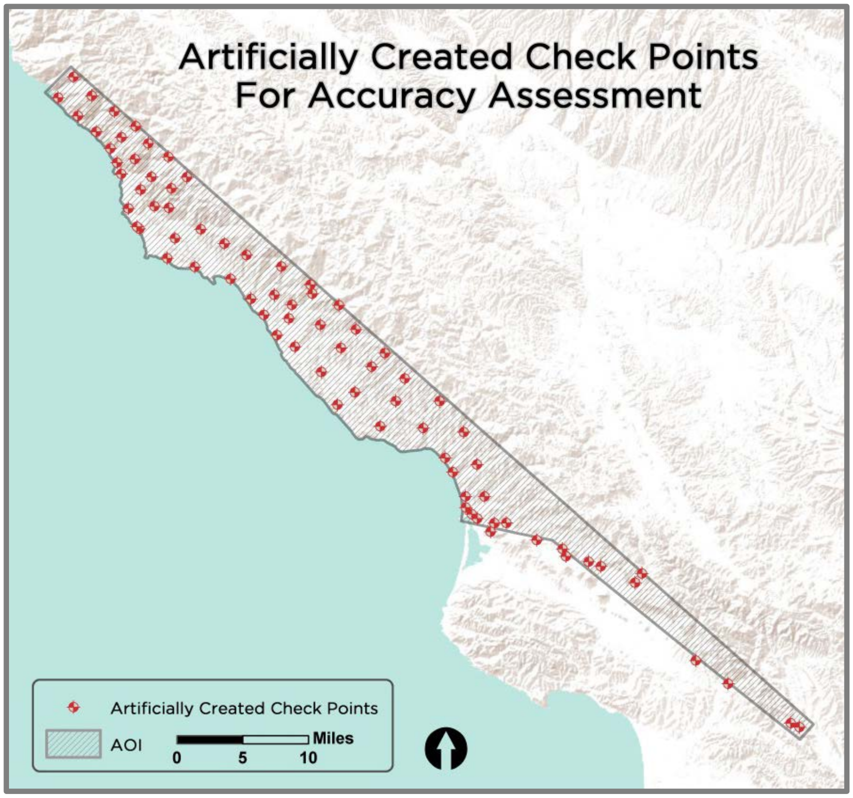
Average Ground Point Density	
(points/m^2)	(points/ft^2)
3.1	0.2

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Seventy-seven check points, distributed evenly across the total acquired area, were generated on surface features such as painted road lines and fixed high-contrast objects on the ground surface. They were then compared against control points identified from the LiDAR intensity images. The accuracy of the final mosaic was calculated in relation to the LiDAR-derived control points and is listed to the right.

Example of co-registration of color images with LiDAR intensity images. Artificially created check points from color images were compared against LiDAR-derived control points to assess orthophoto accuracy.

Orthophoto Horizontal Accuracy (n=77)	WSI Achieved (m)	WSI Achieved (ft)
RMSE	0.215	0.704
1 Sigma	0.222	0.728
2 Sigma	0.371	1.218

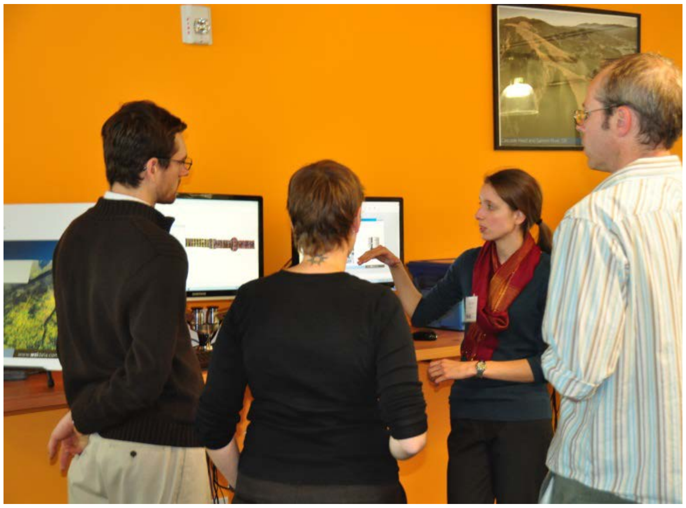


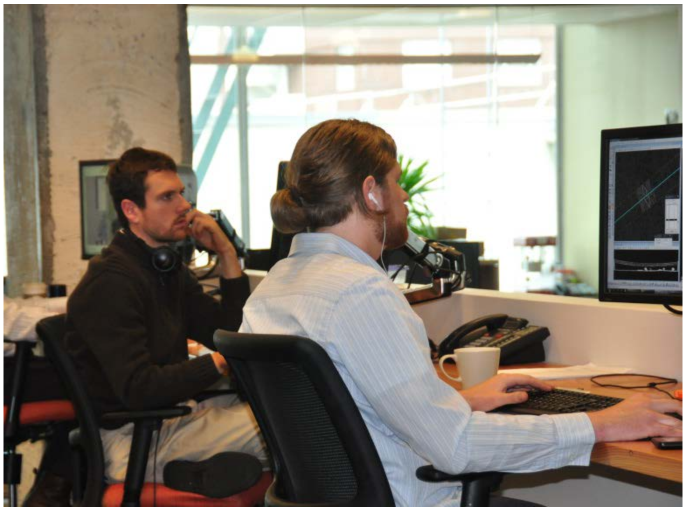
Map of artificially created check points used to assess orthophoto accuracy within the San Simeon project area.

QA/QC

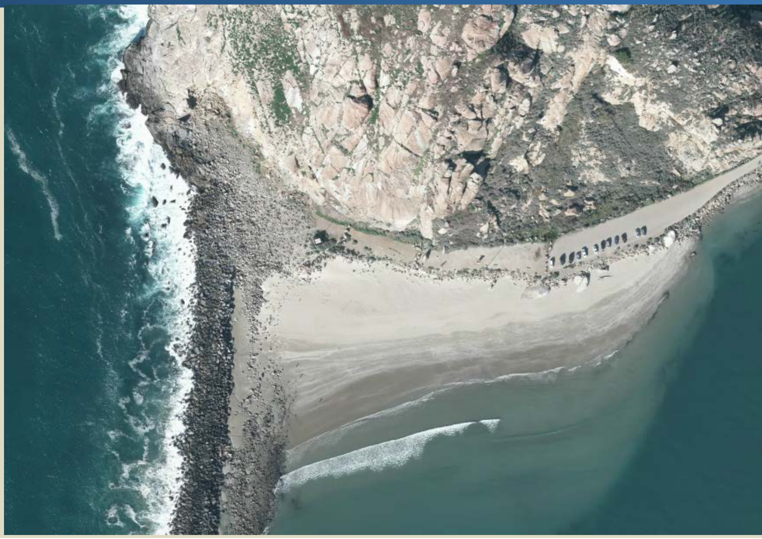
WSI has high standards and adheres to best practices in all efforts. In the field, rigorous quality control methods include deployment of base stations at pre-surveyed level one monuments, collecting RTK, and efficient planning to reduce flight times and mobilizations.

In the laboratory, quality checks are built in throughout processing steps, and automated methodology allows for rapid data processing. There is no off-shoring, which allows for in-house, US citizen-based project control for all data collection and processing. WSI's innovation and adaptive culture rises to technical challenges and the needs of clients like PG&E. Reporting and communication to our clients are prioritized through regular updates and meetings.





3" Orthophoto of Morro Rock and adjacent jetty.



WSI strives to provide the most comprehensive and user-friendly deliverable products possible. Deliverables can be categorized according to LiDAR, rasters, vectors, and orthophotography.

This section describes all specifications and deliverable formats that are required by PG&E for the DCCP San Simeon survey. WSI is committed to meeting or exceeding all data specifications at all times. Deliverables are designed to provide PG&E with accurate and useful information. Please note that not all PG&E deliverables are hosted by OpenTopography.

Delivered Data

LiDAR Point Data

LiDAR points (LAS 1.2) have been fully feature coded with the following attributes: Number, XYZ, Intensity (8-bit), Return Number, Class, GPS Time, and RGB values from orthophotography (8-bit). LiDAR points are delivered in a 0.375" (1/400 USGS Quad) tile scheme.

Rasters

Bare earth (BE) and highest hits (HH) DEMs are delivered in ESRI .shp format (7.5" USGS Quads). Multiple days of acquisition resulted in a difference in water levels within the Morro Bay inlet. To preserve geomorphological integrity, no hydro-flattening was performed on the data.

PG&E San Simeon Data Products:

- **Calibrated LiDAR Point Data**
  - **LAS 1.2**
- **Rasters (1-m resolution)**
  - **Bare Earth DEM**
  - **Highest Hit DEM**
- **Vectors (shapefile format)**
  - **Area of interest (AOI)**
  - **1-ft Contours (clipped to cliff edge polygon)**
  - **Cliff edge polygon**
  - **Vegetation Crown Polygons**
  - **Vegetation Stand Polygons**
- **Orthoimagery,**
  - **4-band (RGBI)**
  - **3-inch pixel resolution**
  - **Geo TIFF format**
- **Technical Data Report**

Digital Orthophotography

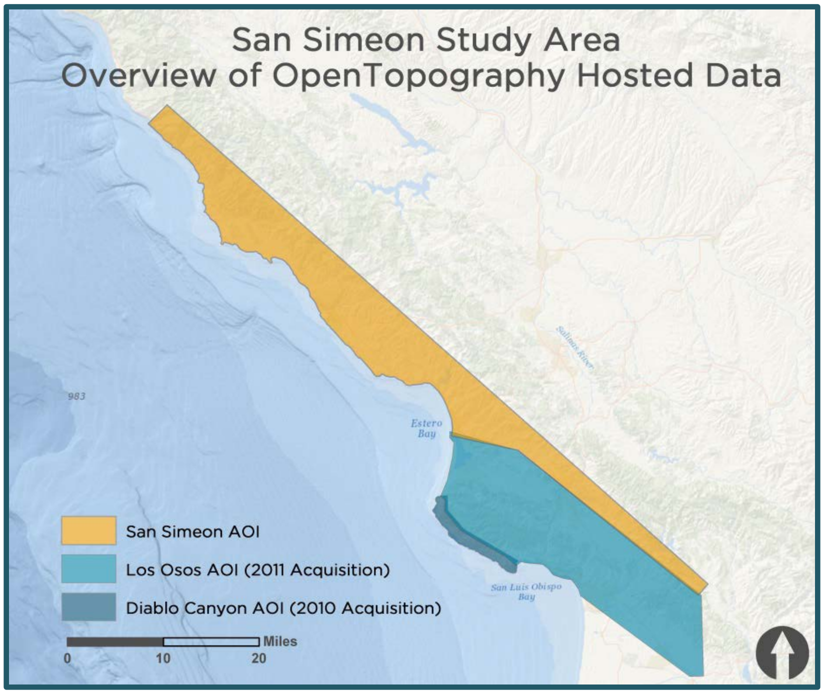
Four-band (RGBI) orthophotos with three-inch resolution are delivered in GeoTIFF format (0.375" tiles- 1/400 USGS Quad).

Vectors

Delivered vectors include: Area of Interest (AOI), tiling delineations, cliff edge polygon, vegetation crown and stand polygons, and 1' contours clipped to cliff edges (per PG&E request) in ESRI .shp format. All vectors are delivered in a 0.75" tile scheme (1/100 USGS Quad).

OpenTopography Hosting

OpenTopography, a data hosting service supported by the National Science Foundation, provides community access to high-resolution topographic data. WSI is sending full-resolution orthos, RGB-extracted LiDAR points (LAS 1.2), as well as Bare Earth and Highest Hits rasters, of the DCCP San Simeon Study Area to Open Topography concurrently with delivery of data to PG&E. LiDAR points, BE and HH rasters of Diablo Canyon and Los Osos Study Areas were previously acquired (in 2010 and 2011 respectively) by WSI and have been uploaded to OpenTopography (along with orthophotos collected in 2011 by Tetra Tech) and their respective data reports.



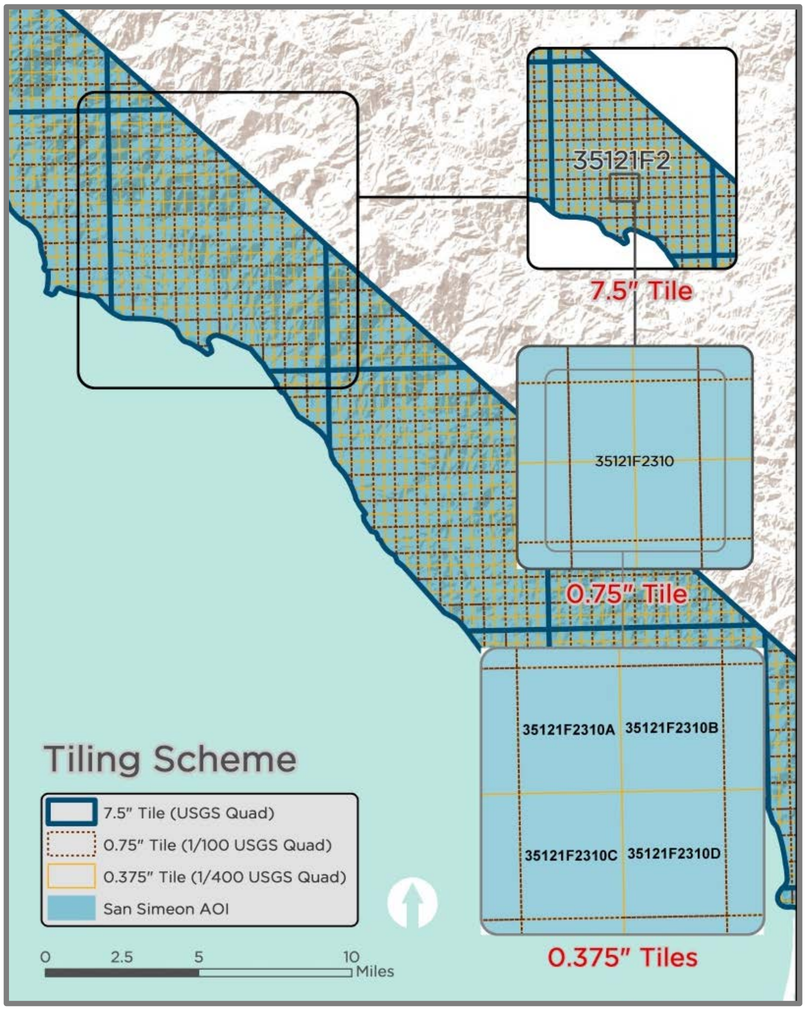
OpenTopography San Simeon Data Products:

- **Calibrated LiDAR Point Data**
- **Rasters (1-m resolution)**
  - **Bare Earth DEM**
  - **Highest Hit DEM**
- **Vectors (all shapefile format)**
  - **Area of interest**
- **Color infrared orthoimagery, 3-inch pixel resolution, Geo TIFF format**
- **Technical Data Report**

Tiling Schemes

Due to the high data density of deliverable products, WSI used custom tiling schemes for the various deliverable formats. The tiling scheme for each product is given in the following table. A visual is provided below with examples of each of the three tiling schemes.

Deliverable	Tiling Scheme	Tile Size	Data deliverd to:
Rasters (Bare Earth & Highest Hit DEM)	7.5" Tile	USGS Quad	PG&E, OpenTopography
Total Area Flown (TAF) Shapefile	Dissolved	NA	PG&E, OpenTopography
Contours, Vegetation Crown and Stand Polygons, Cliff Edge polygon	0.75" Tile	1/100 USGS Quad	PG&E
Caibrated LiDAR Point Data	0.375" Tile	1/400 USGS Quad	PG&E, OpenTopography
3" Orthophotos	0.375" Tile	1/400 USGS Quad	PG&E, OpenTopography
Data Report	NA	NA	PG&E, OpenTopography



A visual description of the three different tiling schemes used to deliver San Simeon LiDAR data, vectors, rasters, and orthophotography can be seen in the image to the left.

Appendix A

TUCKER & ASSOCIATES
Surveying and Mapping

GPS 1362 Lincoln Ave. ▪ Calistoga, CA 94515 ▪ 707 942-6001 ▪ Fax 707 942-0642

February 28, 2013

I herby certify the methodologies and results of the attached LIDAR Remote Sensing and Photo Control project (PG&E- San Simeon, located in San Luis Obispo County, California, as described in the above report as conducted by: **Watershed Sciences, Inc..**

Field work commenced on January 13, 2013 and was completed on February 17, 2013.

Thomas J. Tucker

CA PLS 4460

LICENSED LAND SURVEYOR
THOMAS J. TUCKER
No. 4460
State of California

Expires: 09/30/2013

POINT OF CONTACT

Susan Jackson
Chief Marketing Officer
Oakland, CA
PH: 510-910-8669
E: sjackson@wsidata.com

Thank You

WSI Portland Office
421 SW 6th Ave., Suite 800
Portland, OR 97204
PH: 503-505-5100
FX: 503-546-6801