



# Understanding strath terrace formation and abandonment, South Fork Eel River, California

## Mapping Project Report

### Principal Investigator: Jonathan. Perkins

University of California, Santa Cruz  
 513 Capp St., Apt. 1  
 San Francisco

e-mail: j.p.perkins@gmail.com  
 Phone: 916-715-1053  
 Fax: 510-643-7629

### Mapping Project Report Table of Contents

1. LiDAR System Description and Specifications .....	1
2. Survey Area. ....	2
3. Airborne Survey Planning Process. ....	4
4. LiDAR and GPS Data Collection Campaign.....	5
5. Data Processing and Final Product Generation. ....	5
6. Deliverables Description. ....	8
7. Appendices .....	<b>Error! Bookmark not defined.</b>

## 1. LiDAR System Description and Specifications

This survey was performed with an Optech GEMINI Airborne Laser Terrain Mapper (ALTM) serial number 06SEN195 mounted in a twin-engine Cessna Skymaster (Tail Number N337P). The instrument nominal specifications are listed in table 1.

Operating Altitude	150 - 4000 m, Nominal
Horizontal Accuracy	1/5,500 x altitude (m AGL); 1 sigma
Elevation Accuracy	5 - 30 cm; 1 sigma
Range Capture	Up to 4 range measurements, including 1 <sup>st</sup> , 2 <sup>nd</sup> , 3 <sup>rd</sup> , last returns
Intensity Capture	12-bit dynamic range for all recorded returns, including last returns
Scan FOV	0 - 50 degrees; Programmable in increments of ±1 degree
Scan Frequency	0 – 70 Hz
Scanner Product	Up to Scan angle x Scan frequency = 1000
Roll Compensation	±5 degrees at full FOV – more under reduced FOV
Pulse Rate Frequency	33 - 167 kHz
Position Orientation System	Applanix POS/AV 510 OEM includes embedded BD950 12-channel 10Hz GPS receiver
Laser Wavelength/Class	1047 nanometers / Class IV (FDA 21 CFR)
Beam Divergence nominal ( full angle)	Dual Divergence 0.25 mrad (1/e) or 0.80 mrad (1/e)

Table 1 – Optech GEMINI specifications

See <http://www.optech.ca> for more information from the manufacturer.

## 2. Survey Area.

The survey area was in the form of a 2.25 Km wide and 108 Km long corridor following the EEL River, located in California, about 250 Km north of San Francisco. The location is shown below

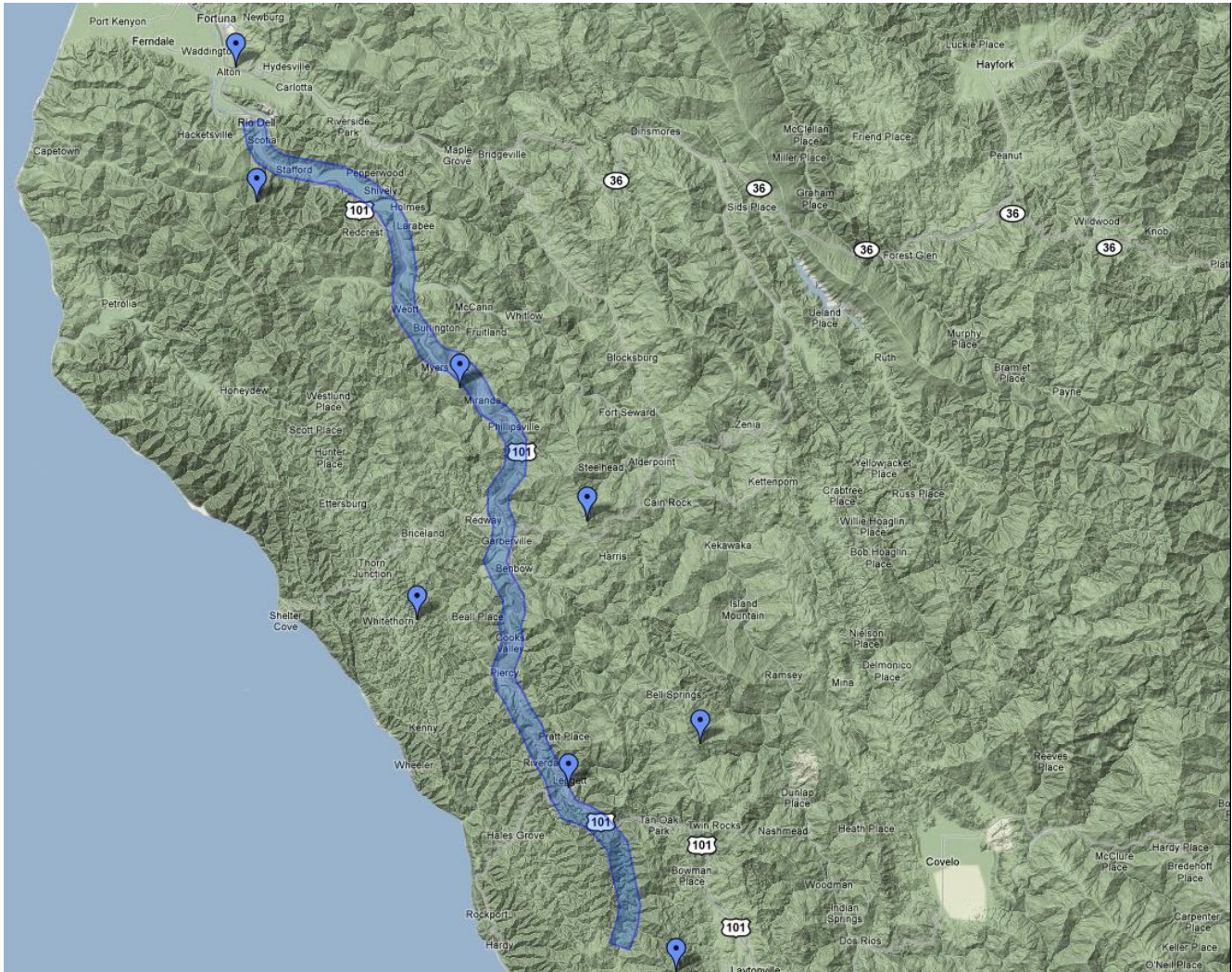


Figure 1(a) – Shape and location of survey polygon and Control GPS stations (Google Maps)



Figure 2(b) – Shape and location of survey polygon (TopoUSA)

### 3. Survey Planning and Parameters.

The survey was composed of a corridor 108 km long and 8 corridor lines. Figure 2 and Figure 3 (below) are images from the planning software showing both sets of planned flight lines along with other survey parameters.

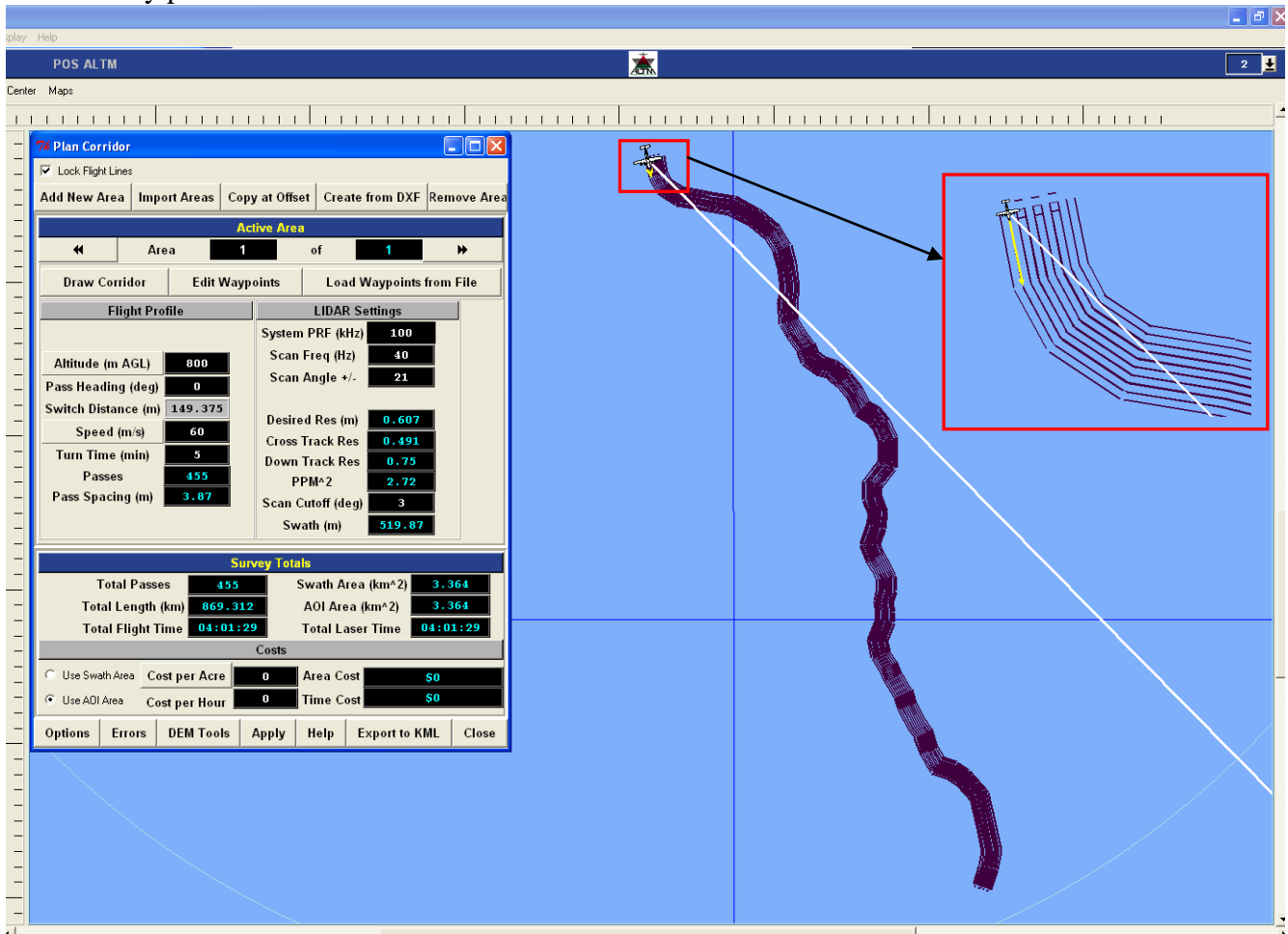


Figure 3 Flight lines from the planning software

Survey parameters are given below in Table 3.

Survey Parameters	
Altitude (m)	800
Swath Width (m)	520
Overlap (%)	50
Corridor passes	8
Laser PRF (kHz)	100
Scan Freq (Hz)	40
Scan Angle (degrees)	21
Scan Cutoff (degrees)	3

Table 3 – Survey parameters



## 4. LiDAR and GPS Data Collection Campaign.

This survey was flown as a part of Seed Money Survey Campaign that took place in Aug-Sept 2009. This section was completed in three survey flights: the first one was on Sept 4, 2009 (Day-Of-Year 247), second one on Sept 6, 09(249) and the last one was Sept 7, 09 (250). The airport used was Ukiah Municipal Airport in Ukiah California. The total flight time was 9 hrs 39 min. (including the time of transition to and from the airport) and the total Laser on time was 5 hrs 40 min. Area surveyed totaled to 243.86 square Kms.

Four GPS reference stations, all of them part of the CORS (Continuously operated Reference system) network were used during the survey. The list of the station and their locations is given below in table 4. The airborne receiver is an integrated GPS receiver module Trimble BD950, logging at 10 Hz.

Station Name	Lat	Long
P158	40.4225	-124.1072
P164	40.1193	-123.6933
P314	39.6857	-123.5828
P317	39.9057	-123.5528

Table 4 Ground Control Stations

## 5. Data Processing

### 5.1. GPS & INS Navigation Solution.

Reference coordinates for the stations were obtained from the CORS website. The GPS data required for differential processing was also downloaded from their website. For further information on the CORS network see <http://www.ngs.noaa.gov/CORS/>.

Airplane GPS trajectories for this survey were processed using KARS (Kinematic and Rapid Static), software created by Dr. Gerry Mader. KARS kinematic GPS processing uses the dual-frequency phase history files of the reference and airborne receivers to determine a high-accuracy fixed integer ionosphere-free differential solution at 1 Hz. GPS trajectories are created using all the above four mentioned ground control stations. These trajectories are then differenced to determine the best solutions. Figure 3 shows the plot for positional difference between trajectories obtained from P164 and P314. The table below gives the mean and standard deviation of the differences between the two trajectory positions.

	Easting	Northing	Up
Mean	-0.020	0.033	0.029
Standard dev.	0.009	0.012	0.022

Table 5 Mean and Standard Deviation for positional differences between the two trajectories

### Positional Differences in Aircraft Trajectory

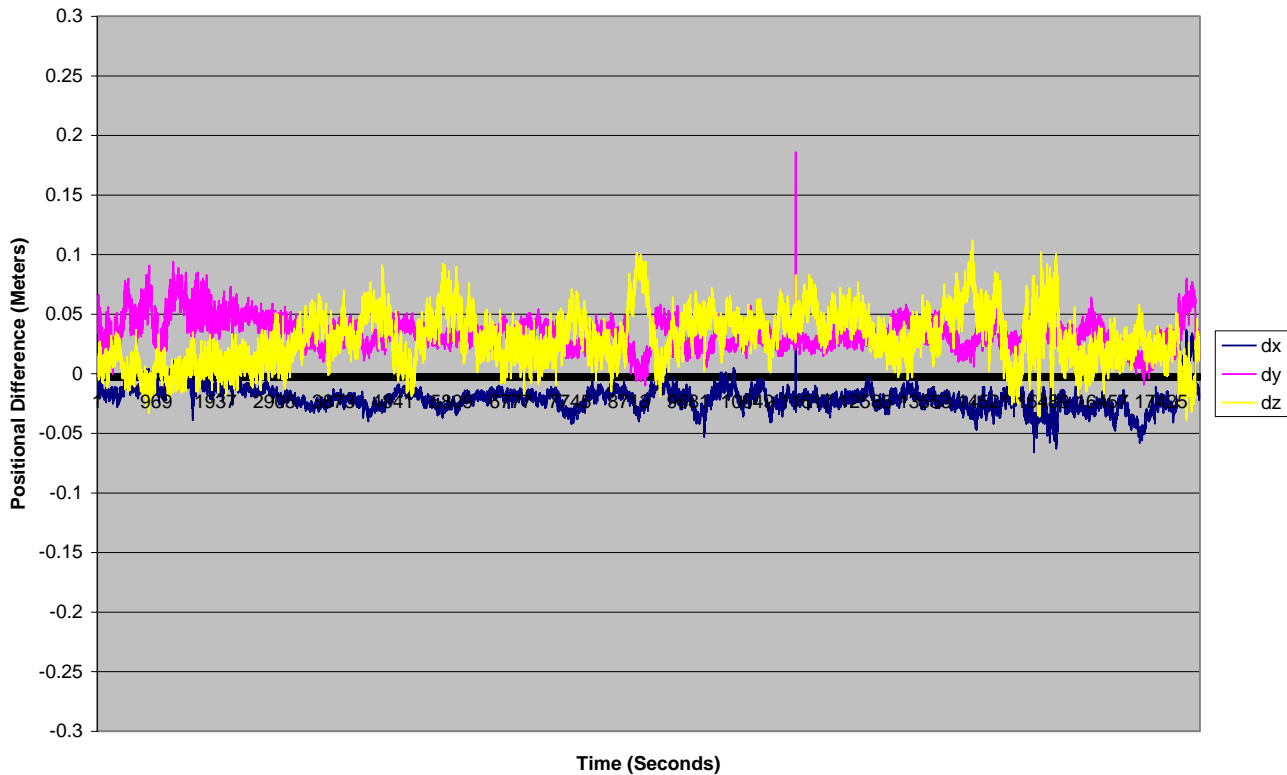


Figure 3 Positional differences between the two trajectories

After GPS processing, the 1Hz differential GPS trajectory and the Inertial Measurement Unit (IMU) data are processed together in the POSProc software (version 5.2). POSproc software combines GPS trajectory with the orientation information in a Kalman Filter to produce a final, smoothed and complete navigation solution at 200Hz. This final solution is known as the SBET (Smoothed Best Estimated Trajectory).

## 5.2 Laser Point Processing

An SBET together with laser ranges and mirror angles are finally combined in Optech's DashMap software (Version 4.1) to generate a flight-strip point cloud in LAS format. All point cloud coordinates were processed with respect to **NAD83** and referenced to the international CORS network. The projection is UTM Zone 10, with units in meters. **Heights are NAVD88** orthometric heights computed using the **NGS GEOID 03**. Scan angle cut-offs are done to improve the overall DEM accuracy as points farthest from the scan nadir are the most affected by small errors in pitch, roll and scanner mirror angle measurements.

## 5.3 Classification and Filtering

TerraSolid's TerraScan (<http://terrasolid.fi>) software was used to classify the last return LiDAR points and generate the "bare-earth" dataset.

The classification used for this project consists of two algorithms:

- 1) Removal of isolated points. This routine removes points that have no close neighbors (within 5 meters).
- 2) Ground Classification. This routine classifies ground points by iteratively building a triangulated surface model. The algorithm starts by selecting some local low points assumed as sure hits on the ground, within a specified windows size. This makes the algorithm particularly sensitive to low outliers in the initial dataset, hence the requirement of removing as many erroneous low points as possible in the first step.

The routine builds an initial model from selected low points. Triangles in this initial model are mostly below the ground with only the vertices touching ground. The routine then starts molding the model upwards by iteratively adding new laser points to it. Each added point makes the model follow ground surface more closely. Iteration parameters determine how close a point must be to a triangle plane so that the point can be accepted to the model. Iteration angle is the maximum angle between point, its projection on triangle plane and closest triangle vertex. The smaller the Iteration angle, the less eager the routine is to follow changes in the point cloud. Iteration distance parameter makes sure that the iteration does not make big jumps upwards when triangles are large. This helps to keep low buildings out of the model. The routine can also help avoid adding unnecessary points to the ground model by reducing the eagerness to add new points to ground inside a triangle with all edges shorter than a specified length.

Ground classification parameters used:  
Max Building Size (window size): 10.0 m  
Max Terrain Angle: 88.0  
Iteration Angle: 6.0  
Iteration Distance: 1.2 m

Overall there were a total of 295.6 million ground-class points for this project, or about 1.35 points per meter square. Put another way, approximately 12% of the ~11 shots per square meter yielded a ground-class point. But note that point density varies dramatically, from just a few ground-class points in a 10 x 10 meter area (100 meter square) in the thick jungle to over one thousand points in a treeless area similarly sized.

## 6. Deliverables.

- a) **Horizontal Datum:** NAD83(CORS96)
- b) **Vertical Datum:** NAVD 88, GEOID 03
- c) **Projection:** UTM Zone 10N
- d) **File Formats:**

1. Point Cloud in Ascii format, classified as ground or non-ground, in 1 km square tiles.
2. ESRI format 1-m DEM from ground classified points.
3. ESRI format 1-m Hillshade raster from ground classified points
4. ESRI format 1-m DEM from all points (canopy included).
5. ESRI format 1-m Hillshade raster from all points (canopy included).

**File naming convention:** 1 Km tiles follow a naming convention using the lower left coordinate (minimum X, Y) as the seed for the file name as follows: XXXXXX\_YYYYYYY. For example if the tile bounds coordinate values from easting equals 404000 through 405000, and northing equals 4483000 through 4484000 then the tile filename incorporates 404000\_4483000. These tile footprints are available as an AutoCAD DXF or ESRI shape file. The ESRI DEMs are single mosaic files created by combining together the 1KM tiles. Their name consists of prefix 'fme' and the lowest Easting coordinate rounded to the nearest 1000, for e.g. 'fme404000'. The hillshade files have a prefix 'sh' after the name, for e.g. 'fme404000sh'.