Data Collection & Processing Report for 2014 Seed Project: Fine Grained Patches in a Steep, Boulder-Bedded Channel – The Hydraulics of Bedrock-Forced Pools

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1. LiDAR System Description & Specifications

This survey was performed with an Optech ALTM Gemini (serial number: 06SEN195) and Optech ALTM Aquarius (serial number: 11SEN279) mounted in a twin-engine Piper PA-31-350 Navajo Chieftain (tail number: N154WW). The instrument nominal specifications are listed in **Table 1** and **Table 2**.

Laser Wavelength	1064 nm (Infrared)
Operating Altitude	150–4000 m AGL nominal
Range Capture	Up to 4 range measurements, including 1st, 2nd, 3rd, and last returns
Intensity Capture	12-bit dynamic range
Scan FOV	0–50°
Scan Frequency	0–70 Hz
Pulse Rate Frequency	33–167 kHz
Beam Divergence (Full Angle)	Dual divergence, 0.25 mrad (1/e) or 0.80 mrad (1/e) nominal
Position Orientation System	Applanix POS/AV 510 OEM, includes embedded BD960 72-channel 10 Hz (GPS) receiver

Table 1: Optech Gemini specifications

Laser Wavelength	532 nm (Green)
Operating Altitude	300–600 m AGL nominal (300–2500 m topography only)
Range Capture	Up to 4 range measurements, including 1st, 2nd ,3rd, and last returns
Intensity Capture	12-bit dynamic range
Scan FOV	0–50°
Scan Frequency	0–70 Hz
Pulse Rate Frequency	33–70 kHz
Laser Footprint on Water Surface	30–60 cm
Position Orientation System	Applanix POS/AV 510 OEM, includes embedded BD960 72-channel 10 Hz (GPS) receiver
Optional Full Waveform Capture	12-bit IWD-2 Intelligent Waveform Digitizer

Table 2: Optech Aquarius specifications

2. Area of Interest

The requested survey area consisted of two corridor polygons located over portions of Big Creek, a coastal drainage area in central California, south of Salinas and west of King City, CA. The polygons enclose approximately 1.7 km^2 (0.7 mi^2). **Figure 1** is an image from Google Earth showing the location of the survey.

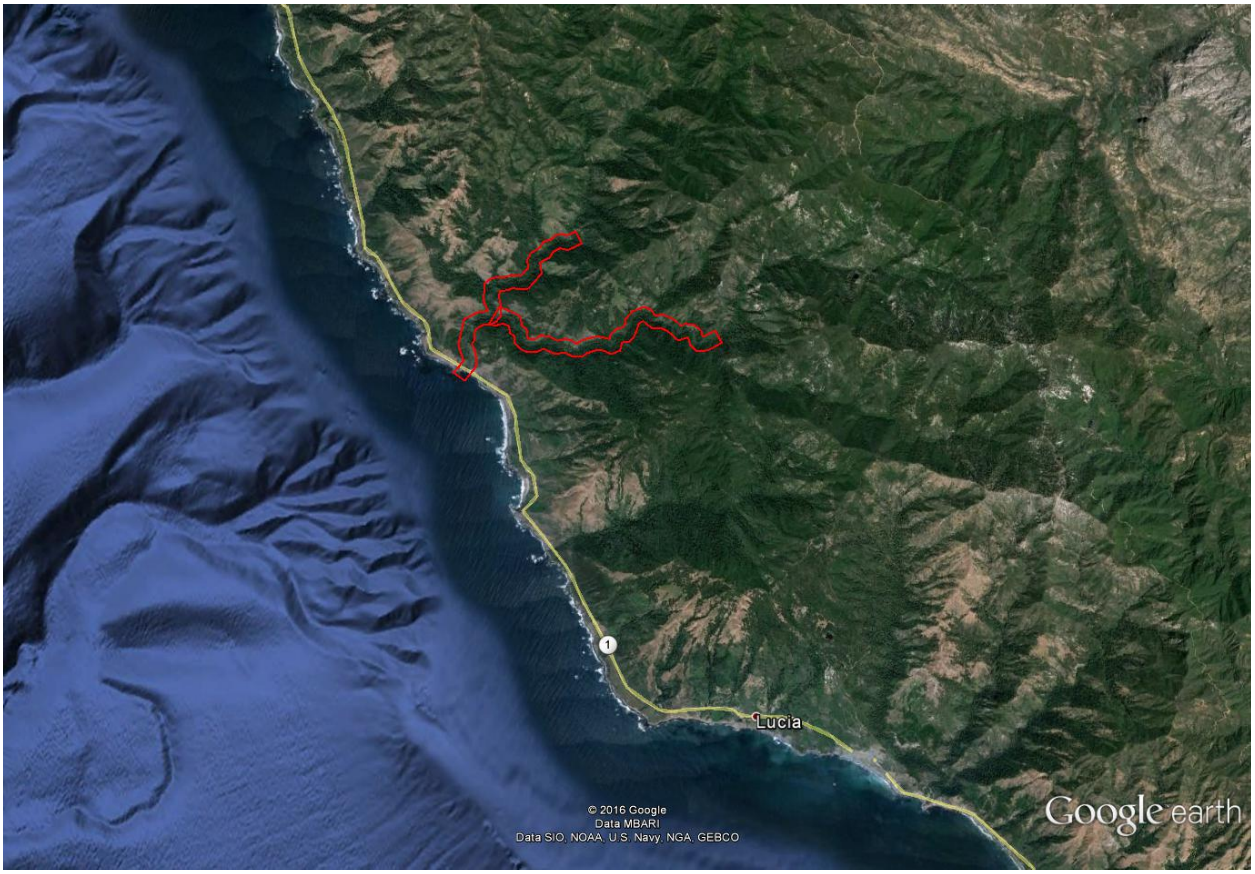

Figure 1: Location of survey polygon in red

3. Data Collection

a) Survey Dates: The survey took place on July 16–17, 2015 (DOY 197 and 199). The airport that served as the base of operation was the Salinas Municipal Airport (KSNS).

b) Airborne Survey Parameters: Survey parameters are provided in **Table 3** and **Table 4**.

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	900 m	Laser PRF	100 kHz	Total Flight Time	1.85 hr
Flight Speed	+/- 65 m/s	Beam Divergence	0.25 mrad	Total Laser Time	0.22 hr
Swath Width	850 m	Scan Frequency	35 Hz	Total Swath Area	10.4 km^2
Swath Overlap	~50%	Scan Angle	± 24°	Total AOI Area	1.7 km^2
Point Density	10 pt/m^2	Scan Cutoff	± 1°	Pass spacing	150 m

Table 3: Nominal flight parameters, equipment settings, and survey totals for Gemini flight (actual parameters vary with terrain)

Nominal Flight Parameters		Equipment Settings		Survey Totals	
Flight Altitude	900 m	Laser PRF	50 kHz	Total Flight Time	3.70 hr
Flight Speed	+/- 65 m/s	Beam Divergence	1.0 mrad	Total Laser Time	0.59 hr
Swath Width	850 m	Scan Frequency	35 Hz	Total Swath Area	9.6 km^2
Swath Overlap	~50%	Scan Angle	± 24°	Total AOI Area	1.7 km^2
Point Density	11 pt/m^2	Scan Cutoff	± 1°	Pass spacing	150 m

Table 4: Nominal flight parameters, equipment settings, and survey totals for Aquarius flight (actual parameters vary with terrain)

c) Ground GPS: Several UNAVCO PBO GPS reference stations were used during the survey. The GPS reference observations were logged at 1 Hz. **Table 5** gives the coordinates of the stations.

GPS Station	P171	P172	P173	P174	P180	QCY2
Agency	UNAVCO	UNAVCO	UNAVCO	UNAVCO	UNAVCO	UNAVCO
Latitude	36°29'07.88"	36°13'41.06"	36°59'44.57"	36°18'07.73"	36°17'34.18"	36°09'39.82"
W Longitude	121°47'33.0"	121°46'02.0"	121°17'25.2"	121°03'03.2"	121°24'11.6"	121°08'14.4"
Ell Elevation	573.301 m	313.200 m	339.826 m	342.706 m	693.760 m	102.020 m

Table 5: Coordinates of GPS reference station in NAD83(2011) epoch 2010.00, ellipsoid height in meters

4. GPS/IMU Data Processing

Reference coordinates (NAD83(2011) epoch 2010.00) for all stations are derived from observation sessions taken over the project duration and submitted to the NGS's on-line processor OPUS, which processes static differential baselines tied to the international CORS network. For further information on OPUS see: http://www.ngs.noaa.gov/OPUS/, and for more information on the CORS network see: http://www.ngs.noaa.gov/CORS/.

Airplane trajectories for this survey were processed using KARS (Kinematic and Rapid Static) software, written by Dr. Gerald Mader of the NGS Research Laboratory. 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. All final aircraft trajectories for this project (except in rare instances) are blended solutions from at least two of the three available stations.

After GPS processing, the 1-Hz trajectory solution and the 200-Hz raw inertial measurement unit (IMU) data, collected during the flights, are combined in APPLANIX software POSPac MMS (Mobile Mapping Suite Version 7.1). POSPac MMS implements a Kalman filter algorithm to produce a final, smoothed, and complete navigation solution, including both aircraft position and orientation at 200 Hz. This final navigation solution is known as an SBET (Smoothed Best Estimated Trajectory).

5. LiDAR Data Processing Overview

The following diagram (**Figure 2**) shows a general overview of the NCALM LiDAR data processing work-flow.

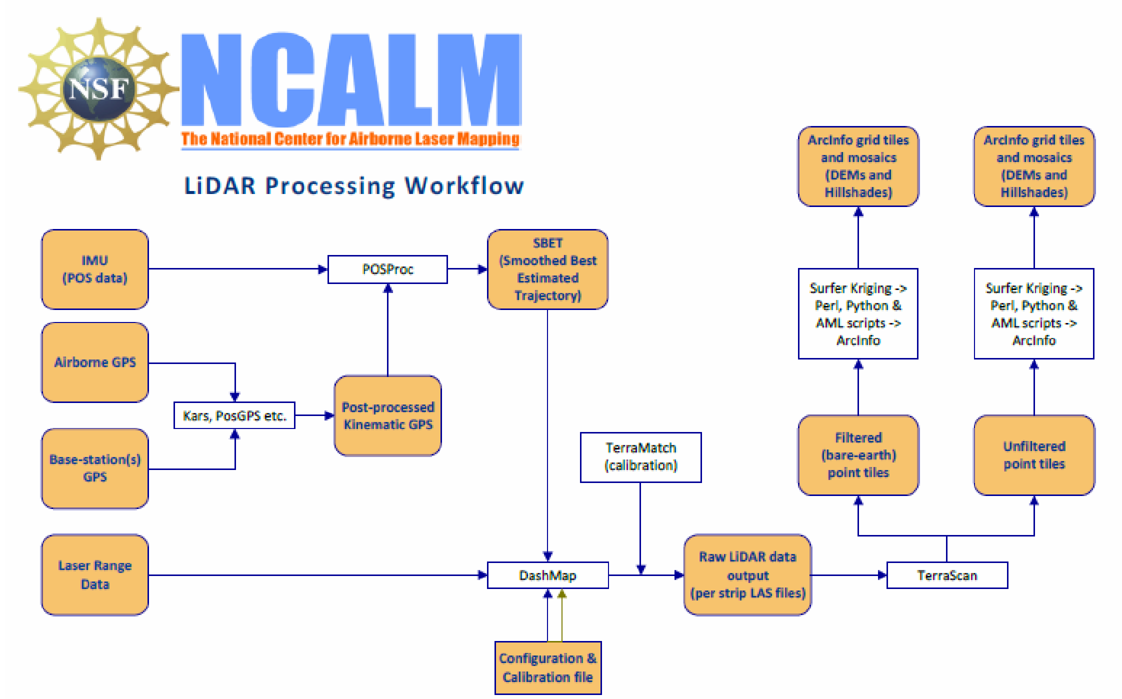

Figure 2: NCALM LiDAR processing workflow

There are some important differences in processing Aquarius range data with respect to the processing of traditional terrain or bathymetric systems. The main difference concerns the fact that the laser pulse can travel through both air and water. For the accurate determination of ranges, it is necessary to determine what portion of the laser pulse trajectory occurred in each medium, to account for the difference in the speed of light. Therefore, additional steps are involved in processing Aquarius data. This includes the classification of points representing laser shots that penetrated the water and correcting the elevation values for the above-mentioned phenomena.

Classification was done by automated means, using TerraSolid Software (TerraScan Version 15.033: http://www.terrasolid.com/products/terrascanpage.php).

NCALM makes every effort to produce the highest quality LiDAR data possible, but every LiDAR point cloud and derived DEM will have visible artifacts if it is examined at a sufficiently fine level. Examples of such artifacts include visible swath edges, corduroy (visible scan lines), errors in bathymetry determination, and data gaps. A detailed discussion on the causes of data artifacts, and how to recognize them, can be found here:
http://ncalm.berkeley.edu/reports/GEM_Rep_2005_01_002.pdf. A discussion of the procedures NCALM uses to ensure data quality can be found here:
http://ncalm.berkeley.edu/reports/NCALM_WhitePaper_v1.2.pdf.

NCALM cannot devote the required time to remove all artifacts from datasets. If researchers find areas with artifacts that influence their applications, they should contact NCALM, and we will assist them in removing the artifacts to the extent possible – but this may well involve the PIs devoting additional time and resources to this process.

6. Accuracy Assessment

a) Relative Accuracy: System calibration of the sensor's three boresight angles (roll, pitch, and yaw) and scanner mirror scale factor was done by automated means using TerraSolid Software (TerraMatch Version 15.022). Project lines or off-project lines flown with opposite headings, combined with perpendicular cross lines, are used as input in TerraMatch. These calibration values are checked on a flight-by-flight basis.

After the calibration values are optimized, project flight lines are output and classified into ground and non-ground classes. Surfaces are developed for each flight strip from the ground class points, then these individual flight strip surfaces are differenced, and a value for the magnitude of the height mismatch over the entire project area is calculated.

For the surveyed area, the average magnitude for vertical mismatch of ground surfaces (unsigned vertical differences between flight strips) in overlap zones for Gemini and Aquarius data is 0.196 and 0.164 m, respectively.

b) Absolute Accuracy: No ground check points were collected for this project, so a small (< 0.15 m) vertical bias in the elevations of the final point cloud and DEM may exist, with respect to NAVD88. Note that any LiDAR-derived DEM accuracy will usually degrade on steep terrain and under canopy. Bathymetry points from the Aquarius (green laser) data were determined using Gemini (infrared laser) data as control, so any bias may potentially be compounded further.

7. Data Deliverables

a) Horizontal Datum: NAD83(2011)

b) Vertical Datum: NAVD88 (GEOID12A)

c) Projection: UTM Zone 10N

d) Units: Meters

e) File Formats:

1. Point cloud in LAS format (Version 1.2), classified with ground and bathymetry (where applicable), in 1000-m × 1000-m rectangular tiles
2. ESRI format 50-cm DEM from classified Aquarius ground and bathymetry points
3. ESRI format 50-cm Hillshade raster from classified Aquarius ground and bathymetry points
4. ESRI format 50-cm DEM from first-return Aquarius points (canopy included)
5. ESRI format 50-cm Hillshade raster from first-return Aquarius points (canopy included)

f) File Naming Convention: The 1000-m × 1000-m 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 are the coordinate values from Easting 550000 through 551000, and Northing 4330000 through 4331000, then the tile filename incorporates *550000_4330000*. The ESRI DEMs are mosaic files created by combining all the tiles. Due to the limited number of characters that can be used for ArcGIS data products, the resulting format is followed: *XXX_YYYY_aabb*. Again, the coordinates of the lower-left bound of the raster are used as the seed, e.g., 550_4330. Here the last digits are excluded to conserve characters. Next, the type of return used for creating the raster, represented as "aa," will be either "be" for bare earth (i.e., filtered or ground and bathymetry points) or "fr" for first-return (i.e., unfiltered or default points). Last, the raster-type of the file, represented by "bb," can be "gd" for a grid *.flt file or "hs" for a hillshade.

g) LAS File Information: Each of the returns contained on the LAS tiles have been encoded with a laser channel value. As noted above, both the Optech Gemini and Optech Aquarius were utilized. The values used are *1* (Gemini, infrared), and *2* (Aquarius, green), and are stored in the User Data record of the Point Data records in the LAS file. Additionally, the Classification Values follow the ASPRS Standard: www.asprs.org/Committee-General/LASer-LAS-File-Format-Exchange-Activities.html.