

April 28, 2005

Project Report
**Sustainable Environments LLC – Skagit Environmental
Bank**

Contract #2322-H



Report Presented to:

Sustainable Environments, LLC
9 Teaberry Lane
Tiburon CA 94920
Point of Contact: Jerome Ryan
Phone: (415) 434 – 3734

1. Project Overview

Field Crew:

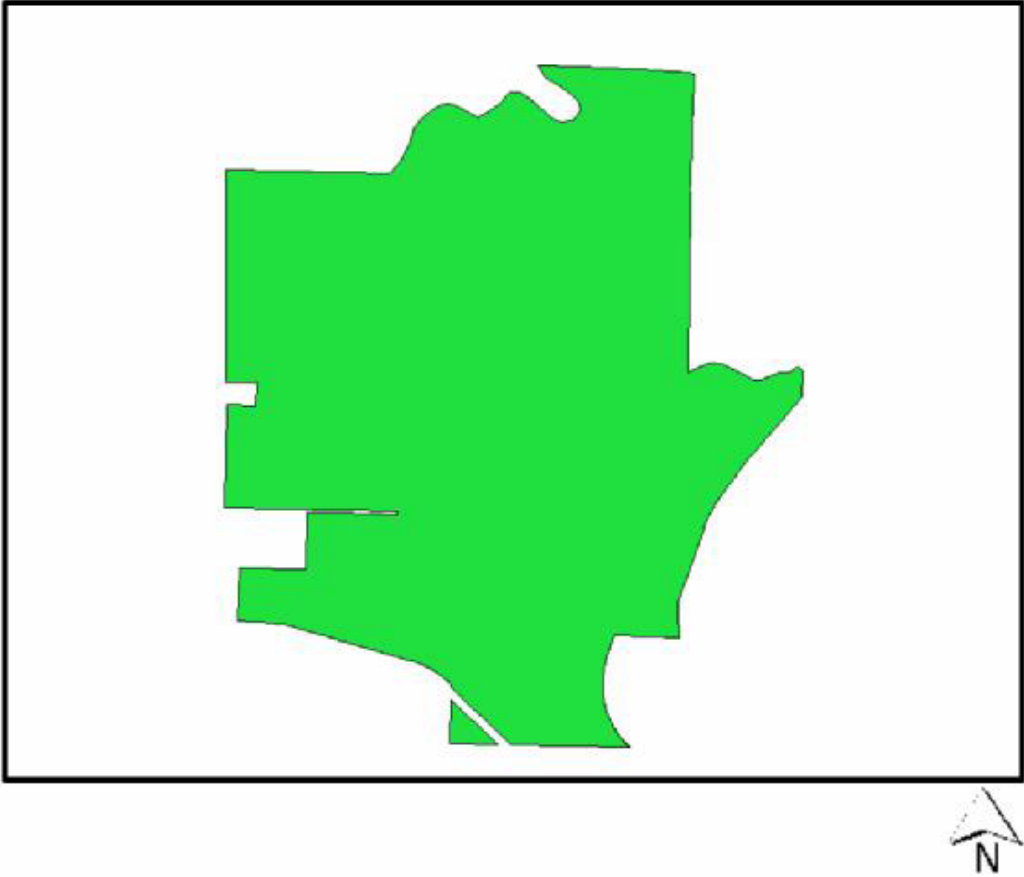
The Terrapoint field crew consisted of John Anderson, field project manager and Louis Hill, LIDAR operator. The Aries Aviation aircraft crew consisted of Rory Clayton, pilot and Bob Passon, flight engineer.

Post Processing Crew:

John Anderson completed the processing of GPS data. Craig Glennie carried out data validation and calibration. Vegetation removal and final product generation were completed the Houston processing team: Peggy Cobb, Andrew Pace and Joe Sackett.

Size of Project:

The project site covered approximately 1.26 square miles, as shown in the following image.



Location:

The project area is located in Skagit County Washington .

Project Type:

The purpose of this project is to provide a high quality DEM and contours of the site for Sustainable Environments, LLC.

Approximate Duration of Project:

The field data collection took place on April 6th, 2005. The control network and check point surveys were performed from April 9th to 11th, 2005.

Calibration, vegetation removal and product generation took place from April 15th to April 25th, 2005.

Number of Flights:

One flight was required to cover the project area with 13 flight lines, six flight lines in a N-S direction, and seven flight lines in a E-W direction.

Coordinate System(s) Used:

All horizontal coordinate data was collected and referenced to NAD83 (1998) and NAVD88 and delivered in US State Plane Zone Washington North (4601). GEOID03 for CONUS was applied to the vertical component of all deliverables.

Survey Measurement Units Used/Delivered:

All surveys were conducted and products delivered in US survey feet.

Processing Software Used:

The following software was used to reduce the GPS kinematic data, compute the 3-D laser points, classify and edit laser points, produce shaded relief images and transform the ellipsoidal heights to Orthometric:

- ArcView
- Flykin
- Microstation
- TerraScan
- TerraModeler
- TerraModel
- Terrapoint Proprietary LiDAR processing software

Capsule Review of Ground Control Survey(s) and Adjustment(s)

Terrapoint's field crew acquired and adjusted the ground control survey information. Terrapoint collected all of their LiDAR data referenced to NGS monument PID TR2547 and WSDOT monument WS1945. Kinematic and Static

GPS check points were acquired as discrete x, y, z points were collected as part of the ground truthing activities. A summary of all control coordinates is given in Table 1.

Table 1: Control and Base Coordinate							
NAME	Latitude			Longitude			Ellipsoidal Elevations (meters)
TR2547	48	09	42.67994	-122	10	12.44883	17.4394
WS1945	48	25	48.28410	-122	15	52.35410	11.443

2. Health and Safety

Following Terrapoint’s safety procedures, the field crew conducted a safety meeting upon arrival at the project site.

3. Equipment Used

Aircraft Type:

A Navajo twin-engine aircraft (C-FVZM) was used for this project. The aircraft was based out of Arlington Municipal Airport. The Navajo was typically flying at an altitude of 3500 feet AGL (above ground level) for the duration of the survey.

Sensors Used:

The Airborne LiDAR survey was conducted using Terrapoint’s 40 kHz ALTMS (Airborne Laser Terrain Mapping System), flying at an optimum height of 3500 ft AGL at 140 knots. The system consists of a 36-degree full angle laser, a Trimble 4700 GPS receiver and a Honeywell H764 IMU unit. The nominal flight line spacing was 1070 feet, providing overlap of 50% between flight lines.

GPS Type(s):

Two Sokkia GSR2600 dual frequency GPS receivers were used to support the airborne operations on this project.

4. Accuracy

The following list itemizes the accuracy attainable over the project area, as a function of terrain type and vegetation cover. Note that the accuracy quoted is the accuracy of the attainable DEM, once it is processed and edited to this stage. All data accuracies quoted relate to post processed GPS/IMU/LiDAR solutions.

Accuracy is as follows, quoted at the 95% confidence level (2 sigma),

1. Absolute Vertical Accuracy:
 +/- 10-15 centimeters on Hard Surfaces (roads and buildings)
 +/- 15-25 centimeters on Soft/Vegetated Surfaces (flat to rolling terrain)
 +/- 25-40 centimeters on Soft/Vegetated Surfaces (hilly terrain)
2. Absolute Horizontal Accuracy:
 +/- 20 – 60 centimeters on all but extremely hilly terrain.
3. Contour Accuracy (as agreed with CUSTOMER):
 1 ft Contour National Map Accuracy Standard (NMAS)

To verify that the accuracy criteria were being achieved, static and kinematic checkpoints were compared with a triangulated surface generated from the bald earth LiDAR points.

A comparison of LIDAR data with 10 static checkpoints yielded the results given in Table 2 (values in meters).

Table 2: Static Control Comparison					
Pt ID	Easting	Northing	Elevation	Laser Elev.	dZ
2322gt01	554430.926	5364410.367	32.989	33.010	0.021
2322gt02	552428.431	5364995.029	16.153	16.050	-0.103
2322gt03	552818.780	5364674.742	23.032	22.990	-0.042
2322gt04	552887.327	5367376.170	37.290	37.330	0.040
2322gt06	555357.567	5366150.417	15.969	15.950	-0.019
2322gt07	554807.040	5366357.346	13.333	13.400	0.067
2322gt08	554389.799	5366738.601	12.043	12.100	0.057
2322gt09	553157.202	5367220.868	23.021	23.070	0.049
DH212	554407.742	5364965.546	37.257	37.500	0.243
WS1945	554404.085	5364364.745	33.698	33.660	-0.038

Average dz	0.028
Minimum dz	-0.103
Maximum dz	0.243
Average magnitude	0.068
Root mean square	0.092
Std deviation	0.093

A comparison of LIDAR data with 278 kinematic checkpoints yielded the results given in Table 3 (values in meters).

Table 3: Kinematic Point Comparison	
Average dz	-0.019
Minimum dz	-0.156
Maximum dz	0.123
Average magnitude	0.036
Root mean square	0.046
Std deviation	0.042

5. Quality Control

Quality control of the data was ongoing throughout the process. Following data acquisition, preliminary GPS processing was conducted in the field to ensure completeness and integrity.

The GPS and inertial data were processed in tandem to achieve the best positional result. Once the position and attitude of the aircraft were known at each epoch (1-second intervals), then these data were integrated with the laser ranges to provide a position for each data point on the ground. The data were then processed using the proprietary laser processing software suite to produce coordinates.

Each flight involved setting up two base stations to collect data. Utilizing two base stations ensures GPS data collection in the event that the main base station fails. For all flights the GPS data were of high quality. This minimized the absolute error for the aircraft position.

The primary quality control tool for the laser ranges is the percentage of returns that are received back at the laser after it has emitted a signal. The acceptable range for returns, typically between 90% and 95% was met for this project. Lower percentages are normal over water and other poor reflectivity surfaces.

Terrapoint also utilizes a proprietary software package that performs a fully automated analysis of the quality of the LIDAR data using overlapping flight lines. Our flight lines overlap 30 to 50% on either side and thus 60 to 100% of points can be checked for overlap consistency. The overlap analysis attempts to minimize the differences in overlap areas by fine-tuning the calibration parameters of the LIDAR system.

6. Point Generation

The points are generated as Terrascan binary Format using Terrapoint's proprietary Laser Postprocessor Software. This software combines the Raw Laser file and GPS/IMU information to generate a point cloud for each individual flight.

All the point cloud files encompassing the project area were then divided into quarter quad tiles. The referencing system of these tiles is based upon the project boundary minimum and maximums. This process is carried out in Terrascan.

The bald earth is subsequently extracted from the raw LiDAR points using Terrascan in a Microstation environment. The automated vegetation removal process takes place by building an iterative surface model. This surface model is generated using three main parameters: Building size, Iteration angle and Iteration distance.

The initial model is based upon low points selected by a roaming window and are assumed to be ground points. The size of this roaming window is determined by the building size parameter. These low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the Iteration angle and distance constraints (fig. 1). This process is repeated until no additional points are added within an iteration.

There is also a maximum terrain angle constraint that determines the maximum terrain angle allowed within the model.



Figure 1: Terrascan iteration methodology.

(Image Source: Terrascan User's Guide, www.terrasolid.fi)

7. Quality Control

Once the data setup has taken place the manual quality control of the surface occurs. This process consists of visually examining the LiDAR points within Terrascan and correcting errors that occurred during the automated process. These corrections include verifying that all non ground elements, such as vegetation and buildings are removed from the ground model and that all small terrain undulations such as road beds, dykes, rock cuts and hill tops are present within the model.

This process is done with the help of hillshades, contours, profiles and cross-sections. To correct misclassifications, a full suite of Terrascan and custom in-house data tools are used.

8. Deliverables

Below is a list of the deliverables for this project:

All LiDAR Data Products were delivered on DVD-ROM. Two copies were provided.

Full Feature or All Return Point Data (DEM)

Data delivered in format:

- ArcInfo Grid File Format. Six foot grid spacing. File delivered by USGS quarter quad in gzipped Arcinfo Exchange Format (e00)

Bare Earth Point Data (DTM)

Data delivered in two formats:

- ArcInfo Grid File Format. Six foot grid spacing. File delivered by USGS quarter quad in gzipped Arcinfo Exchange Format (e00)
- ASCII xyz file format. Space delimited (.txt gzipped by USGS quarter quad)

All Return Text File (All Return)

All collected data delivered in ASCII text file format (space delimited) with the following columns

- GPS Week
- GPS Time (seconds)
- Easting (US feet)
- Northing (US feet)
- Elevation (Orthmetric, US feet)
- Total # of Returns in Pulse
- Current Pulse Return Number
- Scan Angle
- Intensity
- Classification Code

Data is delivered by 1/25th of a USGS quarter quad in gzipped .txt files

One Foot Contour Map

Contour Map was delivered in two formats:

- Microstation V8 DGN File
- Arcview 3D Shape File

Aircraft Trajectory File

Time stamped GPS trajectory with location and quality metrics for all missions flown. Trajectories are delivered as Arcinfo Shape Files