Dewberry

Dewberry & Davis LLC
1000 N. Ashley Drive, Suite 801
Tampa, FL 33602-3718
813.225.1325
813.225.1385 fax
www.dewberry.com

USGS/FEMA Region IX – Orange County, CA LiDAR

Report Produced for U.S. Geological Survey

USGS Contract: G10PC0013

Task Order: G12PD00039.

Report Date: 7/31/2012

SUBMITTED BY:
Dewberry
1000 North Ashley Drive
Suite 801
Tampa, FL 33602
813.225.1325

SUBMITTED TO:
U.S. Geological Survey
1400 Independence Road
Rolla, MO 65401

Table of Contents

Executive Summary

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (LiDAR) technology for the USGS FEMA IX Orange County, California Project Area.

The LiDAR data were processed to a bare-earth digital terrain model (DTM). Detailed breaklines and bare-earth Digital Elevation Models (DEMs) were produced for the project area. Data was formatted according to tiles with each tile covering an area of 1500m by 1500m. A total of 868 tiles were produced for the project encompassing an area of approximately 681 sq. miles.

THE PROJECT TEAM

Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for LAS classification, all LiDAR products, breakline production, Digital Elevation Model (DEM) production, and quality assurance.

Dewberry's Steven A. Wood completed ground surveying for the project and delivered surveyed checkpoints. His task was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the LiDAR-derived surface model. He also verified the GPS base station coordinates used during LiDAR data acquisition to ensure that the base station coordinates were accurate. Note that a separate Survey Report was created for this portion of the project.

Digital Mapping, Inc (DMI) completed LiDAR data acquisition and data calibration for the project area.

SURVEY AREA

The project area addressed by this report falls within the California counties of Los Angeles, Orange, Riverside, and San Bernardino.

DATE OF SURVEY

The LiDAR aerial acquisition was conducted from December 17, 2011 thru February 9, 2012.

DATUM REFERENCE

Data produced for the project were delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 (NAD 83)
Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88)
Coordinate System: UTM Zone 11
Units: Horizontal units are in meters, Vertical units are in meters.
Geiod Model: Geoid09 (Geoid 09 was used to convert ellipsoid heights to orthometric heights).

LIDAR VERTICAL ACCURACY

For the FEMA IX Orange County, CA LiDAR Project, the tested $RMSE_z$ for checkpoints in open terrain equaled **0.10 m** compared with the 0.125 m specification; and the FVA computed using $RMSE_z$ x 1.9600 was equal to **0.19 m**, compared with the 0.245 m specification.

For the FEMA IX Orange County, CA LiDAR Project, the tested CVA computed using the 95th percentile was equal to **0.17 m,** compared with the 0.363 m specification.

PROJECT DELIVERABLES

The deliverables for the project are listed below.

1. Raw Point Cloud Data (Swaths)
2. Classified Point Cloud Data (Tiled)
3. Bare Earth Surface (Raster DEM – IMG Format)
4. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
5. Breakline Data (File GDB)
6. Control & Accuracy Checkpoint Report & Points
7. Metadata
8. Project Report (Acquisition, Processing, QC)
9. Project Extents, Including a shapefile derived from the LiDAR Deliverable

PROJECT TILING FOOTPRINT

Eight hundred sixty-eight (868) tiles were delivered for the project. Each tile's extent is 1,500 meters by 1,500 meters.

Figure 1: Project Map

LIST OF DELIVERED TILES (1,327):

11SMS396985
11SMS411985
11SMS426985
11SMT381000
11SMT396000
11SMT411000
11SMT426000
11SMT441000
11SMT366015
11SMT381015
11SMT396015
11SMT411015
11SMT426015
11SMT441015
11SMT456015
11SMT336030
11SMT351030
11SMT366030
11SMT381030
11SMT396030
11SMT411030
11SMT426030
11SMT441030
11SMT456030
11SMT321045
11SMT336045
11SMT351045
11SMT366045
11SMT381045
11SMT396045
11SMT411045
11SMT426045
11SMT441045
11SMT456045
11SMT471045
11SMT306060
11SMT321060
11SMT336060
11SMT351060
11SMT366060
11SMT381060
11SMT396060
11SMT411060
11SMT426060
11SMT441060
11SMT456060
11SMT471060
11SMT306075
11SMT321075
11SMT336075
11SMT351075
11SMT366075
11SMT381075
11SMT396075
11SMT411075
11SMT426075
11SMT441075
11SMT456075
11SMT471075
11SMT486075
11SMT291090
11SMT306090
11SMT321090
11SMT336090
11SMT351090
11SMT366090
11SMT381090
11SMT396090
11SMT411090
11SMT426090
11SMT441090
11SMT456090
11SMT471090
11SMT486090
11SMT276105
11SMT291105
11SMT306105
11SMT321105
11SMT336105
11SMT351105
11SMT366105
11SMT381105
11SMT396105
11SMT411105
11SMT426105
11SMT441105
11SMT456105
11SMT471105
11SMT486105
11SMT501105
11SMT246120
11SMT261120
11SMT276120
11SMT291120
11SMT306120
11SMT321120
11SMT336120
11SMT351120
11SMT366120
11SMT381120
11SMT396120
11SMT411120
11SMT426120
11SMT441120
11SMT456120
11SMT471120
11SMT486120
11SMT501120
11SMT231135
11SMT246135
11SMT261135
11SMT276135
11SMT291135
11SMT306135
11SMT321135
11SMT336135
11SMT351135
11SMT366135
11SMT381135
11SMT396135
11SMT411135
11SMT426135

11SMT441135
11SMT456135
11SMT471135
11SMT486135
11SMT501135
11SMT516135
11SMT216150
11SMT231150
11SMT246150
11SMT261150
11SMT276150
11SMT291150
11SMT306150
11SMT321150
11SMT336150
11SMT351150
11SMT366150
11SMT381150
11SMT396150
11SMT411150
11SMT426150
11SMT441150
11SMT456150
11SMT471150
11SMT486150
11SMT501150
11SMT516150
11SMT171165
11SMT186165
11SMT201165
11SMT216165
11SMT231165
11SMT246165
11SMT261165
11SMT276165
11SMT291165
11SMT306165
11SMT321165
11SMT336165
11SMT351165
11SMT366165
11SMT381165
11SMT396165
11SMT411165
11SMT426165
11SMT441165
11SMT456165
11SMT471165
11SMT486165
11SMT501165
11SMT516165
11SMT141180
11SMT156180
11SMT171180
11SMT186180
11SMT201180
11SMT216180
11SMT231180
11SMT246180
11SMT261180
11SMT276180
11SMT291180
11SMT306180
11SMT321180
11SMT336180
11SMT351180
11SMT366180
11SMT381180
11SMT396180
11SMT411180
11SMT426180
11SMT441180
11SMT456180
11SMT471180
11SMT486180
11SMT501180
11SMT516180
11SMT126195
11SMT141195
11SMT156195
11SMT171195
11SMT186195
11SMT201195
11SMT216195
11SMT231195
11SMT246195
11SMT261195
11SMT276195
11SMT291195
11SMT306195
11SMT321195
11SMT336195
11SMT351195
11SMT366195
11SMT381195
11SMT396195
11SMT411195
11SMT426195
11SMT441195
11SMT456195
11SMT471195
11SMT486195
11SMT501195
11SMT096210
11SMT111210
11SMT126210
11SMT141210
11SMT156210
11SMT171210
11SMT186210
11SMT201210
11SMT216210
11SMT231210
11SMT246210
11SMT261210
11SMT276210
11SMT291210
11SMT306210
11SMT321210
11SMT336210
11SMT351210
11SMT366210
11SMT381210
11SMT396210
11SMT411210
11SMT426210

11SMT441210
11SMT456210
11SMT471210
11SMT486210
11SMT501210
11SMT081225
11SMT096225
11SMT111225
11SMT126225
11SMT141225
11SMT156225
11SMT171225
11SMT186225
11SMT201225
11SMT216225
11SMT231225
11SMT246225
11SMT261225
11SMT276225
11SMT291225
11SMT306225
11SMT321225
11SMT336225
11SMT351225
11SMT366225
11SMT381225
11SMT396225
11SMT411225
11SMT426225
11SMT441225
11SMT456225
11SMT471225
11SMT486225
11SMT501225
11SMT066240
11SMT081240
11SMT096240
11SMT111240
11SMT126240
11SMT141240
11SMT156240
11SMT171240
11SMT186240
11SMT201240
11SMT216240
11SMT231240
11SMT246240
11SMT261240
11SMT276240
11SMT291240
11SMT306240
11SMT321240
11SMT336240
11SMT351240
11SMT366240
11SMT381240
11SMT396240
11SMT411240
11SMT426240
11SMT441240
11SMT456240
11SMT471240
11SMT486240
11SMT051255
11SMT066255
11SMT081255
11SMT096255
11SMT111255
11SMT126255
11SMT141255
11SMT156255
11SMT171255
11SMT186255
11SMT201255
11SMT216255
11SMT231255
11SMT246255
11SMT261255
11SMT276255
11SMT291255
11SMT306255
11SMT321255
11SMT336255
11SMT351255
11SMT366255
11SMT381255
11SMT396255
11SMT411255
11SMT426255
11SMT441255
11SMT456255
11SMT471255
11SMT486255
11SMT036270
11SMT051270
11SMT066270
11SMT081270
11SMT096270
11SMT111270
11SMT126270
11SMT141270
11SMT156270
11SMT171270
11SMT186270
11SMT201270
11SMT216270
11SMT231270
11SMT246270
11SMT261270
11SMT276270
11SMT291270
11SMT306270
11SMT321270
11SMT336270
11SMT351270
11SMT366270
11SMT381270
11SMT396270
11SMT411270
11SMT426270
11SMT441270
11SMT456270
11SMT471270
11SMT021285
11SMT036285
11SMT051285

11SMT066285
11SMT081285
11SMT096285
11SMT111285
11SMT126285
11SMT141285
11SMT156285
11SMT171285
11SMT186285
11SMT201285
11SMT216285
11SMT231285
11SMT246285
11SMT261285
11SMT276285
11SMT291285
11SMT306285
11SMT321285
11SMT336285
11SMT351285
11SMT366285
11SMT381285
11SMT396285
11SMT411285
11SMT426285
11SMT441285
11SMT006300
11SMT021300
11SMT036300
11SMT051300
11SMT066300
11SMT081300
11SMT096300
11SMT111300
11SMT126300
11SMT141300
11SMT156300
11SMT171300
11SMT186300
11SMT201300
11SMT216300
11SMT231300
11SMT246300
11SMT261300
11SMT276300
11SMT291300
11SMT306300
11SMT321300
11SMT336300
11SMT351300
11SMT366300
11SMT381300
11SMT396300
11SMT411300
11SMT426300
11SMT441300
11SMT456300
11SLT976315
11SLT991315
11SMT006315
11SMT021315
11SMT036315
11SMT051315
11SMT066315
11SMT081315
11SMT096315
11SMT111315
11SMT126315
11SMT141315
11SMT156315
11SMT171315
11SMT186315
11SMT201315
11SMT216315
11SMT231315
11SMT246315
11SMT261315
11SMT276315
11SMT291315
11SMT306315
11SMT321315
11SMT336315
11SMT351315
11SMT366315
11SMT381315
11SMT396315
11SMT411315
11SMT426315
11SMT441315
11SMT456315
11SLT961330
11SLT976330
11SLT991330
11SMT006330
11SMT021330
11SMT036330
11SMT051330
11SMT066330
11SMT081330
11SMT096330
11SMT111330
11SMT126330
11SMT141330
11SMT156330
11SMT171330
11SMT186330
11SMT201330
11SMT216330
11SMT231330
11SMT246330
11SMT261330
11SMT276330
11SMT291330
11SMT306330
11SMT321330
11SMT336330
11SMT351330
11SMT366330
11SMT381330
11SMT396330
11SMT411330
11SMT426330
11SMT441330
11SMT456330
11SLT946345
11SLT961345

11SLT976345
11SLT991345
11SMT006345
11SMT021345
11SMT036345
11SMT051345
11SMT066345
11SMT081345
11SMT096345
11SMT111345
11SMT126345
11SMT141345
11SMT156345
11SMT171345
11SMT186345
11SMT201345
11SMT216345
11SMT231345
11SMT246345
11SMT261345
11SMT276345
11SMT291345
11SMT306345
11SMT321345
11SMT336345
11SMT351345
11SMT366345
11SMT381345
11SMT396345
11SMT411345
11SMT426345
11SMT441345
11SMT456345
11SLT961360
11SLT976360
11SLT991360
11SMT006360
11SMT021360
11SMT036360
11SMT051360
11SMT066360
11SMT081360
11SMT096360
11SMT111360
11SMT126360
11SMT141360
11SMT156360
11SMT171360
11SMT186360
11SMT201360
11SMT216360
11SMT231360
11SMT246360
11SMT261360
11SMT276360
11SMT291360
11SMT306360
11SMT321360
11SMT336360
11SMT351360
11SMT366360
11SMT381360
11SMT396360
11SMT411360
11SLT961375
11SLT976375
11SLT991375
11SMT006375
11SMT021375
11SMT036375
11SMT051375
11SMT066375
11SMT081375
11SMT096375
11SMT111375
11SMT126375
11SMT141375
11SMT156375
11SMT171375
11SMT186375
11SMT201375
11SMT216375
11SMT231375
11SMT246375
11SMT261375
11SMT276375
11SMT291375
11SMT306375
11SMT321375
11SMT336375
11SMT351375
11SMT366375
11SLT976390
11SLT991390
11SMT006390
11SMT021390
11SMT036390
11SMT051390
11SMT066390
11SMT081390
11SMT096390
11SMT111390
11SMT126390
11SMT141390
11SMT156390
11SMT171390
11SMT186390
11SMT201390
11SMT216390
11SMT231390
11SMT246390
11SMT261390
11SMT276390
11SMT291390
11SMT306390
11SMT321390
11SMT336390
11SLT976405
11SLT991405
11SMT006405
11SMT021405
11SMT036405
11SMT051405
11SMT066405
11SMT081405
11SMT096405

11SMT111405
11SMT126405
11SMT141405
11SMT156405
11SMT171405
11SMT186405
11SMT201405
11SMT216405
11SMT231405
11SMT246405
11SMT261405
11SMT276405
11SMT291405
11SMT306405
11SMT321405
11SLT991420
11SMT006420
11SMT021420
11SMT036420
11SMT051420
11SMT066420
11SMT081420
11SMT096420
11SMT111420
11SMT126420
11SMT141420
11SMT156420
11SMT171420
11SMT186420
11SMT201420
11SMT216420
11SMT231420
11SMT246420
11SMT261420
11SMT276420
11SMT291420
11SMT306420
11SLT991435
11SMT006435
11SMT021435
11SMT036435
11SMT051435
11SMT066435
11SMT081435
11SMT096435
11SMT111435
11SMT126435
11SMT141435
11SMT156435
11SMT171435
11SMT186435
11SMT201435
11SMT216435
11SMT231435
11SMT246435
11SMT261435
11SMT276435
11SMT291435
11SMT006450
11SMT021450
11SMT036450
11SMT051450
11SMT066450
11SMT081450
11SMT096450
11SMT111450
11SMT126450
11SMT141450
11SMT156450
11SMT171450
11SMT186450
11SMT201450
11SMT216450
11SMT231450
11SMT246450
11SMT261450
11SMT276450
11SMT291450
11SMT306450
11SMT321450
11SMT336450
11SMT351450
11SMT006465
11SMT021465
11SMT036465
11SMT051465
11SMT066465
11SMT081465
11SMT096465
11SMT111465
11SMT126465
11SMT141465
11SMT156465
11SMT171465
11SMT186465
11SMT201465
11SMT216465
11SMT231465
11SMT246465
11SMT261465
11SMT276465
11SMT291465
11SMT306465
11SMT321465
11SMT336465
11SMT351465
11SMT366465
11SMT381465
11SMT021480
11SMT036480
11SMT051480
11SMT066480
11SMT081480
11SMT096480
11SMT111480
11SMT126480
11SMT141480
11SMT156480
11SMT171480
11SMT186480
11SMT201480
11SMT216480
11SMT231480
11SMT246480
11SMT261480
11SMT276480

11SMT291480
11SMT306480
11SMT321480
11SMT336480
11SMT351480
11SMT366480
11SMT036495
11SMT051495
11SMT066495
11SMT081495
11SMT096495
11SMT111495
11SMT126495
11SMT141495
11SMT156495
11SMT171495
11SMT186495
11SMT201495
11SMT216495
11SMT231495
11SMT246495
11SMT261495
11SMT276495
11SMT291495
11SMT306495
11SMT321495
11SMT336495
11SMT351495
11SMT366495
11SMT036510
11SMT051510
11SMT066510
11SMT081510
11SMT096510
11SMT111510
11SMT126510
11SMT141510
11SMT156510
11SMT171510
11SMT186510
11SMT201510
11SMT216510
11SMT231510
11SMT246510
11SMT261510
11SMT276510
11SMT291510
11SMT306510
11SMT321510
11SMT336510
11SMT351510
11SMT051525
11SMT066525
11SMT081525
11SMT096525
11SMT111525
11SMT126525
11SMT141525
11SMT156525
11SMT171525
11SMT186525
11SMT201525
11SMT216525
11SMT231525
11SMT246525
11SMT261525
11SMT276525
11SMT291525
11SMT306525
11SMT321525
11SMT336525
11SMT066540
11SMT081540
11SMT096540
11SMT111540
11SMT126540
11SMT141540
11SMT156540
11SMT171540
11SMT186540
11SMT201540
11SMT216540
11SMT231540
11SMT246540
11SMT261540
11SMT276540
11SMT291540
11SMT306540
11SMT081555
11SMT096555
11SMT111555
11SMT126555
11SMT141555
11SMT156555
11SMT171555
11SMT186555
11SMT201555
11SMT216555
11SMT231555
11SMT246555
11SMT261555
11SMT276555
11SMT291555
11SMT081570
11SMT096570
11SMT111570
11SMT126570
11SMT141570
11SMT156570
11SMT171570
11SMT186570
11SMT201570
11SMT216570
11SMT231570
11SMT246570
11SMT261570

LiDAR Acquisition Report

SCOPE OF WORK

DMI acquired LiDAR data over an Area of Interest (AOI) entire of Orange County California. The acquisition plan entailed a nominal point spacing of 1.76 points per meter square and a side lap of 40% between flight lines. The AOI covers 696 square miles.

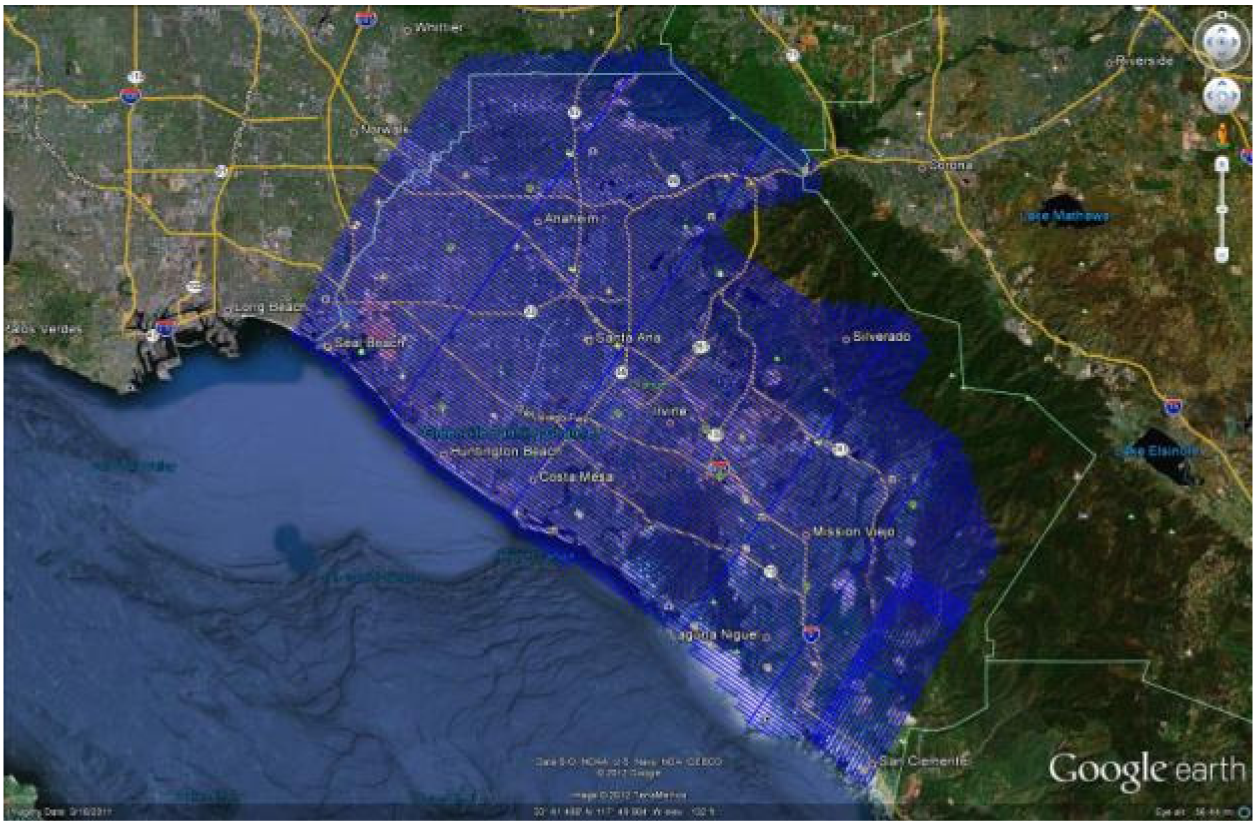


Fig. 1 Flight plan

LIDAR ACQUISITION DETAILS

Collections (Lifts): 14

Collection Dates: 2011 December 17, 20, 21, 23, 24, 26, 27, 28, 29, 30,

Field of View (FOV): 18 degrees

Average Point Density (planned): 0.75 m

Flight Level(s): 914 / 3000 m/ft

Sensor Type: Optech Gemini **Sensor Serial Number(s):** 07SEN204

All acquired LiDAR data was initially quality controlled after every mission for coverage and further verified for content and adherence to flight plan at DMI production facilities Huntington Beach, CA. All data was accepted for processing.

COLLECTION SUMMARY

A detailed report consisting of the GPS/IMU separation plots, trajectories, and flight information has been attached to this report in the form of attachment A. The full report has been separated from this section because of length and technical content.

LiDAR Processing & Qualitative Assessment

DATA CLASSIFICATION AND EDITING

LiDAR mass points were produced to LAS 1.2 specifications, including the following LAS classification codes:

- Class 1 = Unclassified, and used for all other features that do not fit into the Classes 2, 7, 9, 10, or 11, including vegetation, buildings, etc.
- Class 2 = Ground, includes accurate LiDAR points in overlapping flight lines
- Class 7 = Noise, low and high points
- Class 9 = Water, points located within collected breaklines
- Class 10 = Ignored Ground due to breakline proximity.
- Class 11 = Withheld, Points with scan angles exceeding +/- 20 degrees.

The data was processed using GeoCue and TerraScan software. The initial step is the setup of the GeoCue project, which is done by importing a project defined tile boundary index encompassing the entire project area. The acquired 3D laser point clouds, in LAS binary format, were imported into the GeoCue project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious outliers in the dataset to class 7 and points with scan angles exceeding +/- 20 degrees to class 11. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine 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 on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The 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. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model.

The following fields within the LAS files are populated to the following precision: GPS Time (0.000001 second precision), Easting (0.003 meter precision), Northing (0.003 meter precision), Elevation (0.003 meter precision), Intensity (integer value - 12 bit dynamic range), Number of Returns (integer - range of 1-4), Return number (integer range of 1-4), Scan Direction Flag (integer - range 0-1), Classification (integer), Scan Angle Rank (integer), Edge of flight line (integer, range 0-1), User bit field (integer - flight line information encoded). The LAS file also contains a Variable length record in the file header that defines the projection, datums, and units.

Once the initial ground routine has been performed on the data, Dewberry creates Delta Z (DZ) orthos to check the relative accuracy of the LiDAR data. These orthos compare the elevations of LiDAR points from overlapping flight lines on a 1 meter pixel cell size basis. If the elevations of points within each pixel are within 10 cm of each other, the pixel is colored green. If the elevations of points within each pixel are between 10 cm and 20 cm of each other, the pixel is colored yellow, and if the elevations of points within each pixel are greater than 20 cm in difference, the pixel is colored red. Pixels that do not contain points from overlapping flight lines are colored according to their intensity values. DZ orthos can be created using the full point cloud or ground only points and are used to review and verify the calibration of the data is acceptable. Some areas are expected to show sections or portions of red, including terrain variations, slope changes, and vegetated areas or buildings if the full point cloud is used. However, large or continuous sections of yellow or red pixels can indicate the data was not calibrated correctly or that there were issues during acquisition that could affect the usability of the data. The DZ orthos for Orange County California showed that the data was calibrated correctly with no issues that would affect its usability. The figure below shows an example of the DZ orthos.

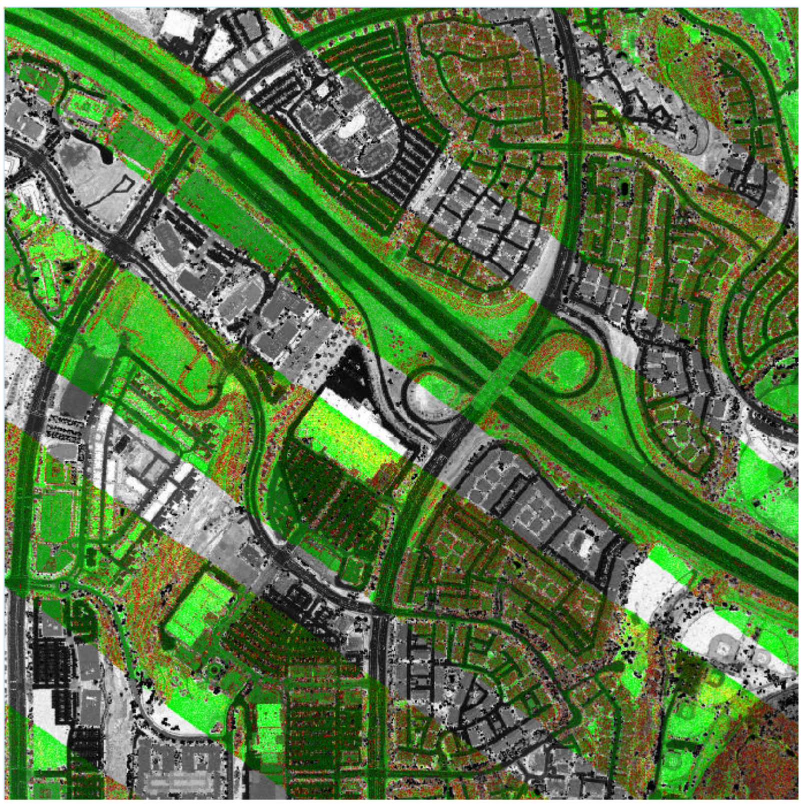


Figure 3: DZ orthos created from the full point cloud. Some red pixels are visible along embankments, sloped terrain, and in vegetated land cover, as expected. Open, flat areas are green indicating the calibration and relative accuracy of the data is acceptable.

Dewberry utilized a variety of software suites for data processing. The LAS dataset was received and imported into GeoCue task management software for processing in Terrascan. Each tile was imported into Terrascan and a surface model was created to examine the ground classification. Dewberry analysts visually reviewed the ground surface model and corrected errors in the ground classification such as vegetation, buildings, and bridges that were present following the initial processing conducted by Dewberry. Dewberry analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that non-ground points are removed from the ground classification. After the ground classification corrections were completed, the dataset was processed through a water classification routine that utilizes breaklines compiled by dewberry to automatically classify hydro features. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. The final classification routine applied to the dataset selects ground points within a specified distance of the water breaklines and classifies them as class 10, ignored ground due to breakline proximity.

QUALITATIVE ASSESSMENT

Dewberry's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology to assess the quality of the data for a bare-earth digital terrain model (DTM). This process looks for anomalies in the data and also identifies areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model.

Within this review of the LiDAR data, two fundamental questions were addressed:

- Did the LiDAR system perform to specifications?
- Did the vegetation removal process yield desirable results for the intended bare-earth terrain product?

Mapping standards today address the quality of data by quantitative methods. If the data are tested and found to be within the desired accuracy standard, then the data set is typically accepted. Now with the proliferation of LiDAR, new issues arise due to the vast amount of data. Unlike photogrammetrically-derived DEMs where point spacing can be eight meters or more, LiDAR nominal point spacing for this project is 1 point per 1 square meters. The end result is that millions of elevation points are measured to a level of accuracy previously unseen for traditional elevation mapping technologies and vegetated areas are measured that would be nearly impossible to survey by other means. The downside is that with millions of points, the dataset is statistically bound to have some errors both in the measurement process and in the artifact removal process.

As previously stated, the quantitative analysis addresses the quality of the data based on absolute accuracy. This accuracy is directly tied to the comparison of the discreet measurement of the survey checkpoints and that of the interpolated value within the three closest LiDAR points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the LiDAR data is actually tested. However there is an increased level of confidence with LiDAR data due to the relative accuracy. This relative accuracy in turn is based on how well one LiDAR point "fits" in comparison to the next contiguous LiDAR measurement, and is verified with DZ orthos. Once the absolute and relative accuracy has been ascertained, the next stage is to address the cleanliness of the data for a bare-earth DTM.

By using survey checkpoints to compare the data, the absolute accuracy is verified, but this also allows us to understand if the artifact removal process was performed correctly. To reiterate the quantitative approach, if the LiDAR sensor operated correctly over open terrain areas, then it most likely operated correctly over the vegetated areas. This does not mean that the entire bare-earth was measured; only that the elevations surveyed are most likely accurate (including elevations of treetops, rooftops, etc.). In the event that the LiDAR pulse filtered through the vegetation and was able to measure the true surface (as well as measurements on the surrounding vegetation) then the level of accuracy of the vegetation removal process can be tested as a by-product.

To fully address the data for overall accuracy and quality, the level of cleanliness (or removal of above-ground artifacts) is paramount. Since there are currently no effective automated testing procedures to measure cleanliness, Dewberry employs a combination of statistical and visualization processes. This includes creating pseudo image products such as LiDAR orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models. By creating multiple images and using overlay techniques, not only can potential errors be found, but Dewberry can also find where the data meets and exceeds expectations. This report will present representative examples where the LiDAR and post processing had issues as well as examples of where the LiDAR performed well.

ANALYSIS

Dewberry utilizes GeoCue software as the primary geospatial process management system. GeoCue is a three tier, multi-user architecture that uses .NET technology from Microsoft. .NET technology provides the real-time notification system that updates users with real-time project status, regardless of who makes changes to project entities. GeoCue uses database technology for sorting project metadata. Dewberry uses Microsoft SQL Server as the database of choice. Specific analysis is conducted in Terrascan and QT Modeler environments.

Following the completion of LiDAR point classification, the Dewberry qualitative assessment process flow for the USGS FEMA IX – Orange County, CA LiDAR project incorporated the following reviews:

1. *Format:* The LAS files are verified to meet project specifications. The LAS files for the USGS FEMA IX – Orange County, CA LiDAR project conform to the specifications outlined below.

- Format, Echos, Intensity
    - LAS format 1.2
    - Point data record format 1
    - Multiple returns (echos) per pulse
    - Intensity values populated for each point
- ASPRS classification scheme
    - Class 1 – unclassified
    - Class 2 – Bare-earth ground
    - Class 7 – Noise
    - Class 9 – Water
    - Class 10 – Ignored Ground due to breakline proximity

  - Class 11 – Withheld due to scan angles exceeding +/- 20 degrees
- Projection
  - Datum – North American Datum 1983
  - Projected Coordinate System – UTM Zone 11
  - Units – Meters
  - Vertical Datum – North American Vertical Datum 1988, Geoid 09
  - Vertical Units - Meters
- LAS header information:
  - Class (Integer)
  - GPS Week Time (0.0001 seconds)
  - Easting (0.003 meters)
  - Northing (0.003 meters)
  - Elevation (0.003 meters)
  - Echo Number (Integer 1 to 4)
  - Echo (Integer 1 to 4)
  - Intensity (8 bit integer)
  - Flight Line (Integer)
  - Scan Angle (Integer degree)

2. *Data density, data voids:* The LAS files are used to produce Digital Elevation Models using the commercial software package “QT Modeler” which creates a 3-dimensional data model derived from Class 2 (ground points) in the LAS files. Grid spacing is based on the project density deliverable requirement for un-obscured areas. For the USGS FEMA IX – Orange County, CA LiDAR project it is stipulated that the minimum post spacing in un-obscured areas should be 1 point per 1 square meter.

   a. Acceptable voids (areas with no LiDAR returns in the LAS files) that are present in the majority of LiDAR projects include voids caused by bodies of water. These are considered to be acceptable voids.

Bare earth quality: Dewberry reviewed the cleanliness of the bare earth to ensure the ground has correct definition, meets the project requirements, there is correct classification of points, and there are less than 5% residual artifacts.

   a. *Artifacts:* Artifacts are caused by the misclassification of ground points and usually represent vegetation and/or man-made structures. The artifacts identified are usually low lying structures, such as porches or low vegetation used as landscaping in neighborhoods and other developed areas. These low lying features are extremely difficult for the automated algorithms to detect as non-ground and must be removed manually. The vast majority of these features have been removed but a small number of these features are still in the ground classification. The limited numbers of features remaining in the ground are usually 0.3 meters or less above the actual ground surface, and should not negatively impact the usability of the dataset.

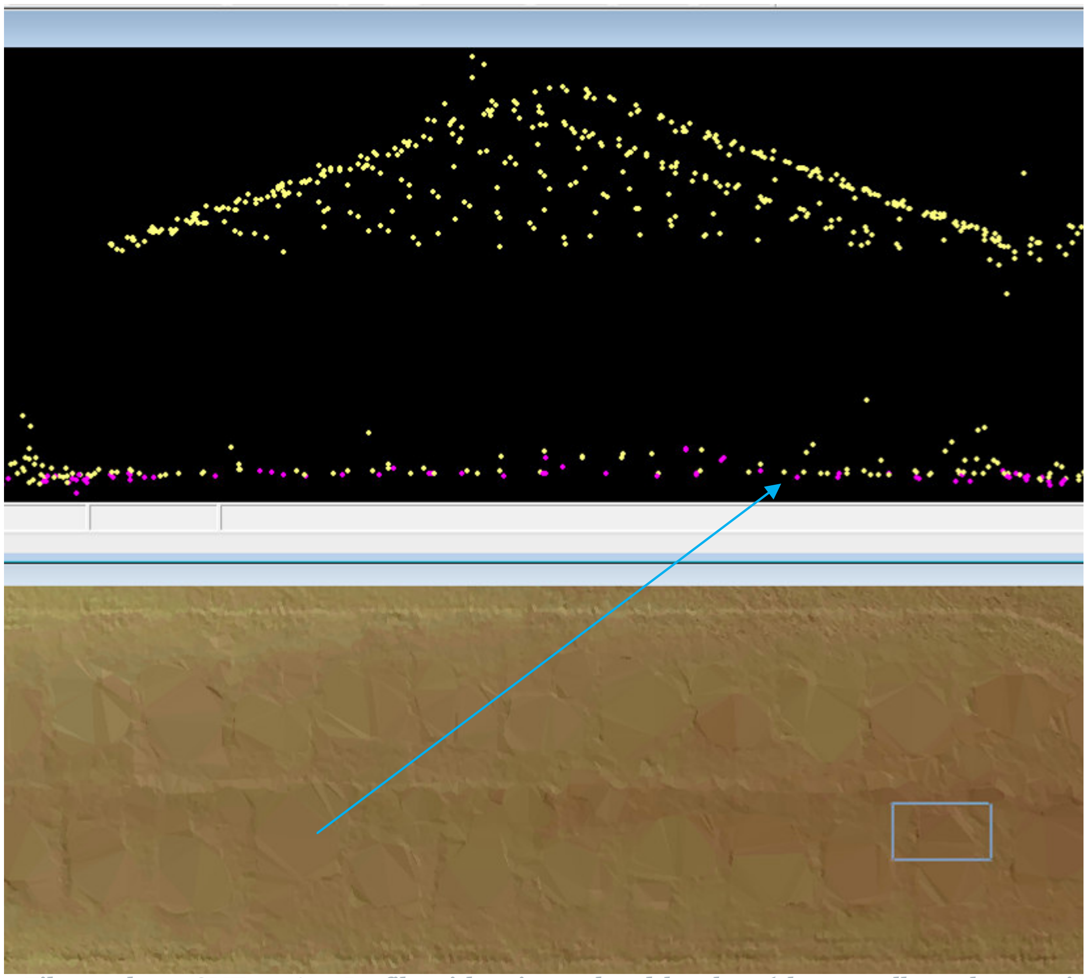


Figure 4 – Tile number 11SMT111465. Profile with points colored by class (class 1=yellow, class 2=pink) is shown in the top view and a TIN of the surface is shown in the bottom view. The arrow identifies low vegetation points. A limited number of these small features are still classified as ground.

b. *Bridge Removal Artifacts:* The DEM surface models are created from TINs or Terrains. TIN and Terrain models create continuous surfaces from the inputs. Because a continuous surface is being created, the TIN or Terrain will use interpolation to triangulate across a bridge opening from legitimate ground points on either side of the actual bridge. This can cause visual artifacts or "saddles." These "artifacts" are only visual and do not exist in the LiDAR points or breaklines.

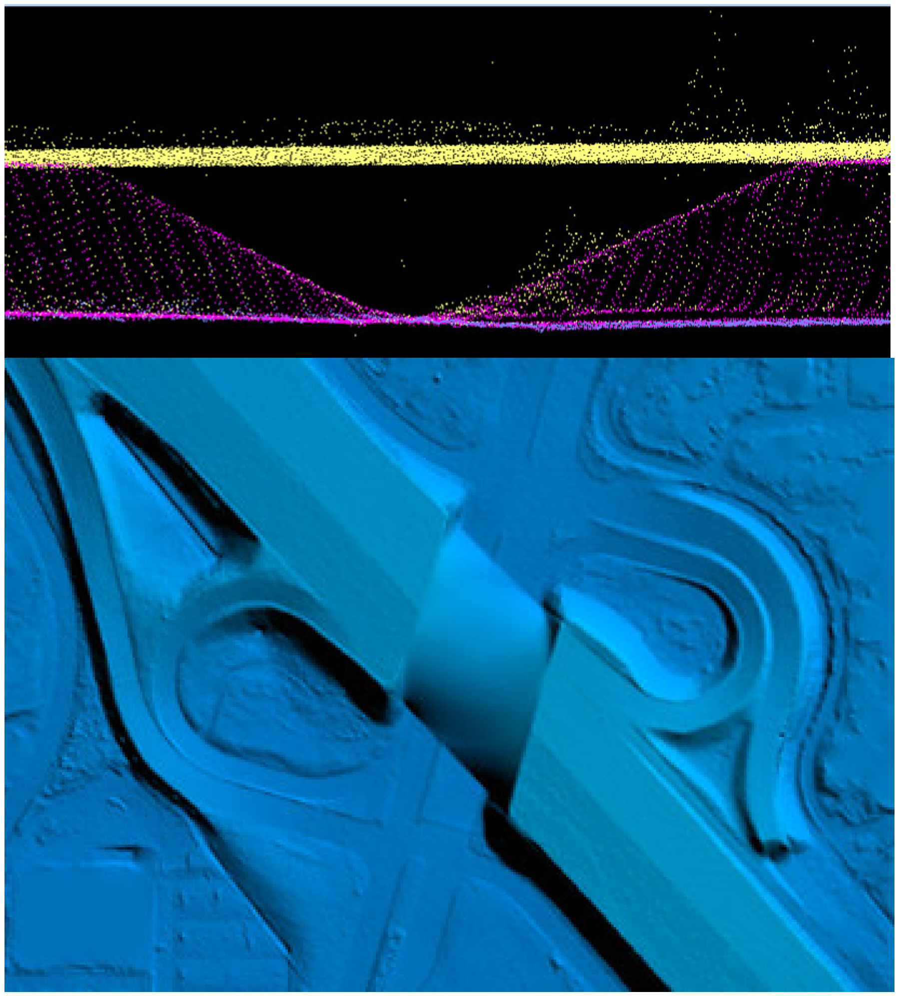


Figure 5 – Tile number 11SMT171390. The DEM in the bottom view shows a visual artifact because the surface model is interpolating from the slope leading to the bridge to the lower ground points on either side of the bridge points that were removed. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This can cause visual artifacts when there are features with large elevation differences. The profile in the top view shows the LiDAR points of this particular feature colored by class. All bridge points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

c. *Building Removal Artifacts:* Large buildings, unique construction, and buildings built on sloped terrain or built into the ground can make a noticeable impact on the bare earth DEM once they have been removed, often in the form of large void areas with obvious triangulation or interpolation across the area and general lack of detail in the ground where the structure stood. In a few areas, this interpolation has resulted in visual artifacts within building footprints. These "artifacts" are only visual and do not exist in the LiDAR points.

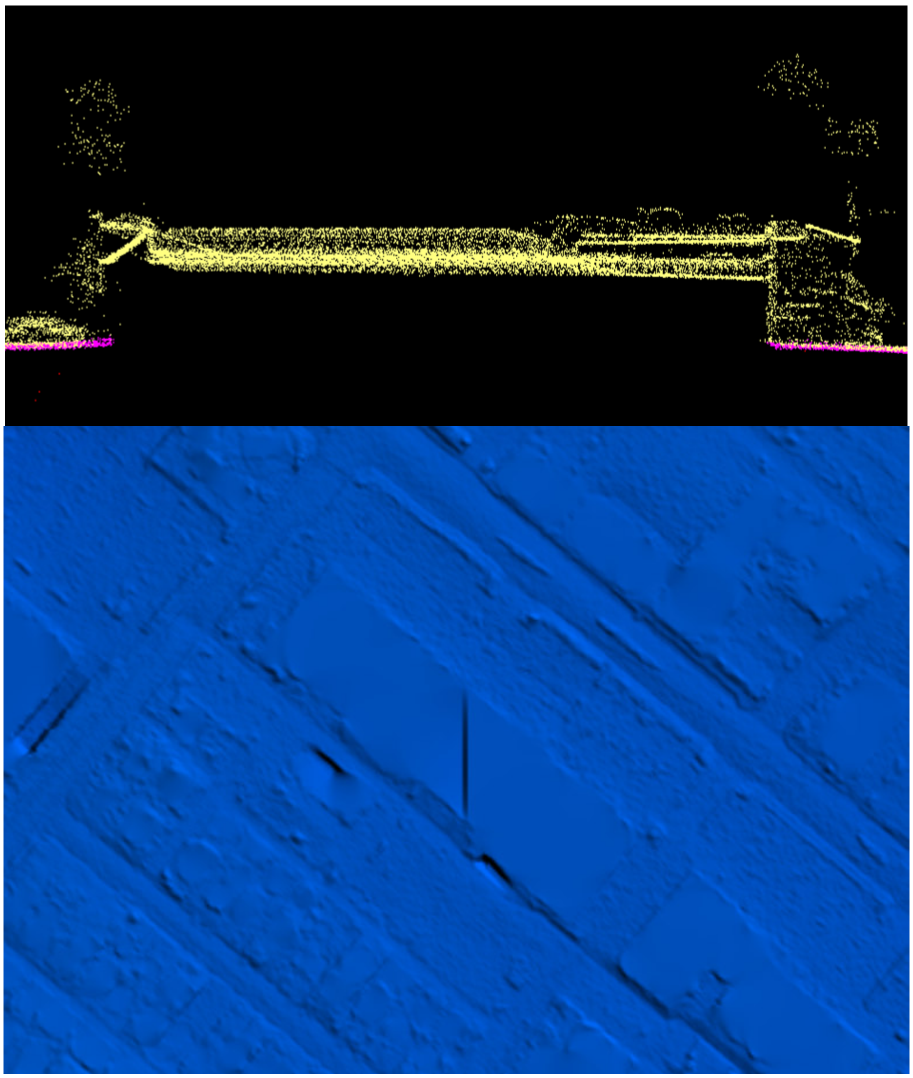


Figure 6 – Tile number 11SMT141210. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of the building points that were removed. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This can cause visual artifacts in areas where the ground elevation is slightly lower on one side of building than the other. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow) or classified as noise (red). There are no ground points that can be modified to correct this visual artifact.

d. *Culverts and Bridges:* Bridges have been removed from the bare earth surface while culverts remain in the bare earth surface. In instances where it is difficult to determine if the feature is a culvert or bridge, such as with some small bridges, Dewberry erred on assuming they would be culverts especially if they are on secondary or tertiary roads. There were also several large structures throughout the project area that Dewberry determined to be box culverts. Below is an example of a culvert that has been left in the ground surface.

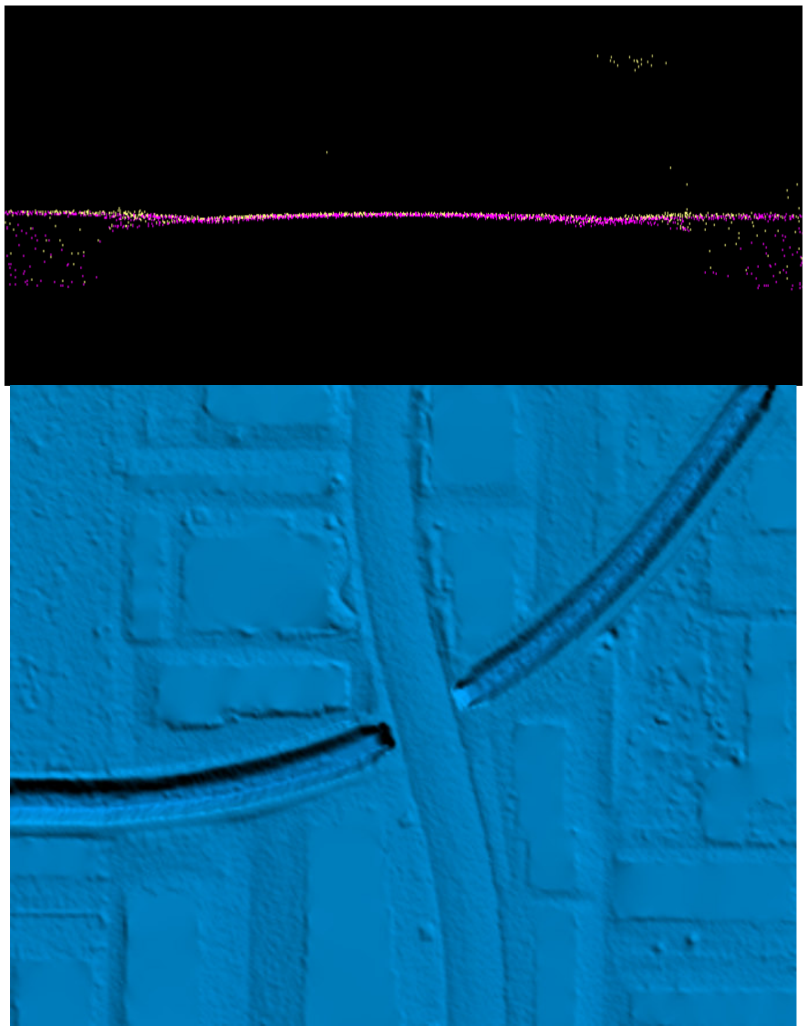


Figure 7– Tile number 11SMT186405. Profile with points colored by class (class 1=yellow, class 2=pink) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 1.

e. *Concrete Railroad Tunnel:* Tunnels are generally included in the final ground model. An odd shaped precast concrete railroad tunnel that occurs within the project area is shown below.

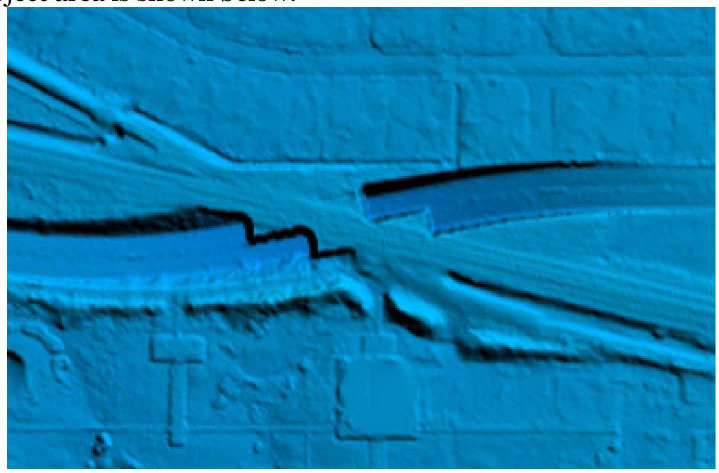


Figure 8– Tile number 11SMT111480. The tunnel shown in the above DEM, remains in the bare earth surface.

f. *In Ground Bunkers:* In ground structures exist within the project area. These occur mainly on military bases. These features are correctly included in the ground classification.

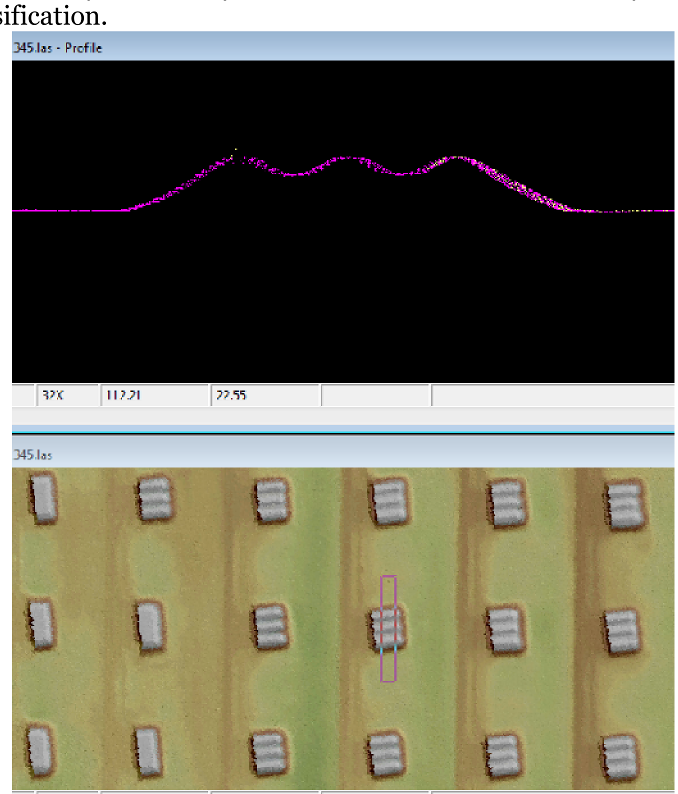


Figure 9 – Tile number 11SMT021345. Profile with points colored by class (class 1=yellow, class 2=pink) is shown in the top view and a TIN of the surface is shown in the bottom view. In ground military structures have been included in the ground classification.

g. *Elevation Change Within Breaklines:* While water bodies are flattened in the final DEMs, other features such as linear hydrographic features and tidal waters can have significant changes in elevation within a small distance. In linear hydrographic features, this is often due to the presence of a structure that affects flow such as a dam or spillway. Sudden changes in elevation occur naturally in tidally influenced areas which are present within the project area. Dewberry has gone through the DEMs making sure that changes in elevation are shown from bank to bank. These changes are often shown as steps to reduce the presence of artifacts while ensuring consistent downhill flow. Examples of elevation change due to a structure and within a tidally influenced area are shown below.

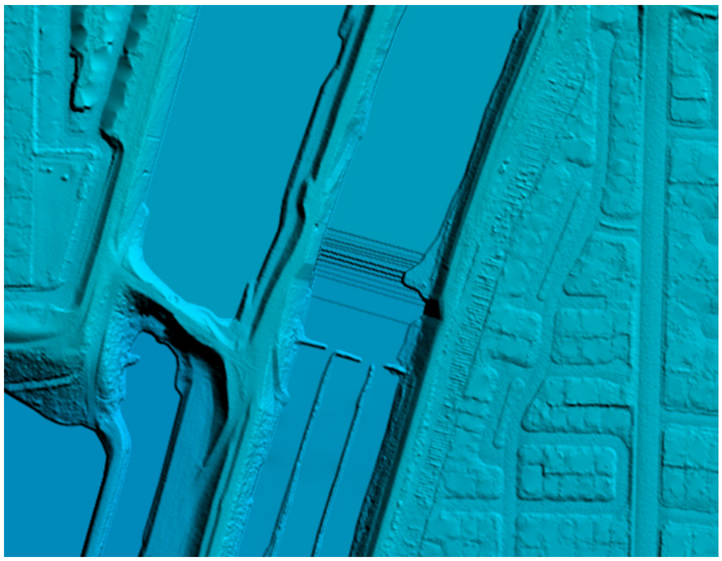


Figure 10 – Tile number 11SMT186435. Elevation change due to the structure has been stair stepped. The steps are straight across from bank to bank and flow consistently downhill.

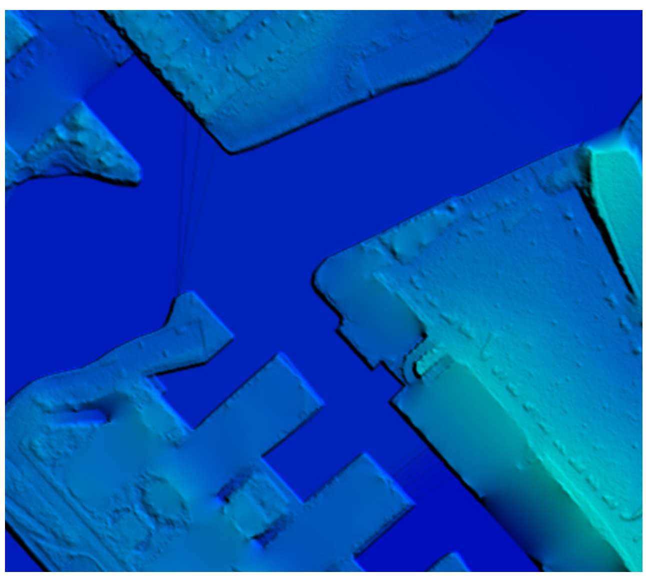


Figure 11 – Tile number 11SLT961360. Sudden changes in elevation within the tidally influenced breaklines have been stair stepped. The steps flow consistently downhill.

h. *Flightline Ridges:* Ridges occur when there is a difference between the elevations of adjoining flightlines or swaths. Some flightline ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible ridge that is within tolerance is shown below.

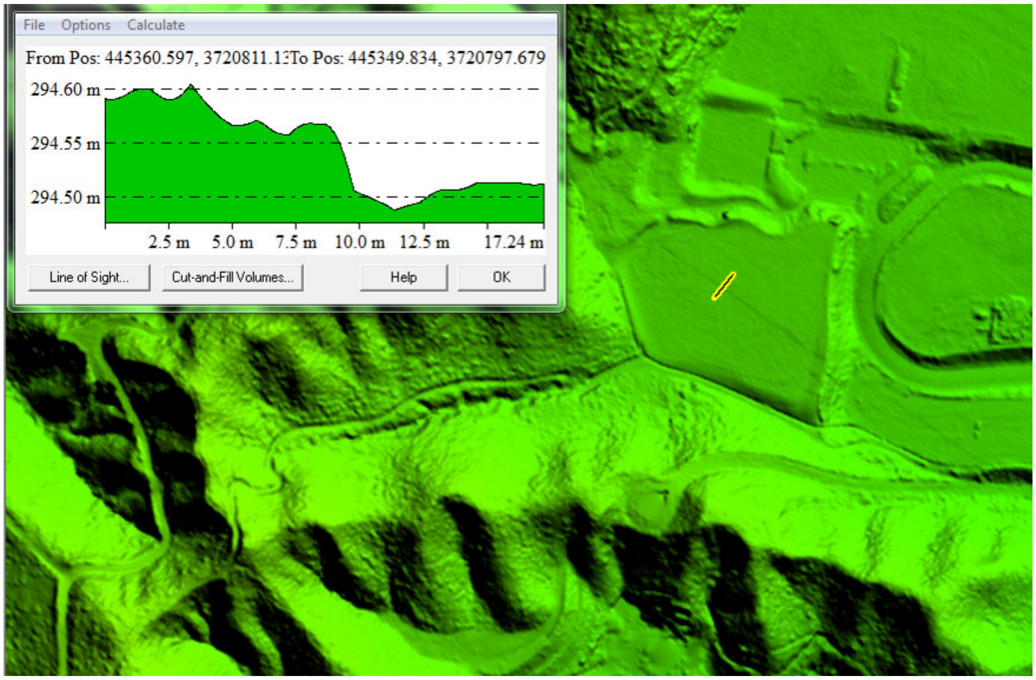


Figure 12 – Tile number 11SMT441195. The flight line ridge is less than 10 cm. Overall, the Orange County LiDAR data meets the project specifications for 10 cm RMSE relative accuracy.

CONCLUSION

The dataset conforms to project specifications for format and header values. The spatial projection information and classification of points is correct. Minor artifacts and small areas of misclassification are isolated and have minimal impact on the usability of the dataset.

Survey Vertical Accuracy Checkpoints

PT. #	EASTING	NORTHING	ELEVS.
	UTM North Zone 11		
POINT ID	**EASTING (M)**	**NORTHING (M)**	**ELEVATION (M)**
Or100_OT13	438012.729	3724661.839	221.174
Or13_OT10	426275.573	3735038.027	54.597
Or18_OT04	424644.543	3740376.689	93.865
Or22_OT11	417088.376	3730138.572	10.467
Or23_OT03	414401.835	3727697.854	12.092
Or28_OT02	405913.505	3728762.660	22.067
Or38_OT05	428144.121	3750220.401	169.177
Or43_OT09	413230.692	3747828.908	41.570
Or47_OT06	417474.859	3751257.435	137.653
Or55_OT01	407885.234	3734301.461	11.476
Or60_OT17	425207.757	3721997.253	91.421
Or61_OT22	446108.639	3734510.662	567.901
Or72_OT12	432080.668	3717316.683	190.207
Or75_OT16	445930.258	3709083.385	89.874
Or76_OT15	442323.009	3708812.603	53.261
Or79_OT07	405702.177	3739859.248	13.319
Or80_OT08	404094.319	3746020.215	14.632
Or87_OT19	434670.780	3706420.686	80.906
Or88_OT20	438963.202	3703614.154	97.036
Or91_OT18	429696.446	3720929.317	122.821
Or95_OT14	436148.223	3720575.444	124.737
Or03_B16	417186.773	3719657.949	20.642
Or06_B17	420335.305	3722229.509	30.432
Or101_B21	443533.876	3703411.049	133.315
Or12_B09	425556.625	3729116.119	17.791
Or15_B10	429253.540	3735551.163	101.830
Or17_B04	428164.414	3742582.899	139.752
Or24_B03	412926.323	3725246.850	23.566
Or26_B02	408577.584	3727018.991	16.061
Or29_B01	403778.953	3735141.169	6.275
Or36_B05	425462.436	3754121.327	227.818
Or42_B08	414552.187	3751051.455	87.258
Or44_B07	409942.117	3751030.965	95.168
Or45_B06	408867.848	3748347.427	26.008
Or62_B11	437774.844	3734522.633	307.028
Or63_B12	440641.768	3729195.902	419.832
Or65_B13	444638.023	3724027.225	288.333
Or73_B19	434444.280	3711455.974	65.234
Or82_B15	442722.854	3722284.418	256.239
Or83_B14	445003.482	3721623.581	295.417

Or89_B20	441587.895	3704515.424	73.740
Or93_B16	438805.228	3721997.928	210.623
Or96_B18	427338.383	3724083.628	58.231
Or05_F13	416521.375	3722953.070	26.592
Or19_F10	421855.612	3736582.602	55.953
Or20_F12	416906.251	3733122.349	19.937
Or21_F04	412665.469	3732620.855	15.587
Or25_F03	409892.555	3724186.045	2.141
Or32_F07	407739.403	3742788.274	21.816
Or33_F07	407055.999	3751844.146	55.837
Or34_F08	412432.847	3756075.110	124.401
Or35_F05	422537.849	3753600.315	129.710
Or49_F06	422515.967	3744593.874	99.515
Or53_F01	416045.915	3738186.776	34.934
Or54_F02	410443.187	3736184.793	18.679
Or56_F11	428948.113	3730494.298	53.647
Or59_F19	424199.179	3724839.859	30.257
Or71_F14	433428.124	3715319.792	66.972
Or90_F18	439626.509	3707103.916	29.694
Or92_F16	435433.246	3723792.701	129.317
Or94_F15	437385.865	3715887.885	108.840
Or98_F17	441258.968	3712778.254	150.106
Or01_TW14	414310.974	3720509.940	3.721
Or02_TW13	418712.225	3725144.900	13.346
Or08_TW11	432926.485	3736607.702	248.494
Or10_TW20	423905.552	3727856.964	17.440
Or14_TW10	429822.478	3733317.482	82.484
Or16_TW03	429655.825	3739293.399	191.380
Or31_TW08	402642.728	3744543.059	13.065
Or39_TW05	424047.910	3750065.414	103.609
Or48_TW04	427711.641	3745291.070	133.355
Or52_TW07	411060.754	3740743.217	28.491
Or57_TW09	427543.406	3726459.284	36.908
Or58_TW17	432626.995	3729517.277	122.633
Or61_TW12	446214.928	3734567.891	573.167
Or64_TW02	406200.571	3731497.728	1.391
Or68_TW16	429516.073	3717466.744	93.587
Or69_TW15	429061.781	3714487.070	49.860
Or78_TW01	413283.759	3735869.446	22.870
Or81_TW06	414895.921	3742411.492	43.995
Or84_TW18	444918.667	3714946.274	162.958
Or97_TW19	448803.102	3710710.305	114.163
Or04_U19	432874.006	3708888.836	157.070
Or07_U10	419405.802	3727524.647	10.318
Or09_U17	420938.040	3729546.112	13.111

Or11_U09	423862.622	3732245.302	28.240
Or27_U03	410555.417	3728168.277	3.636
Or30_U08	400215.787	3739495.567	4.581
Or37_U04	434404.506	3750241.984	313.163
Or40_U05	419436.890	3746855.019	63.981
Or41_U06	417709.684	3745155.199	56.987
Or46_U16	433920.904	3726436.423	128.049
Or50_U01	419310.580	3741323.858	50.734
Or51_U07	411231.560	3743926.191	33.878
Or66_U18	432814.707	3719087.889	117.807
Or67_U11	420218.828	3719198.908	89.351
Or70_U12	424439.659	3718154.762	283.761
Or74_U15	435816.432	3708453.594	103.893
Or77_U02	410070.322	3731305.239	9.418
Or85_U14	441538.129	3716056.661	180.438
Or86_U20	443447.236	3701869.101	72.054
Or99_U13	437866.324	3727671.532	269.808

Table 6: USGS FEMA IX-Orange County, CA LiDAR surveyed accuracy checkpoints

LiDAR Vertical Accuracy Statistics & Analysis

BACKGROUND

Dewberry tests and reviews project data both quantitatively (for accuracy) and qualitatively (for usability).

For qualitative assessment (i.e. vertical accuracy assessment), One hundred and two (102) check points were surveyed for the project and are located within bare earth/open terrain, brush/small trees, forested/fully grown, tall weeds/crops and urban land cover categories. The checkpoints were surveyed for the project using RTK survey methods. A survey report was produced which details and validates how the survey was completed for this project.

Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the “dispersed method” of placement.

VERTICAL ACCURACY TEST PROCEDURES

FVA (Fundamental Vertical Accuracy) is determined with check points located only in the open terrain (grass, dirt, sand, and/or rocks) land cover category, where there is a very high probability that the LiDAR sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The FVA determines how well the calibrated LiDAR sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error (RMSEz) of the checkpoints x 1.9600. For the USGS FEMA IX Orange County California LiDAR project, vertical accuracy must be 0.245 meters or less based on an RMSEz of 0.125 meters x 1.9600.

CVA (Consolidated Vertical Accuracy) is determined with all checkpoints in all land cover categories combined where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. CVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all land cover categories combined. The USGS FEMA IX Orange County California LiDAR Project CVA standard is 0.363 meters at the 95% confidence level. The CVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the CVA; these are always the largest outliers that may depart from a normal error distribution. Here, $Accuracy_z$ differs from CVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas CVA assumes LiDAR errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

SVA (Supplemental Vertical Accuracy) is determined for each land cover category other than open terrain. SVA at the 95% confidence level equals the 95th percentile error for all checkpoints in each land cover category. The USGS FEMA IX Orange County California LiDAR Project SVA target is 0.363 meters at the 95% confidence level. Target specifications are given for SVA's as one individual land cover category may exceed this target value as long as the overall CVA is within specified tolerances. Again, $Accuracy_z$ differs from SVA because $Accuracy_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas SVA assumes LiDAR errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

The relevant testing criteria are summarized in Table 7.

Quantitative Criteria	Measure of Acceptability
Fundamental Vertical Accuracy (FVA) in open terrain only using RMSEz *1.9600	0.245 meters (based on RMSEz (0.125 meters) * 1.9600)
Consolidated Vertical Accuracy (CVA) in all land cover categories combined at the 95% confidence level	0.363 meters (based on combined 95th percentile)
Supplemental Vertical Accuracy (SVA) in each land cover category separately at the 95% confidence level	0.363 meters (based on 95th percentile for each land cover category)

Table 7 – Acceptance Criteria

VERTICAL ACCURACY TESTING STEPS

The primary QA/QC vertical accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications.
2. Next, Dewberry interpolated the bare-earth LiDAR DTM to provide the z-value for each of the 102 checkpoints.
3. Dewberry then computed the associated z-value differences between the interpolated z-value from the LiDAR data and the ground truth survey checkpoints and computed FVA, CVA, and SVA values.
4. The data were analyzed by Dewberry to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

The figure below shows the location of the QA/QC checkpoints within the project area.

Figure 13 – Location of QA/QC Checkpoints

VERTICAL ACCURACY RESULTS

Table 8 summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the LiDAR LAS files.

Land Cover Category	# of Points	FVA – Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=0.245 m	CVA – Consolidated Vertical Accuracy (95th Percentile) Spec=0.363 m	SVA – Supplemental Vertical Accuracy (95th Percentile) Target=0.363 m
Consolidated	102		0.17	
Bare Earth-Open Terrain	21	0.19		
Tall Weeds and Crops	20			0.12
Forested and Fully Grown	19			0.13
Brush and Small Trees	22			0.18
Urban	20			0.16

Table 8 – FVA, CVA, and SVA Vertical Accuracy at 95% Confidence Level

The $RMSE_z$ for checkpoints in open terrain only tested 0.10 meters, within the target criteria of 0.125 meters. Compared with the 0.245 meters specification, the FVA tested 0.19 meters at the 95% confidence level based on $RMSE_z$ x 1.9600.

Compared with the 0.363 meters specification, CVA for all checkpoints in all land cover categories combined tested 0.17 meters at the 95% confidence level based on the 95^{th} percentile.

Compared with target 0.363 specification, SVA for checkpoints in the tall weeds and crops land cover category tested 0.12 meters, checkpoints in the forested and fully grown land cover category tested 0.13 meters at the 95% confidence level based on the 95^{th} percentiles, checkpoints in the brush and small trees land cover category tested 0.18 meters at the 95% confidence level based on the 95^{th} percentiles, and checkpoints in the urban land cover category tested 0.16 meters at the 95% confidence level based on the 95^{th} percentiles.

Figure 14 illustrates the magnitude of the differences between the QA/QC checkpoints and LiDAR data. This shows that the majority of LiDAR elevations were within +/- 0.15 meters of the checkpoints elevations, but there were some outliers where LiDAR and checkpoint elevations differed by up to +0.35 meters.

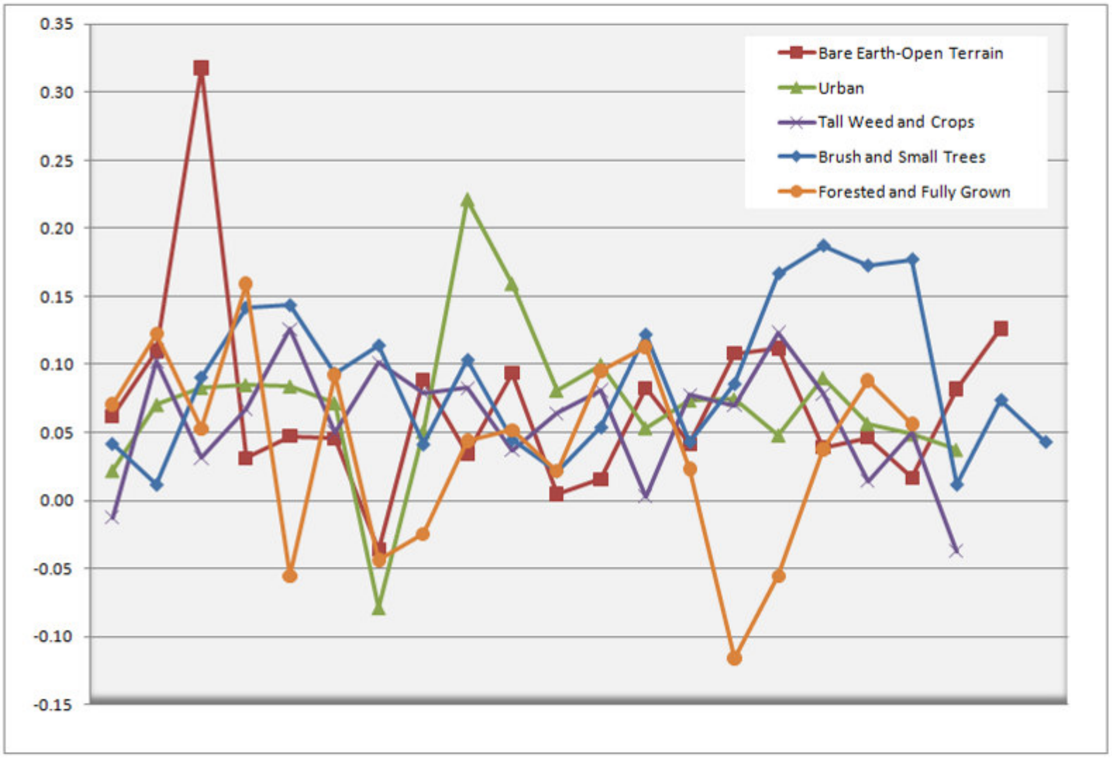


Figure 14 – Magnitude of Elevation Discrepancies

Table 9 lists the 5% outliers that are larger than the 95th percentile.

Point ID	NAD83 UTM North Zone 11		NAVD88	LiDAR - Z (m)	Delta Z	AbsDelta Z
	Easting - X (m)	Northing - Y (m)	Survey -Z (m)			
Or18_OT04	424644.543	3740376.689	93.865	94.1827	0.32	0.32
Or14_TW10	429822.478	3733317.482	82.484	82.61	0.13	0.13
Or69_TW15	429061.781	3714487.070	49.860	49.9833	0.12	0.12
Or19_F10	421855.612	3736582.602	55.953	56.0756	0.12	0.12
Or21_F04	412665.469	3732620.855	15.587	15.7462	0.16	0.16
Or71_F14	433428.124	3715319.792	66.972	66.8562	-0.12	0.12
Or65_B13	444638.023	3724027.225	288.333	288.4998	0.17	0.17
Or73_B19	434444.280	3711455.974	65.234	65.4212	0.19	0.19
Or82_B15	442722.854	3722284.418	256.239	256.4116	0.17	0.17
Or83_B14	445003.482	3721623.581	295.417	295.5941	0.18	0.18
Or41_U06	417709.684	3745155.199	56.987	57.2083	0.22	0.22
Or46_U16	433920.904	3726436.423	128.049	128.2083	0.16	0.16

Table 9 – 5% Outliers

Table 10 provides overall descriptive statistics.

100 % of Totals	RMSE (m) Open Terrain Spec=0.125m	Mean (m)	Mean Absolute (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Consolidated		0.07	0.08	0.07	0.41	0.06	102	-0.12	0.32
Bare Earth-Open Terrain	0.10	0.07	0.07	0.05	2.19	0.07	21	-0.04	0.32
Tall Weeds and Crops		0.06	0.06	0.07	-0.60	0.04	20	-0.04	0.13
Forested and Fully Grown		0.04	0.08	0.05	-0.51	0.07	19	-0.12	0.16
Brush and Small Trees		0.09	0.09	0.09	0.30	0.06	22	0.01	0.19
Urban		0.07	0.08	0.07	0.15	0.06	20	-0.08	0.22

Table 10 — Overall Descriptive Statistics

Figure 15 illustrates a histogram of the associated elevation discrepancies between the QA/QC checkpoints and elevations interpolated from the LiDAR triangulated irregular network (TIN). The frequency shows the number of discrepancies within each band of elevation differences. Although the discrepancies vary between a low of -0.12 meters and a high of +0.32 meters, the histogram shows that the majority of the discrepancies are skewed on the positive side. The vast majority of points are within the ranges of -0.05 meters to +0.05 meters.

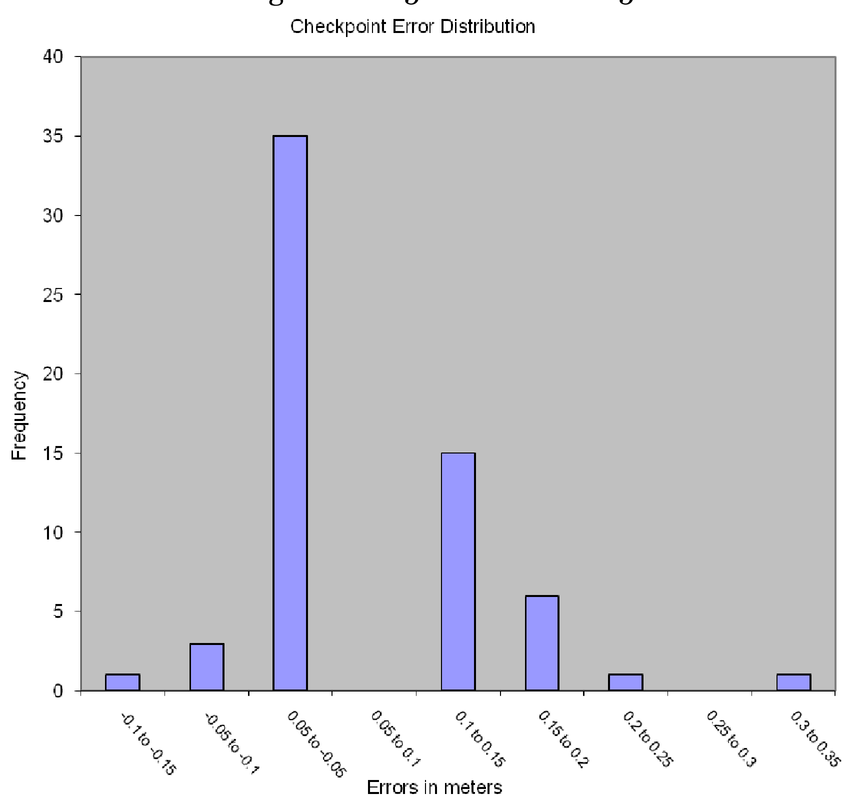


Figure 15 — Histogram of Elevation Discrepancies within errors in feet

CONCLUSION

Based on the vertical accuracy testing conducted by Dewberry, the LiDAR dataset for the USGS FEMA IX – Orange County LiDAR Project satisfies the project's pre-defined vertical accuracy criteria.

Breakline Production & Qualitative Assessment Report

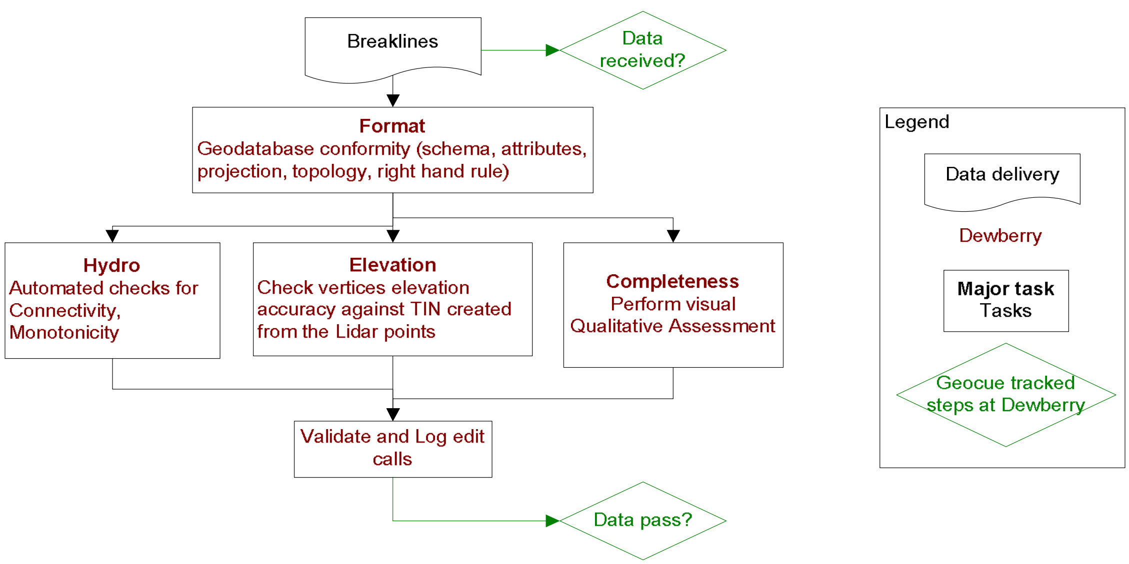
BREAKLINE PRODUCTION METHODOLOGY

Dewberry used GeoCue software to develop LiDAR stereo models of the USGS FEMA IX – Orange County LiDAR Project area so the LiDAR derived data could be viewed in 3-D stereo using Socet Set softcopy photogrammetric software. Using LiDARgrammetry procedures with LiDAR intensity imagery, Dewberry used the stereo models developed by Dewberry to stereo-compile the three types of hard breaklines in accordance with the project's Data Dictionary.

All drainage breaklines are monotonically enforced to show downhill flow. Water bodies are reviewed in stereo and the lowest elevation is applied to the entire waterbody.

BREAKLINE QUALITATIVE ASSESSMENT

Dewberry completed breakline qualitative assessments according to a defined workflow. The following workflow diagram represents the steps taken by Dewberry to provide a thorough qualitative assessment of the breakline data.



BREAKLINE TOPOLOGY RULES

Automated checks are applied on hydro features to validate the 3D connectivity of the feature and the monotonicity of the hydrographic breaklines. Dewberry's major concern was that the hydrographic breaklines have a continuous flow downhill and that breaklines do not undulate. Error points are generated at each vertex not complying with the tested rules and these potential edit calls are then visually validated during the visual evaluation of the data. This step also helped validate that breakline vertices did not have excessive minimum or maximum elevations and that elevations are consistent with adjacent vertex elevations.

The next step is to compare the elevation of the breakline vertices against the elevation extracted from the ESRI Terrain built from the LiDAR ground points, keeping in mind that a discrepancy is expected because of the hydro-enforcement applied to the breaklines and because of the interpolated imagery used to acquire the breaklines. A given tolerance is used to validate if the elevations differ too much from the LiDAR.

Dewberry's final check for the breaklines was to perform a full qualitative analysis. Dewberry compared the breaklines against LiDAR intensity images to ensure breaklines were captured in the required locations. The quality control steps taken by Dewberry are outlined in the QA Checklist below.

BREAKLINE QA/QC CHECKLIST

Project Number/Description: TO G10PC00013 USGS FEMA IX – Orange County LiDAR

Date:______06/13/2012____

Overview

☒ All Feature Classes are present in GDB

☒ All features have been loaded into the geodatabase correctly. Ensure feature classes with subtypes are domained correctly.

☒ The breakline topology inside of the geodatabase has been validated. See Data Dictionary for specific rules

☒ Projection/coordinate system of GDB is accurate with project specifications

Perform Completeness check on breaklines using either intensity or ortho imagery

☒ Check entire dataset for missing features that were not captured, but should be to meet baseline specifications or for consistency (See Data Dictionary for specific collection rules). NHD data will be used to help evaluate completeness of collected hydrographic features. Features should be collected consistently across tile bounds within a dataset as well as be collected consistently between datasets.

☒ Check to make sure breaklines are compiled to correct tile grid boundary and there is full coverage without overlap

☒ Check to make sure breaklines are correctly edge-matched to adjoining datasets if applicable. Ensure breaklines from one dataset join breaklines from another dataset that are coded the same and all connecting vertices between the two datasets match in X,Y, and Z (elevation). There should be no breaklines abruptly ending at dataset boundaries and no discrepancies of Z-elevation in overlapping vertices between datasets.

Compare Breakline Z elevations to LiDAR elevations

☒ Using a terrain created from LiDAR ground points and water points and GeoFIRM tools, drape breaklines on terrain to compare Z values. Breakline elevations should be at or below the elevations of the immediately surrounding terrain. This should be performed before other breakline checks are completed.

Perform automated data checks using PLTS

The following data checks are performed utilizing ESRI's PLTS extension. These checks allow automated validation of 100% of the data. Error records can either be written to a table for future correction, or browsed for immediate correction. PLTS checks should always be performed on the full dataset.

☒ Perform "adjacent vertex elevation change check" on the Inland Ponds feature class (Elevation Difference Tolerance=.001 meters). This check will return Waterbodies whose vertices are not all identical. This tool is found under "Z Value Checks."

☒ Perform "unnecessary polygon boundaries check" on Inland Ponds and Inland Streams feature classes. This tool is found under "Topology Checks."

☒ Perform "duplicate geometry check" on (inland streams to inland streams), (inland ponds to inland ponds), (inland ponds to inland streams). Attributes do not need to be checked during this tool. This tool is found under "Duplicate Geometry Checks."

☒ Perform "geometry on geometry check" on (inland ponds to inland streams). Spatial relationship is contains, attributes do not need to be checked. This tool is found under "Feature on Feature Checks."

☒ Perform "polygon overlap/gap is sliver check" (inland streams to inland streams), (inland ponds to inland ponds), (inland ponds to inland streams). Maximum Polygon Area is not required. This tool is found under "Feature on Feature Checks."

Perform Dewberry Proprietary Tool Checks

☒ Perform monotonicity check on inland streams features using "A3_checkMonotonicityStreamLines." This tool looks at line direction as well as elevation. Features in the output shapefile attributed with a "d" are correct monotonically, but were compiled from low elevation to high elevation. These errors can be ignored. Features in the output shapefile attributed with an "m" are not correct monotonically and need elevations to be corrected. Input features for this tool need to be in a geodatabase. Z tolerance is .01 meters. Polygons need to be exported as lines for the monotonicity tool.

☒ Perform connectivity check between (inland ponds to inland streams) using the tool "07_CheckConnectivityForHydro." The input for this tool needs to be in a geodatabase. The output is a shapefile showing the location of overlapping vertices from the polygon features and polyline features that are at different Z-elevation. The unnecessary polygon boundary check must be run and all errors fixed prior to performing connectivity check. If there are exceptions to the polygon boundary rule then that feature class must be checked against itself, i.e. inland streams to inland streams.

Metadata

☒ Each XML file (1 per feature class) is error free as determined by the USGS MP tool

☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc. Content should be consistent across all feature classes.

Completion Comments: Complete – Approved

Data Dictionary

HORIZONTAL AND VERTICAL DATUM

The horizontal datum shall be North American Datum of 1983, Units in Meters. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88), Units in Meters. Geoid09 shall be used to convert ellipsoidal heights to orthometric heights.

COORDINATE SYSTEM AND PROJECTION

All data shall be projected to UTM Zone 11, Horizontal Units in Meters and Vertical Units in Meters.

INLAND STREAMS AND RIVERS

Feature Dataset: BREAKLINES
Feature Class: STREAMS_AND_RIVERS
Feature Type: Polygon

Contains M Values: No
Contains Z Values: Yes
Annotation Subclass: None

XY Resolution: Accept Default Setting
Z Resolution: Accept Default Setting
XY Tolerance: 0.003
Z Tolerance: 0.001

Description

This polygon feature class will depict linear hydrographic features with a width greater than 100 feet.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Streams and Rivers	Linear hydrographic features such as streams, rivers, canals, etc. with an average width greater than 100 feet in length. In the case of embankments, if the feature forms a natural dual line	Capture features showing dual line (one on each side of the feature). Average width shall be great than 100 feet to show as a double line. Each vertex placed should maintain vertical integrity and data is required to show "closed polygon". Generally both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small branch or offshoot

	channel, then capture it consistent with the capture rules. Other natural or manmade embankments will not qualify for this project.	of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the features on either side of the island meet the criteria for capture. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

INLAND PONDS AND LAKES

Feature Dataset: BREAKLINES
Feature Class: PONDS_AND_LAKES
Feature Type: Polygon

Contains M Values: No
Contains Z Values: Yes
Annotation Subclass: None

XY Resolution: Accept Default Setting
Z Resolution: Accept Default Setting
XY Tolerance: 0.003
Z Tolerance: 0.001

Description

This polygon feature class will depict closed water body features that are at a constant elevation.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Software
SHAPE_AREA	Double	Yes			0	0		Calculated by Software

Feature Definition

Description	Definition	Capture Rules
Ponds and Lakes	Land/Water boundaries of constant elevation water bodies such as lakes, reservoirs, ponds, etc. Features shall be defined as closed polygons and contain an elevation value that reflects the best estimate of the water elevation at the time of data capture. Water body features will be captured for features 2 acres in size or greater. “Donuts” will exist where there are islands within a closed water body feature greater than ½ acre in size.	Water bodies shall be captured as closed polygons with the water feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. An Island within a Closed Water Body Feature will also have a “donut polygon” compiled. These instructions are only for docks or piers that follow the coastline or water’s edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where

		the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.

TIDAL WATERS

Feature Dataset: BREAKLINES
Feature Type: Polygon

Feature Class: Tidal Waters

Contains M Values: No
Annotation Subclass: None

Contains Z Values: Yes

XY Resolution: Accept Default Setting
XY Tolerance: 0.003

Z Resolution: Accept Default Setting
Z Tolerance: 0.001

Description

This polygon feature class will outline the land / water interface at the time of LiDAR acquisition.

Table Definition

Field Name	Data Type	Allow Null Values	Default Value	Domain	Precision	Scale	Length	Responsibility
OBJECTID	Object ID							Assigned by Software
SHAPE	Geometry							Assigned by Software
DATESTAMP_DT	Date	Yes			0	0	8	Assigned by Dewberry
SHAPE_LENGTH	Double	Yes			0	0		Calculated by Dewberry
SHAPE_AREA	Double	Yes			0	0		Calculated by Dewberry

Feature Definition

Description	Definition	Capture Rules
TIDAL_WATERS	The coastal breakline will delineate the land water interface using LiDAR data as reference. In flight line boundary areas with tidal variation the coastal shoreline may require some feathering or edge matching to ensure a smooth transition.	The feature shall be extracted at the apparent land/water interface, as determined by the LiDAR intensity data, to the extent of the tile boundaries. Differences caused by tidal variation are acceptable and breaklines delineated should reflect that change with no feathering. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Breaklines shall snap and merge seamlessly with linear hydrographic features.

CONTACT INFORMATION

Any questions regarding this document should be addressed to:

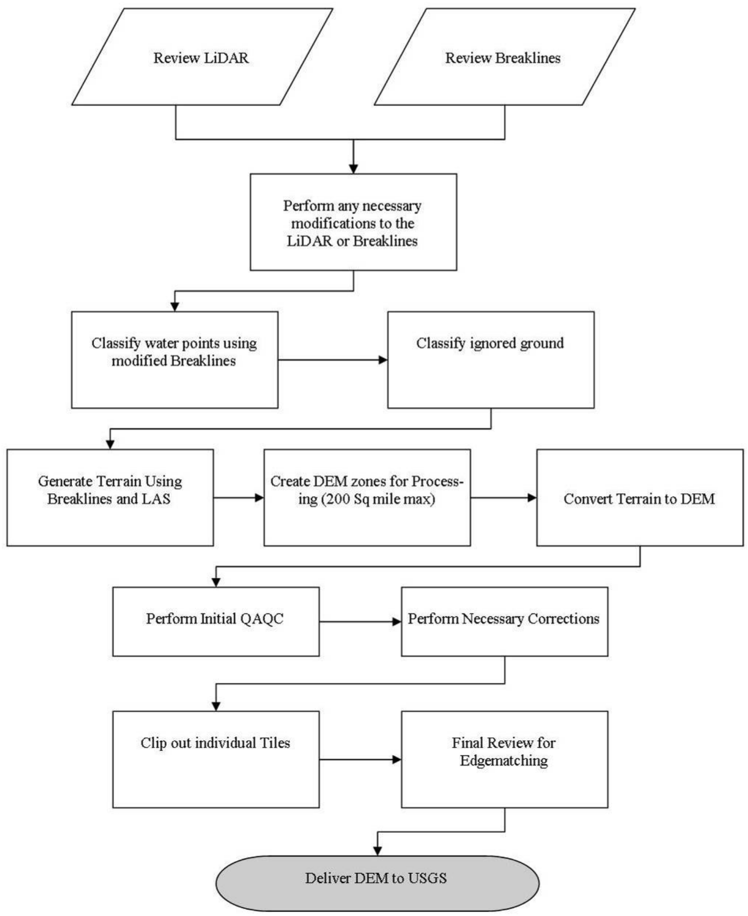
Josh Novac
Project Manager
Dewberry
1000 N. Ashley Dr., Suite 801
Tampa, FL 33602
(813) 421-8632
jnovac@dewberry.com

DEM Production & Qualitative Assessment

DEM PRODUCTION METHODOLOGY

Dewberry utilized ESRI software and Global Mapper for the DEM production and QC process. ArcGIS software is used to generate the products and the QC is performed in both ArcGIS and Global Mapper.

Dewberry Hydro-Flattening Workflow



1. Classify Water Points: LAS point falling within hydrographic breaklines shall be classified to ASPRS class 9 using TerraScan. Breaklines must be prepared correctly prior to performing this task.
2. Classify Ignored Ground Points: Classify points in close proximity to the breaklines from Ground to class 10 (Ignored Ground). Close proximity will be defined as no more than 1x the nominal point spacing on the landward side of the breakline. Breaklines will be buffered using this specification and the subsequent file will need to be prepared in the same manner as the water breaklines for classification. This process will be performed after the water points have been classified and only run on remaining ground points.
3. Terrain Processing: A Terrain will be generated using the Breaklines and LAS data that has been imported into Arc as a Multipoint File. If the final DEMs are to be clipped to a project boundary that boundary will be used during the generation of the Terrain.

4. Create DEM Zones for Processing: Create DEM Zones that are buffered around the edges. Zones should be created in a logical manner to minimize the number of zones without creating zones too large for processing. BAE will make zones no larger than 200 square miles (taking into account that a DEM will fill in the entire extent not just where LiDAR is present). Once the first zone is created it must be verified against the tile grid to ensure that the cells line up perfectly with the tile grid edge.
5. Convert Terrain to Raster: Convert Terrain to raster using the DEM Zones created in step 6. In the environmental properties set the extents of the raster to the buffered Zone. For each subsequent zone, the first DEM will be utilized as the snap raster to ensure that zones consistently snap to one another.
6. Perform Initial QAQC on Zones: During the initial QA process anomalies will be identified and corrective polygons will be created.
7. Correct Issues on Zones: BAE will perform corrections on zones following Dewberry's correction process.
8. Extract Individual Tiles: BAE will extract individual tiles from the zones utilizing the Dewberry created tool.
9. Final QA: Final QA will be performed on the dataset to ensure that tile boundaries are seamless.

DEM QUALITATIVE ASSESSMENT

Dewberry performed a comprehensive qualitative assessment of the DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained the proper referencing information. This process was performed in ArcGIS software with the use of a tool set Dewberry has developed to verify that the raster extents match those of the tile grid and contain the correct projection information. The DEM data was reviewed at a scale of 1:5000 to review for artifacts caused by the DEM generation process and to review the hydro-flattened features. To perform this review Dewberry creates HillShade models and overlays a partially transparent colorized elevation model to review for these issues. Upon completion of this review the DEM data is loaded into Global Mapper to ensure that all files are readable and that no artifacts exist between tiles.

DEM VERTICAL ACCURACY RESULTS

The same 102 checkpoints that were used to test the vertical accuracy of the LiDAR were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source LiDAR and final DEM deliverable. DEMs are created by averaging several LiDAR points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS, which does not average several LiDAR points together but may interpolate (linearly) between two or three points to derive an elevation value.

Table 7 summarizes the tested vertical accuracy results from a comparison of the surveyed checkpoints to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	FVA – Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=0.245 m	CVA – Consolidated Vertical Accuracy (95th Percentile) Spec=0.363 m	SVA – Supplemental Vertical Accuracy (95th Percentile) Target=0.363 m
Consolidated	102		0.17	
Bare Earth-Open Terrain	21	0.18		
Tall Weeds and Crops	20			0.12
Forested and Fully Grown	19			0.13
Brush and Small Trees	22			0.20
Urban	20			0.17

Table 7 – FVA, CVA, and SVA Vertical Accuracy at 95% Confidence Level

The $RMSE_z$ for checkpoints in open terrain only tested 0.09 meters, within the target criteria of 0.125 meters. Compared with the 0.245 meters specification, the FVA tested 0.18 meters at the 95% confidence level based on $RMSE_z$ x 1.9600.

Compared with the 0.363 meters specification, CVA for all checkpoints in all land cover categories combined tested 0.17 meters at the 95% confidence level based on the 95th percentile.

Compared with target 0.363 specification, SVA for checkpoints in the tall weeds and crops land cover category tested 0.12 meters, checkpoints in the forested and fully grown land cover category tested 0.13 meters at the 95% confidence level based on the 95th percentiles, checkpoints in the brush and small trees land cover category tested 0.20 meters at the 95% confidence level based on the 95th percentiles, and checkpoints in the urban land cover category tested 0.17 meters at the 95% confidence level based on the 95th percentiles.

Table 8 lists the 5% outliers that are larger than the 95th percentile.

Point ID	NAD83 UTM North Zone 11		NAVD88	DEM Z (m)	Delta Z	AbsDeltaZ
	Easting - X (m)	Northing - Y (m)	Survey Z (m)			
Or18_OT04	424644.543	3740376.689	93.865	94.158	0.29	0.29
Or65_B13	444638.023	3724027.225	288.333	288.535	0.20	0.20
Or73_B19	434444.28	3711455.974	65.234	65.428	0.19	0.19
Or101_B21	443533.876	3703411.049	133.315	133.543	0.23	0.23
Or41_U06	417709.684	3745155.199	56.987	57.240	0.25	0.25

Table 8 – 5% Outliers

Table 9 provides overall descriptive statistics.

100 % of Totals	RMSE (m) Open Terrain Spec=0.125 m	Mean (m)	Mean Absolute (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Consolidated		0.07	0.08	0.07	0.53	0.06	102	-0.12	0.29
Bare Earth-Open Terrain	0.09	0.07	0.07	0.07	2.02	0.06	21	-0.03	0.29
Tall Weeds and Crops		0.06	0.07	0.07	-0.40	0.04	20	-0.02	0.13
Forested and Fully Grown		0.04	0.08	0.05	-0.71	0.07	19	-0.12	0.16
Brush and Small Trees		0.10	0.10	0.10	0.39	0.06	22	0.01	0.23
Urban		0.07	0.08	0.07	1.26	0.06	20	-0.05	0.25

Table 9 — Overall Descriptive Statistics

DEM QA/QC CHECKLIST

Project Number/Description: TO G10PC00013 USGS FEMA IX – Orange County LiDAR
Date:_______06/13/2012______
Overview
☒ Correct number of files is delivered and all files are in ERDAS IMG format
☒ Verify Raster Extents
☒ Verify Projection/Coordinate System

Review
☒ Manually review bare-earth DEMs with a hillshade to check for issues with hydro-enforcement process or any general anomalies that may be present. Specifically, water should be flowing downhill, water features should NOT be floating above surrounding terrain and bridges should NOT be present in bare-earth DEM. Hydrologic breaklines should be overlaid during review of DEMs.
☒ Overlap points (in the event they are supplied to fill in gaps between adjacent flightlines) are not to be used to create the bare-earth DEMs
☒ DEM cell size is 1 meter
☒ Perform final overview in Global Mapper to ensure seamless product.

Metadata
☒ Project level DEM metadata XML file is error free as determined by the USGS MP tool

☒ Metadata content contains sufficient detail and all pertinent information regarding source materials, projections, datums, processing steps, etc.

Completion Comments: Complete - Approved

Appendix A: Full LiDAR Acquisition Report

Scope of Work

DMI acquired LiDAR data over an Area of Interest (AOI) entire of Orange County California. The acquisition plan entailed a nominal point spacing of 1.76 points per meter square and a side lap of 40% between flight lines. The AOI covers 696 square miles.

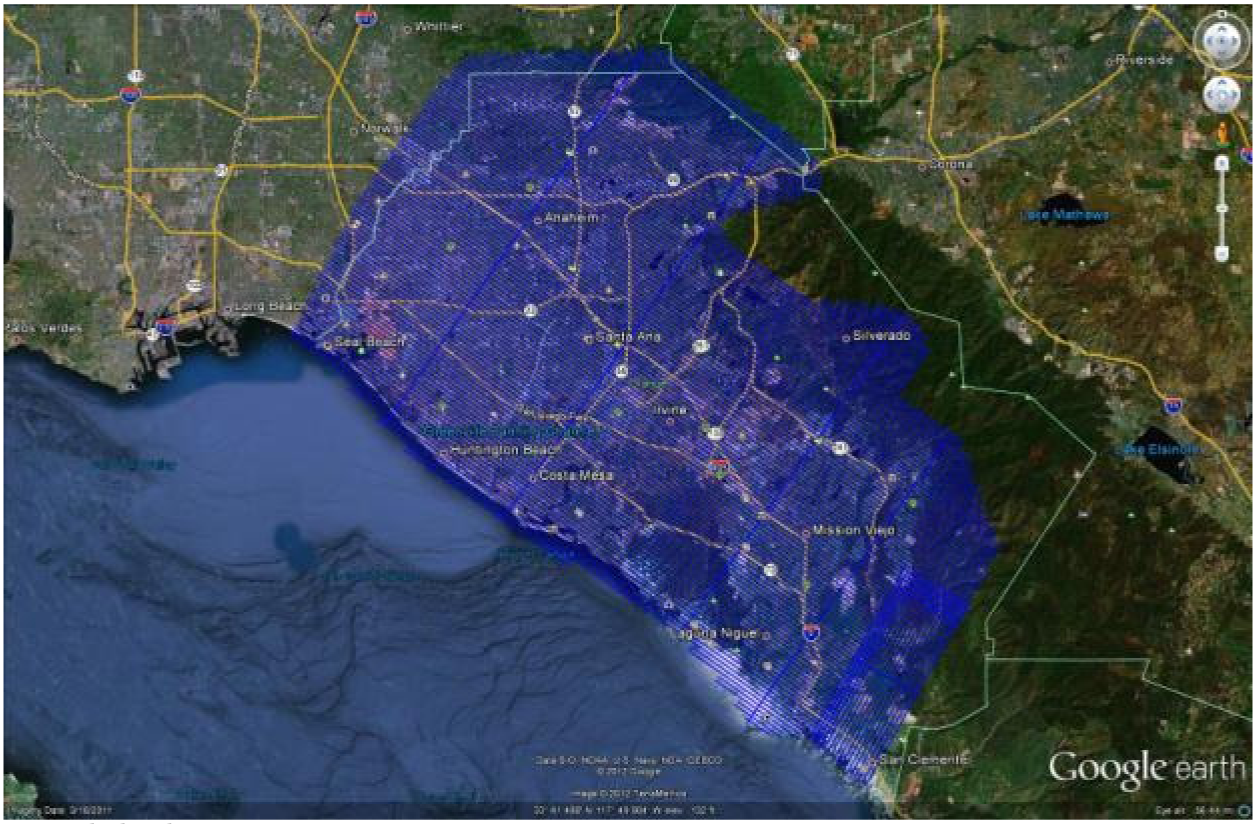


Fig. 1 Flight plan

LiDAR Acquisition Details

Collections (Lifts): 14
Collection Dates: 2011 December 17, 20, 21, 23, 24, 26, 27, 28, 29, 30,
Field of View (FOV): 18 degrees
Average Point Density (planned): 0.75 m
Flight Level(s): 914 / 3000 m/ft
Sensor Type: Optech Gemini **Sensor Serial Number(s):** 07SEN204

All acquired LiDAR data was initially quality controlled after every mission for coverage and further verified for content and adherence to flight plan at DMI production facilities Huntington Beach, CA. All data was accepted for processing.

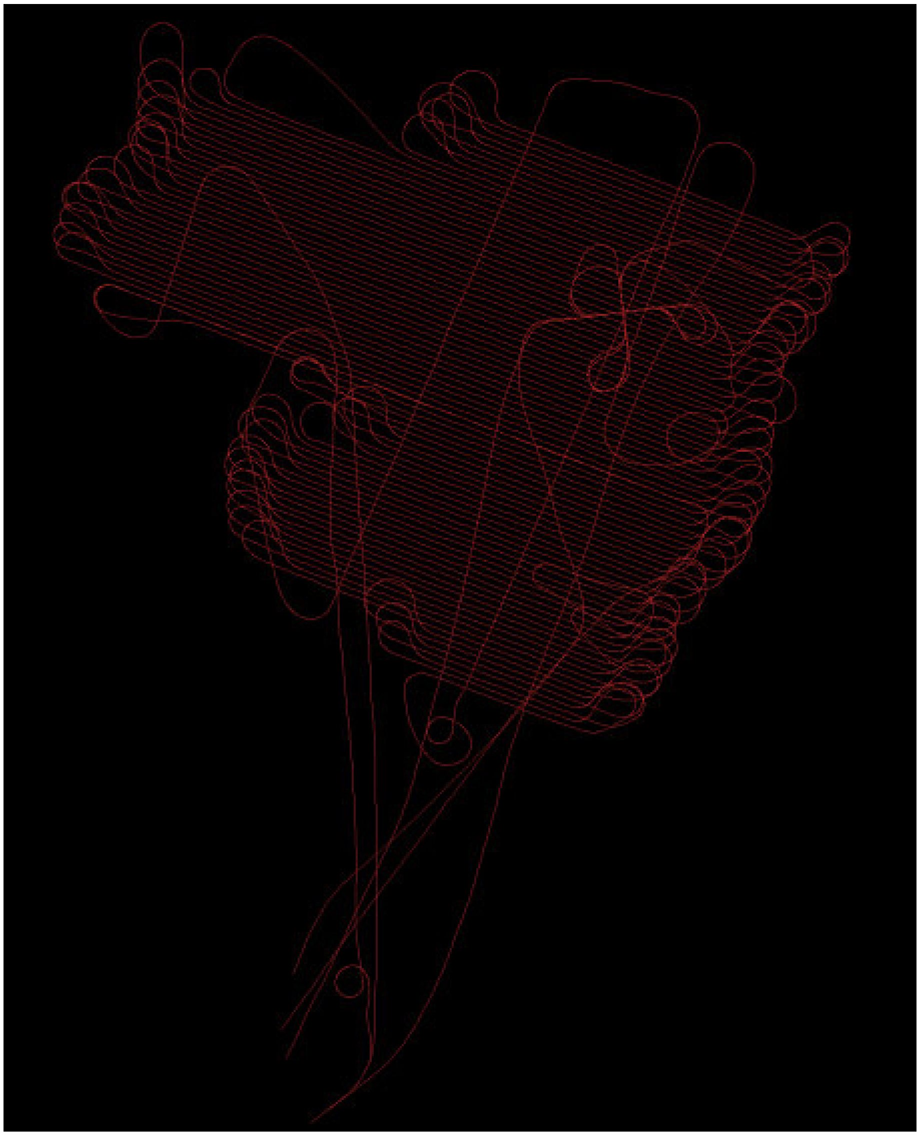
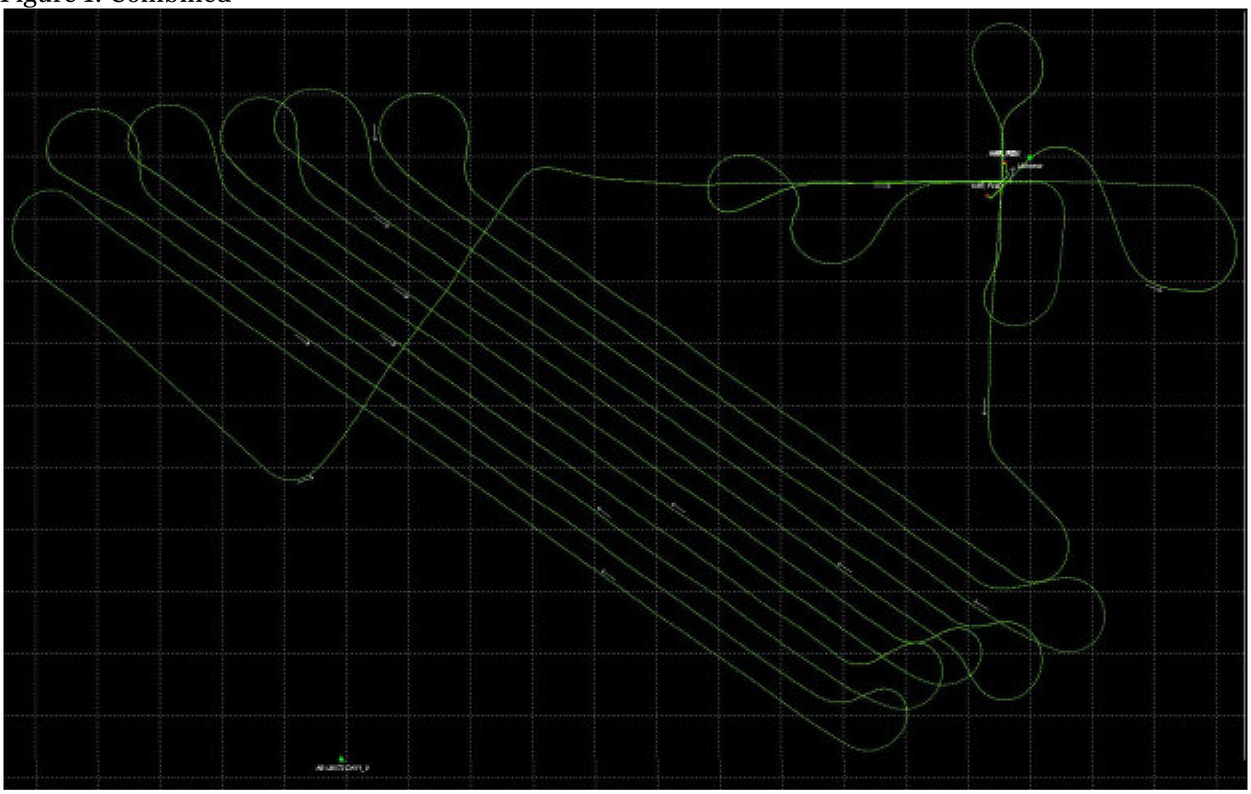


Fig. 2 Orange County AOI Flight Trajectories

Output Results for 12/17/2011AM

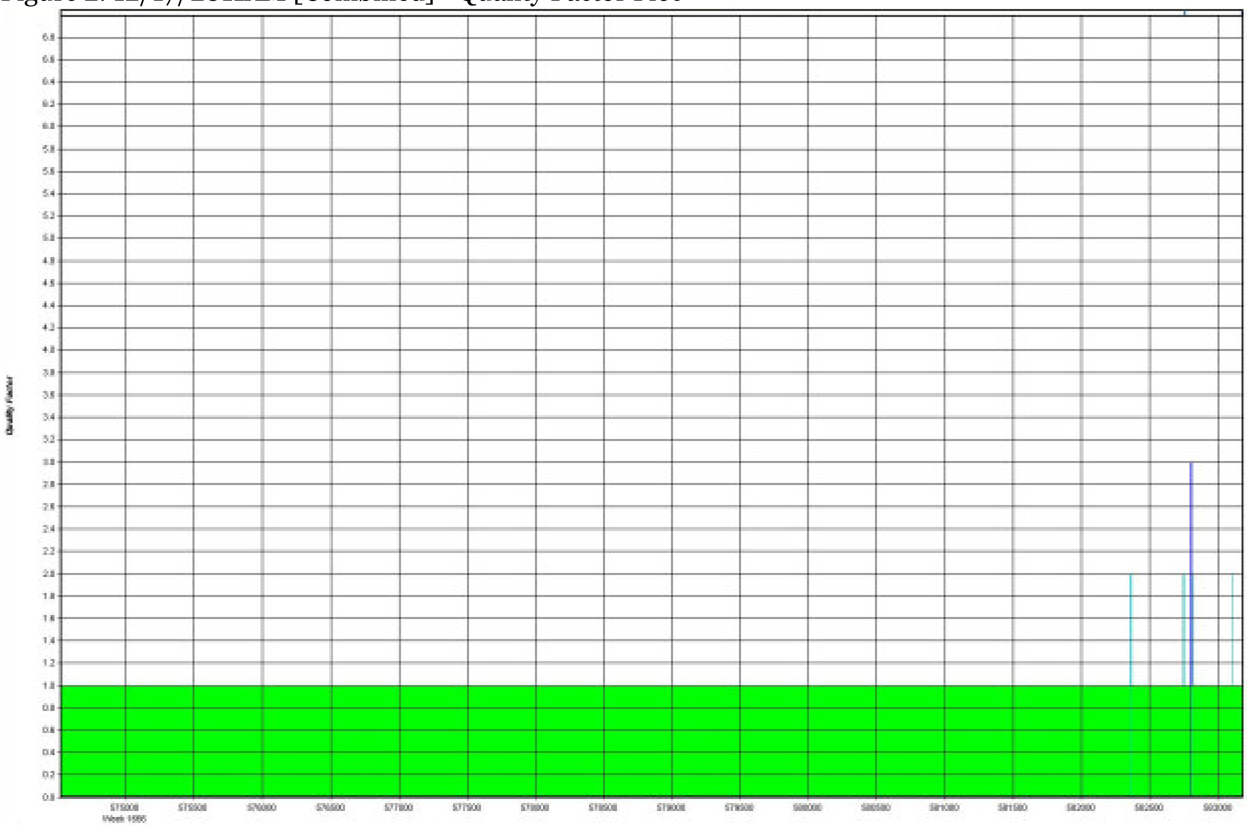
POSPAC Version 4.31

Figure 1: Combined



Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

Figure 2: 12/17/2011AM [Combined] - Quality Factor Plot

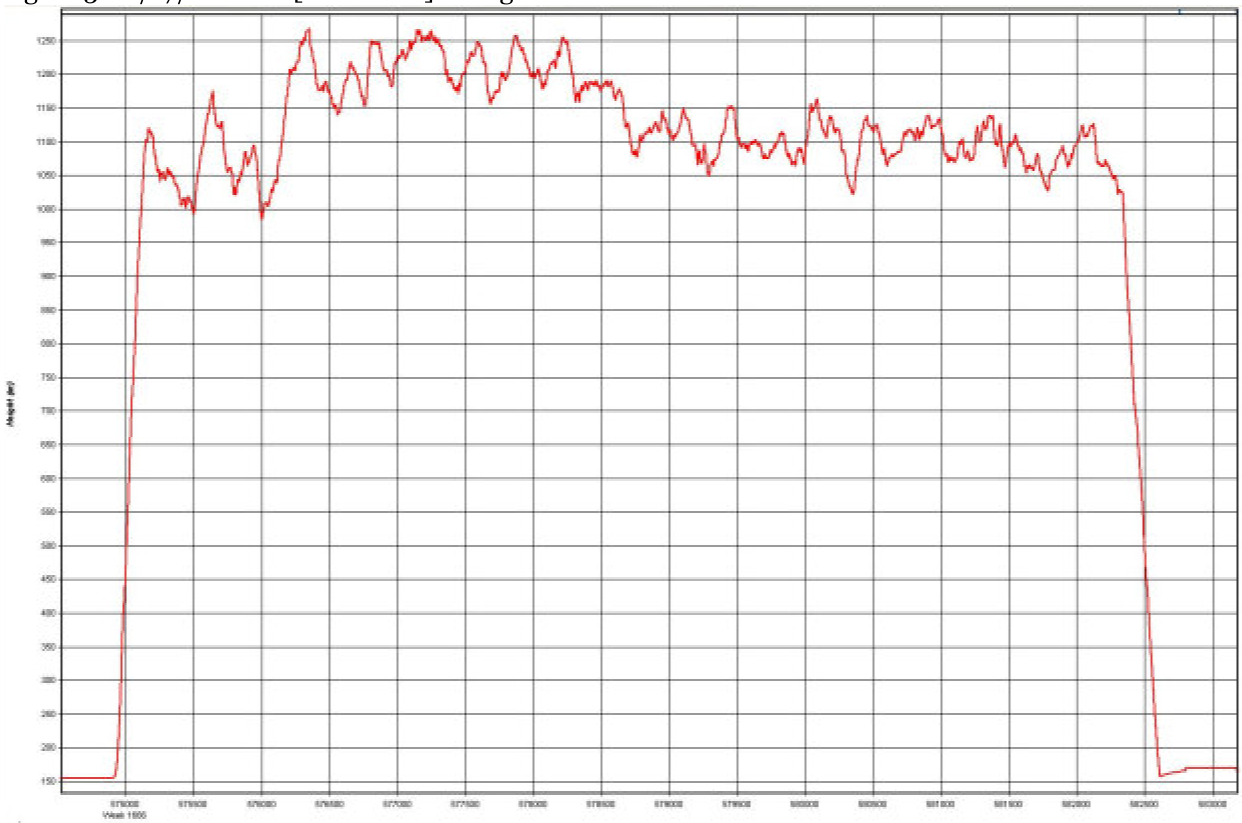


GPS Time

— Fixed Integer — Stable float — Converging float — DGPS or worse — Single Point — No solution

Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

Figure 3: 12/17/2011AM [Combined] - Height Profile Plot

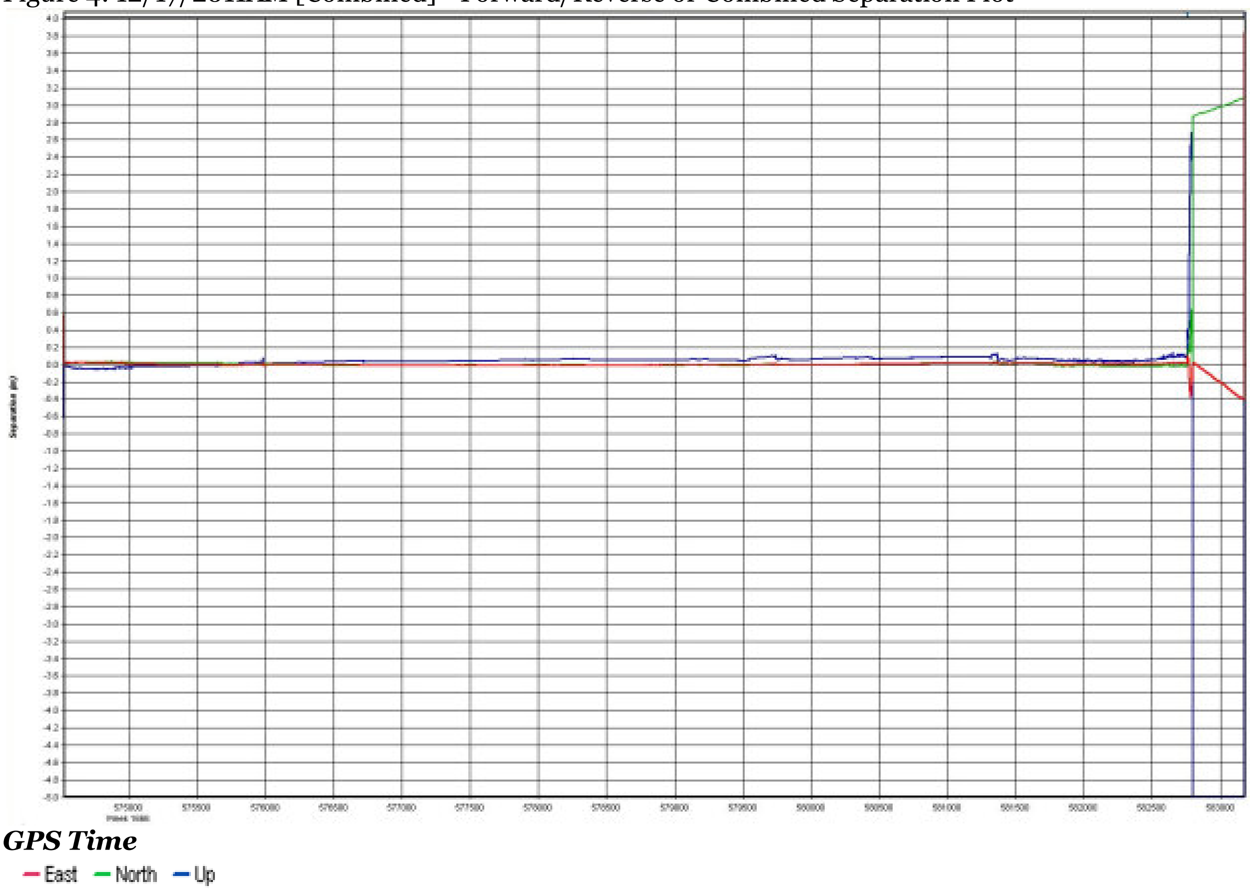


GPS Time

— Height

Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

Figure 4: 12/17/2011AM [Combined] - Forward/Reverse or Combined Separation Plot

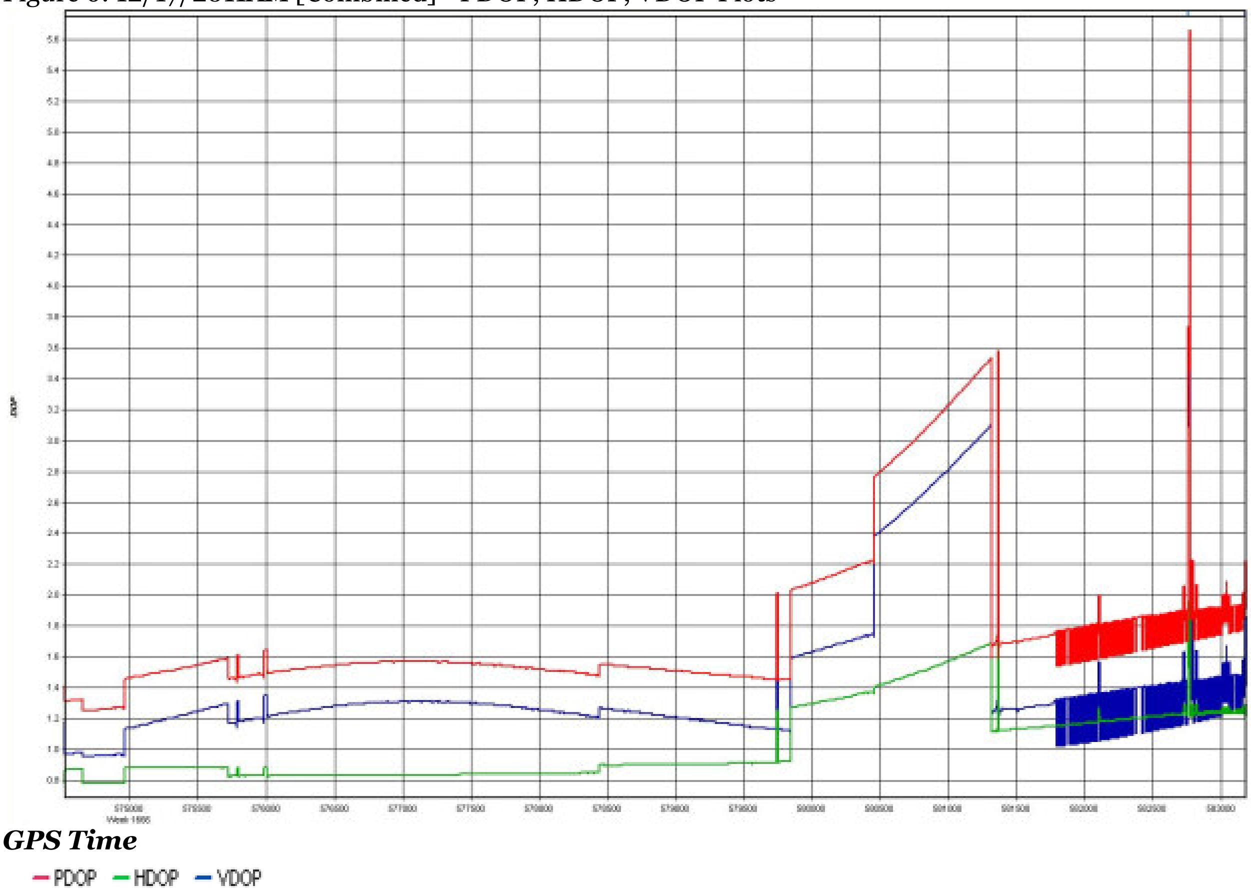


Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

Figure 5: 12/17/2011AM [Combined] - Forward/Reverse or Combined Weighting Plot

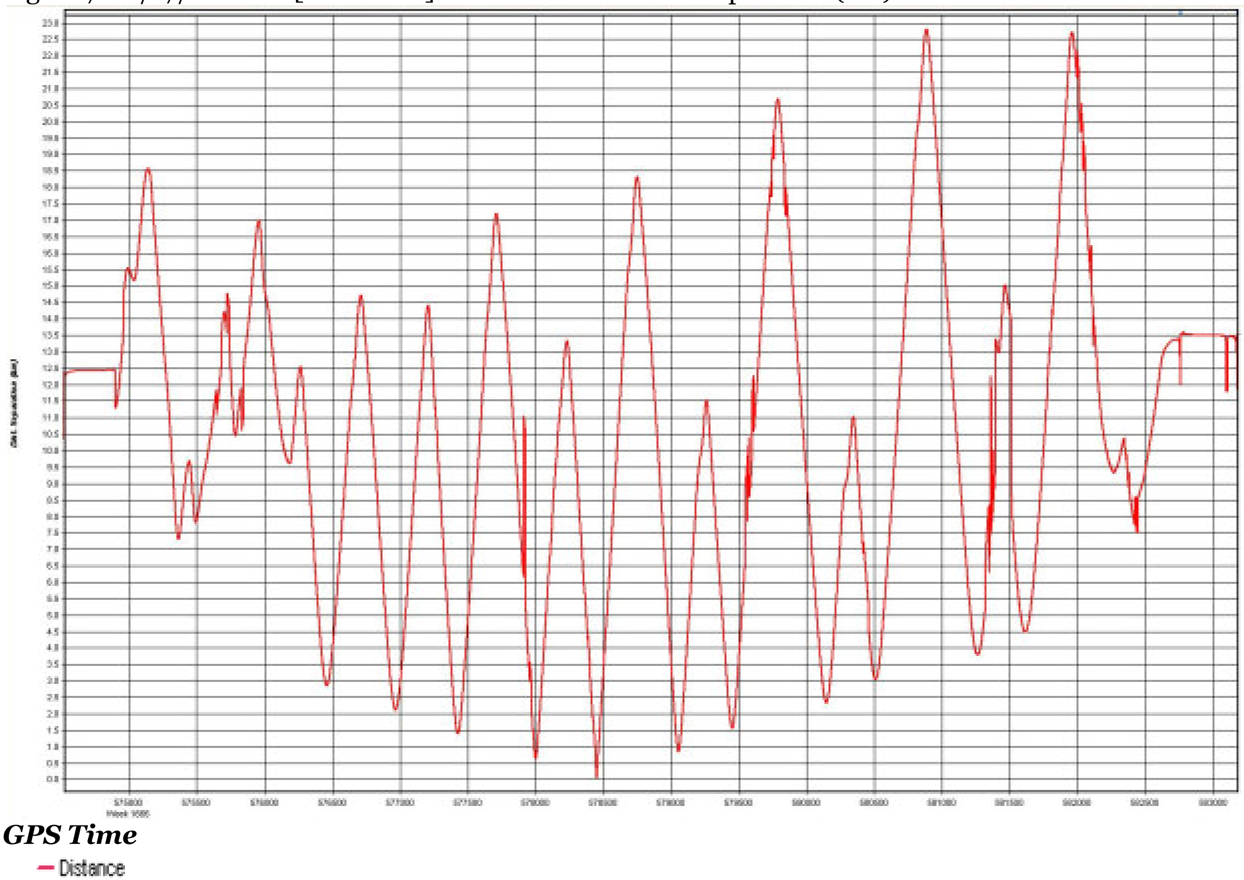
Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

Figure 6: 12/17/2011AM [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

Figure 7: 12/17/2011AM [Combined] - Horizontal Distance Separation (km)

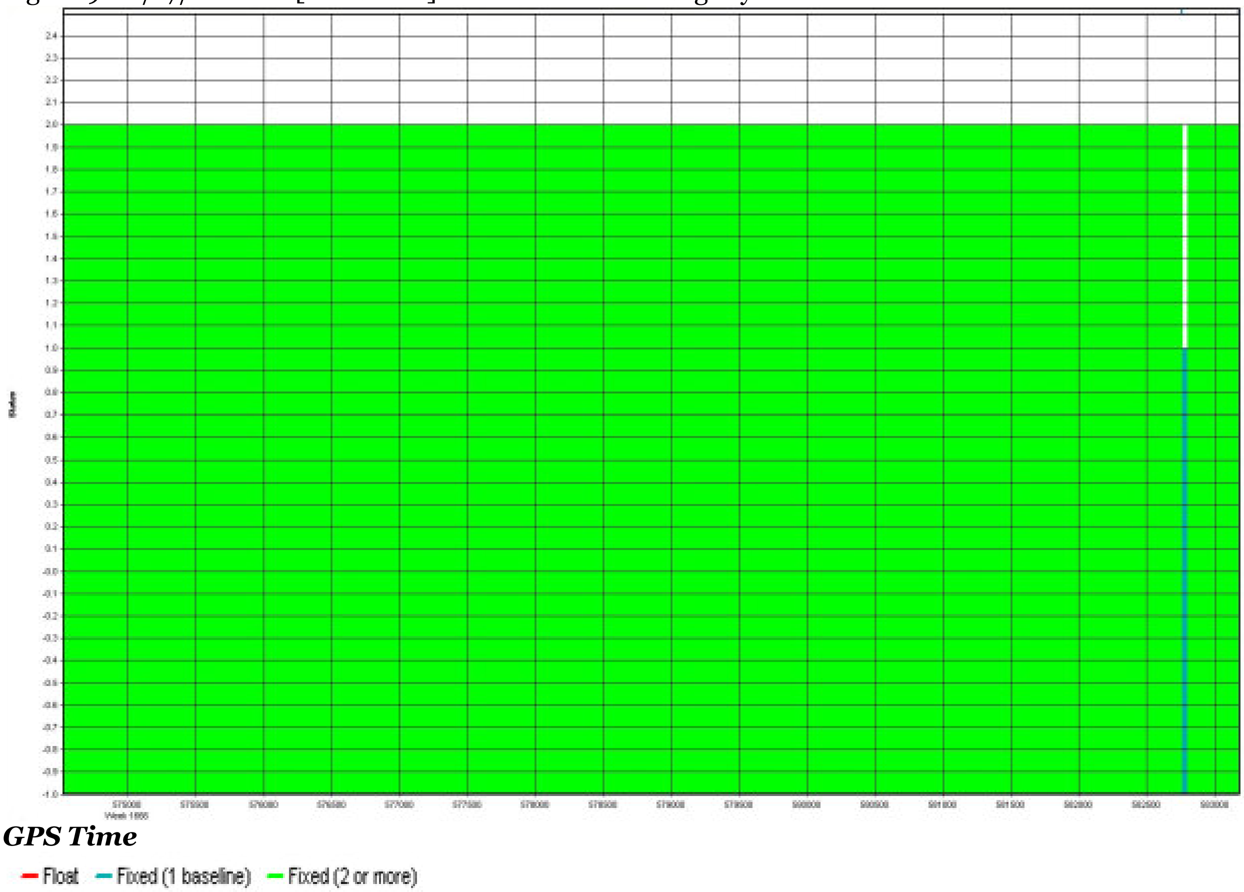


Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

Figure 8: 12/17/2011AM [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

Figure 9: 12/17/2011AM [Combined] - Float or Fixed Ambiguity



Process	Run (12)	by Unknown	on 12/17/2011	at 07:30

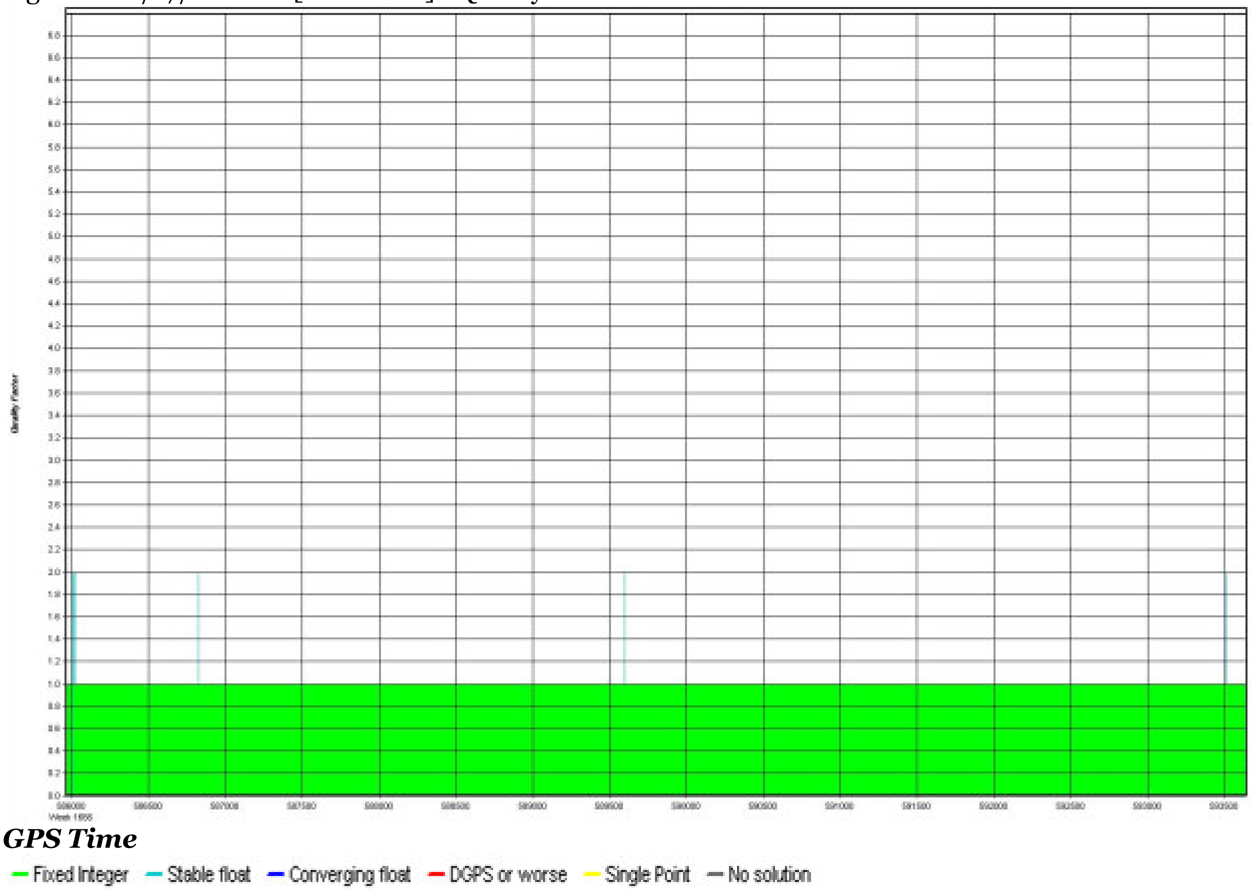
Output Results for 12/17/2011PM

POSPAC Version 4.31

Figure 1: Combined - Map

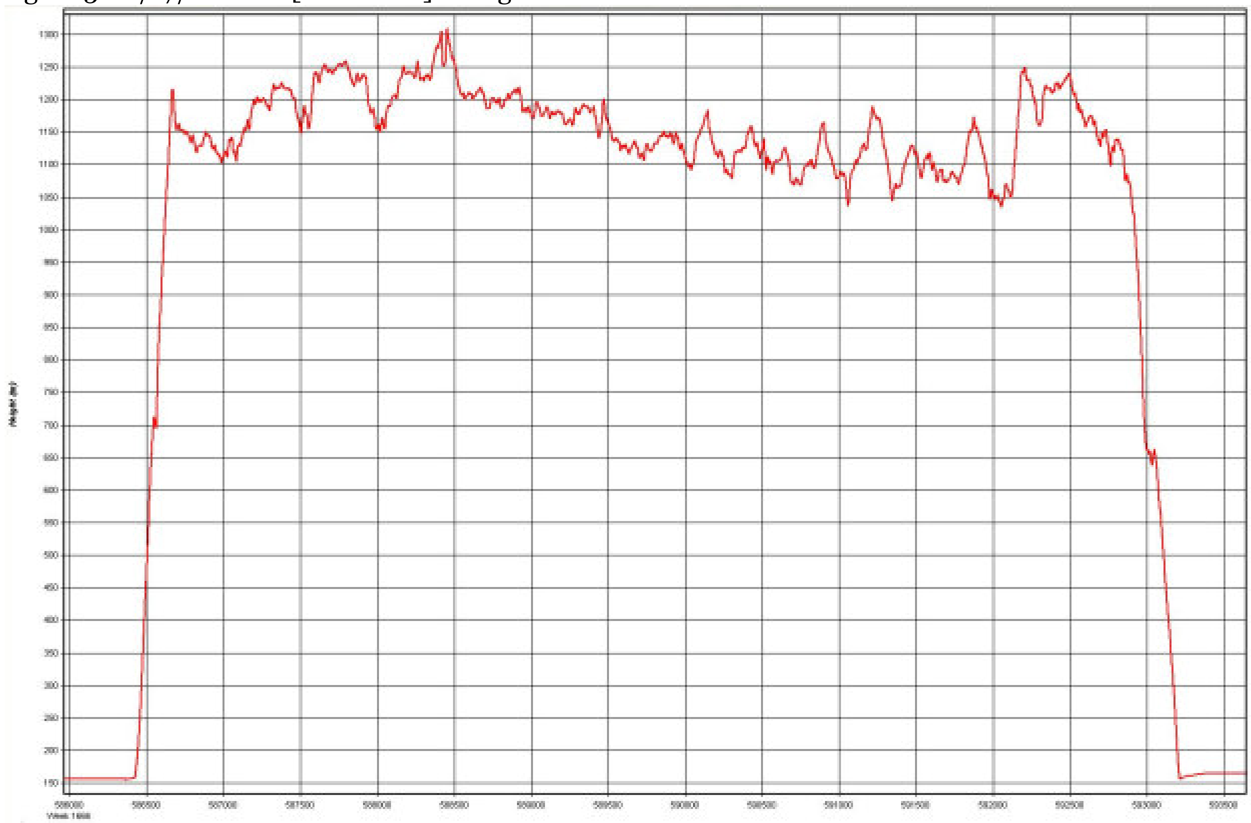
Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Figure 2: 12/17/2011PM [Combined] - Quality Factor Plot



Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Figure 3: 12/17/2011PM [Combined] - Height Profile Plot

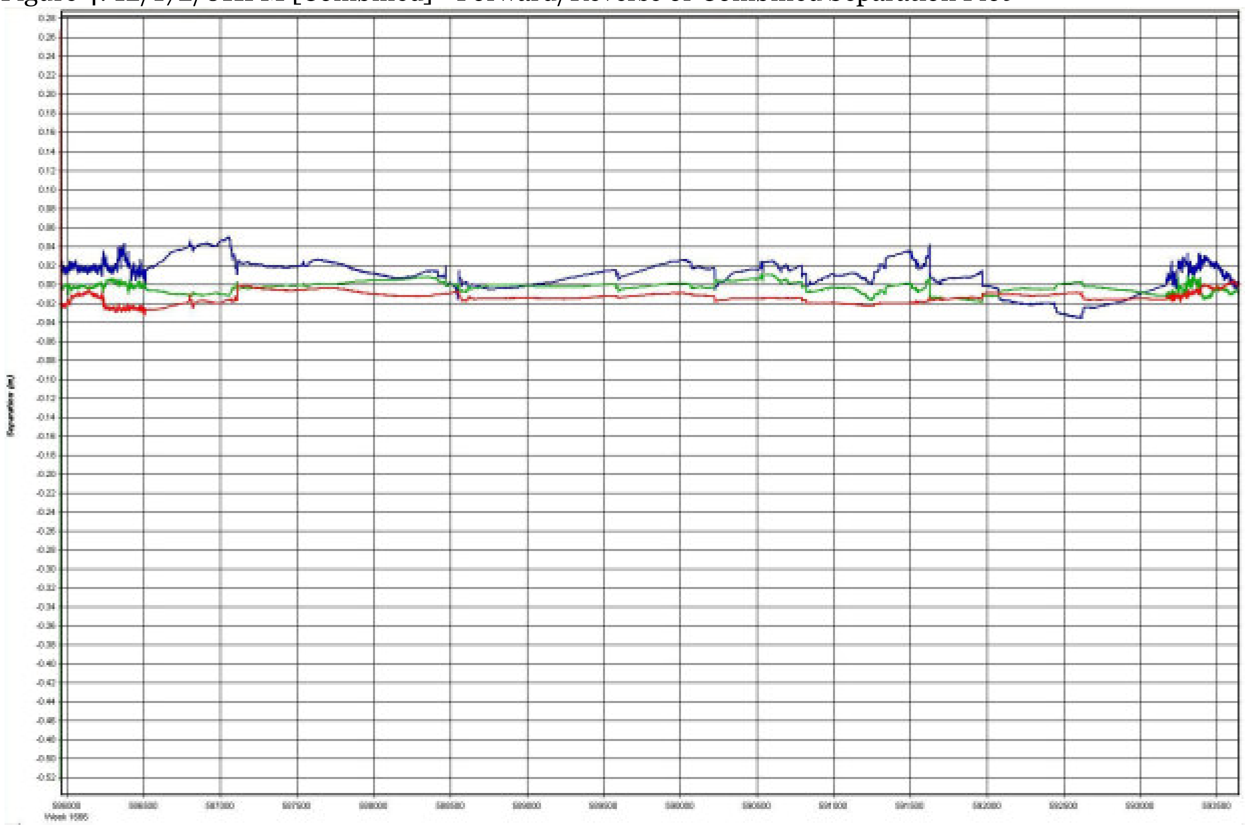


GPS Time

Height

Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Figure 4: 12/172/011PM [Combined] - Forward/Reverse or Combined Separation Plot

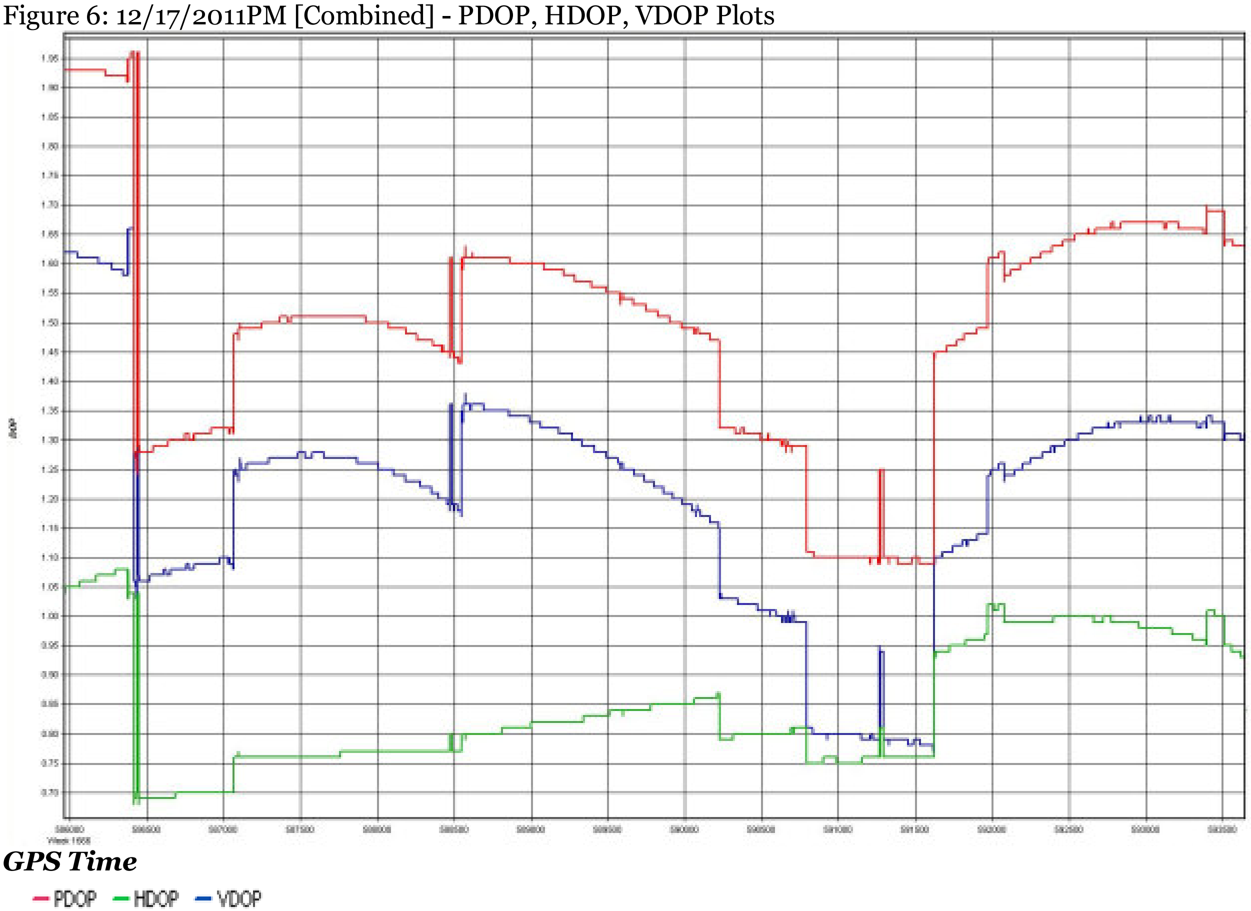


Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Figure 5: 12/17/2011PM [Combined] - Forward/Reverse or Combined Weighting Plot

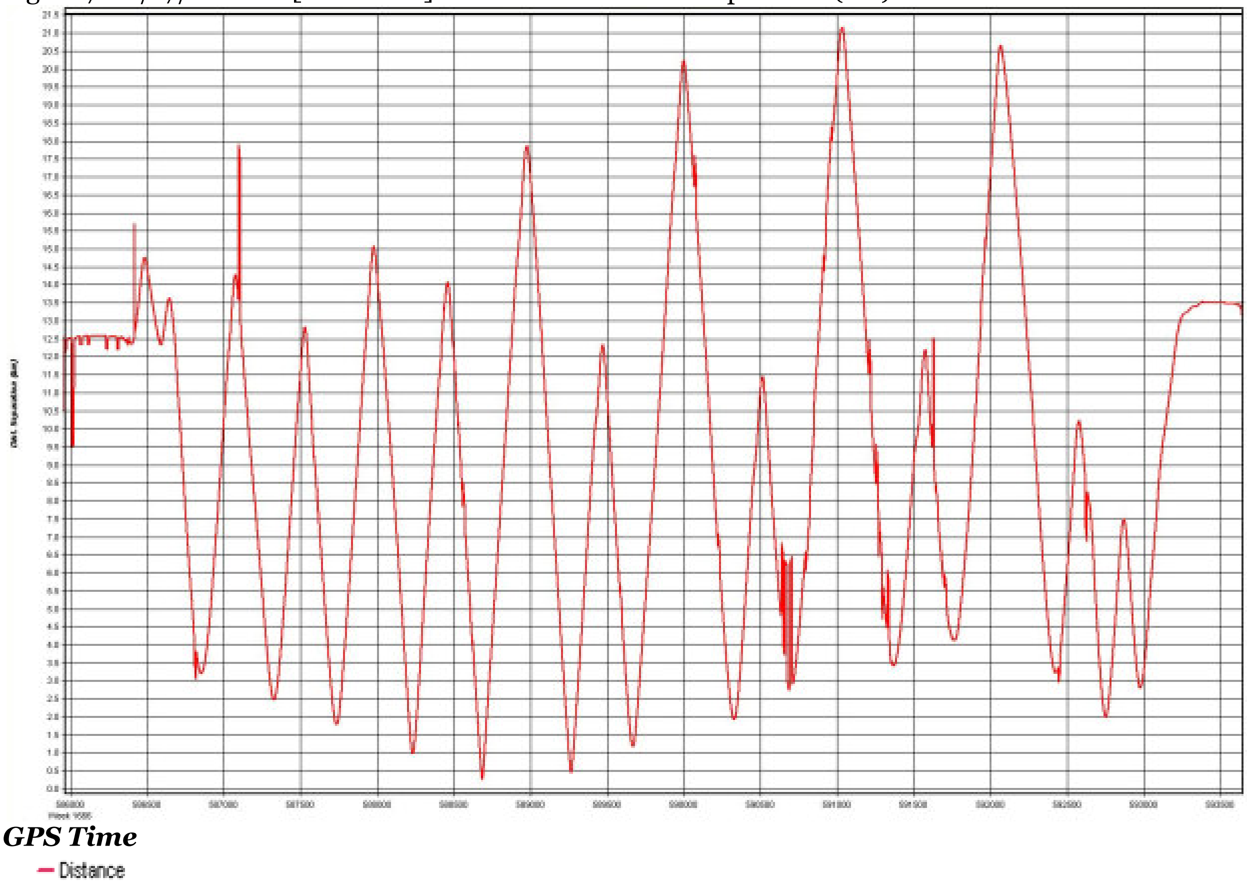
Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Figure 6: 12/17/2011PM [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Figure 7: 12/17/2011PM [Combined] - Horizontal Distance Separation (km)

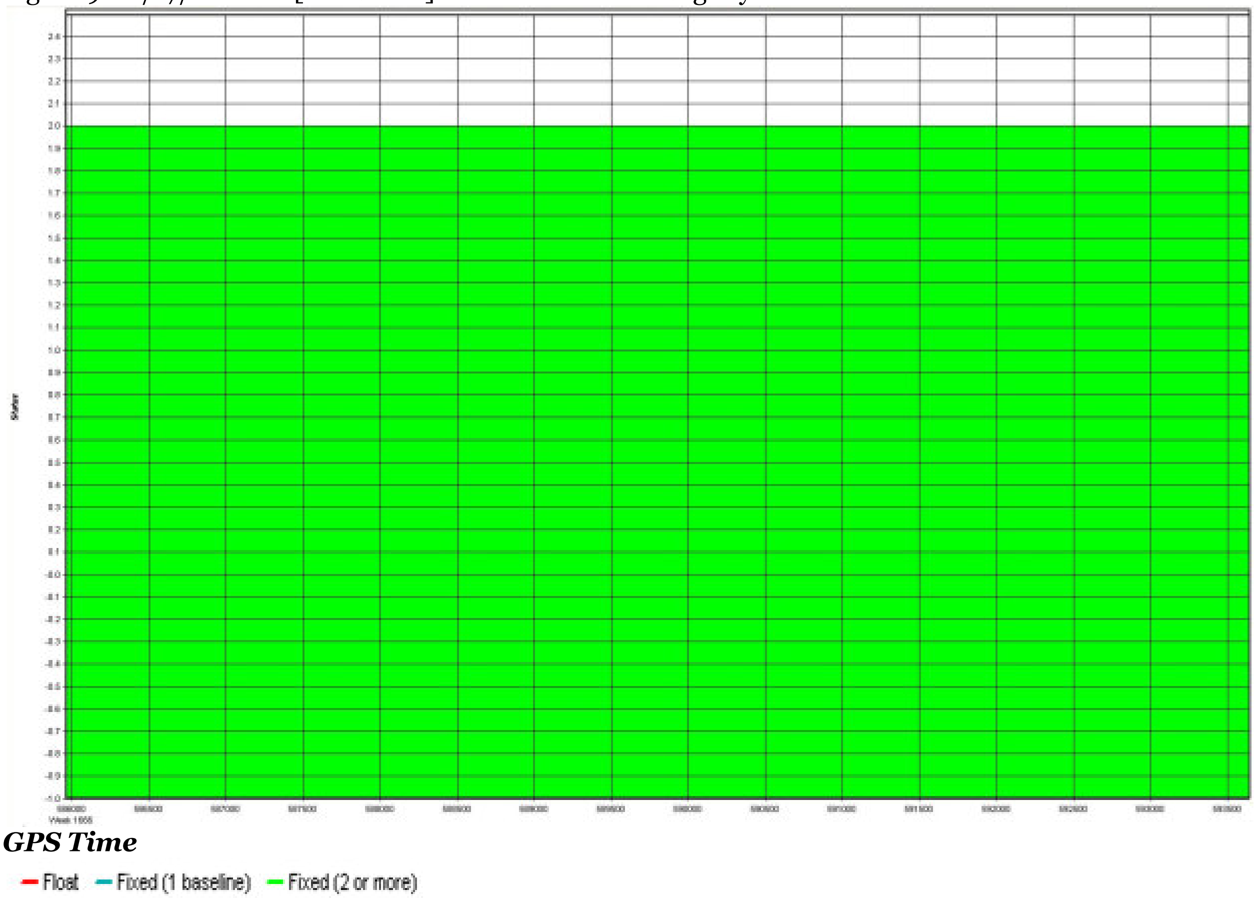


Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Figure 8: 12/17/2011PM [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Figure 9: 12/17/2011PM [Combined] - Float or Fixed Ambiguity

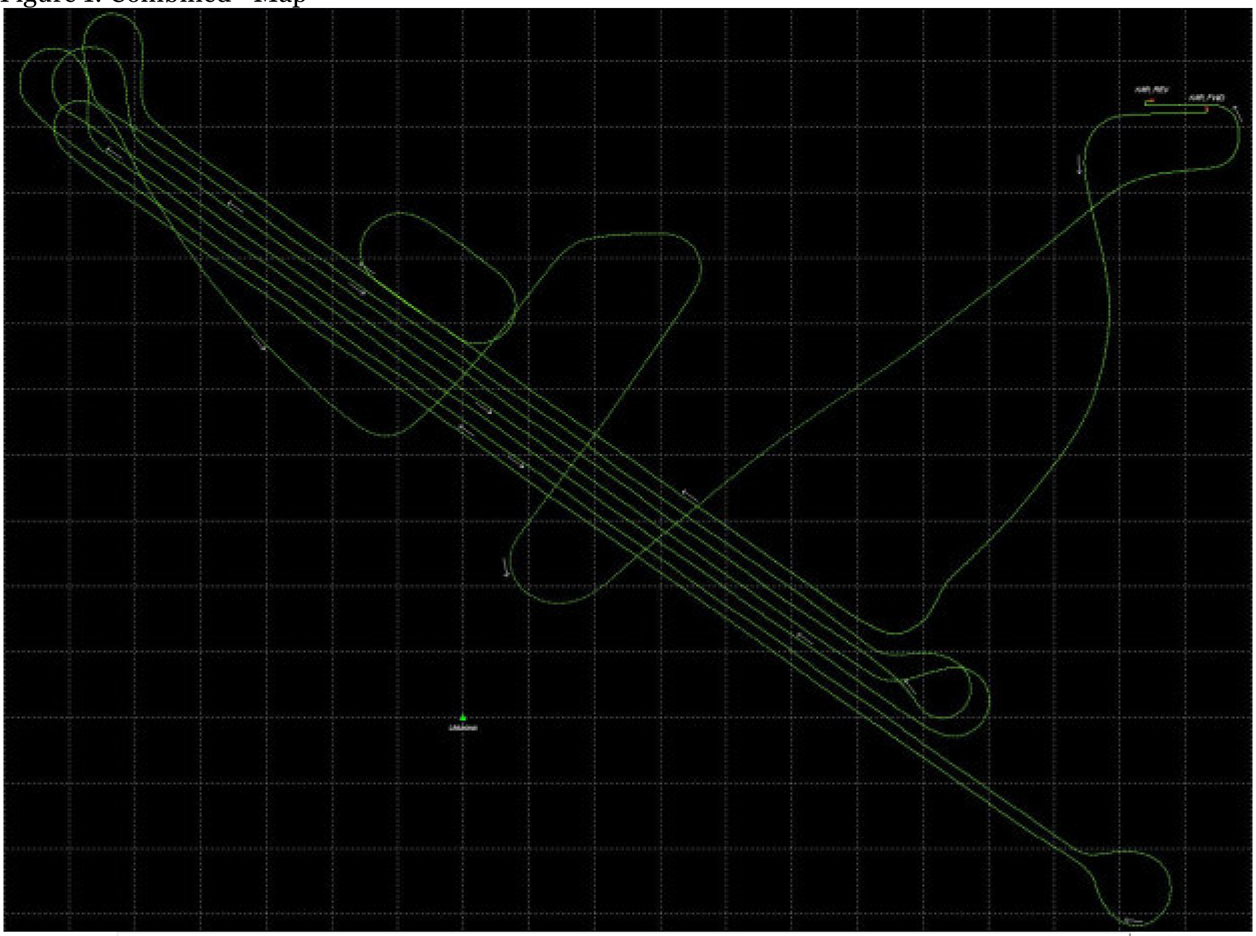


Process	Run (12)	by Unknown	on 12/17/2011	at 13:00

Output Results for 12/20/2011

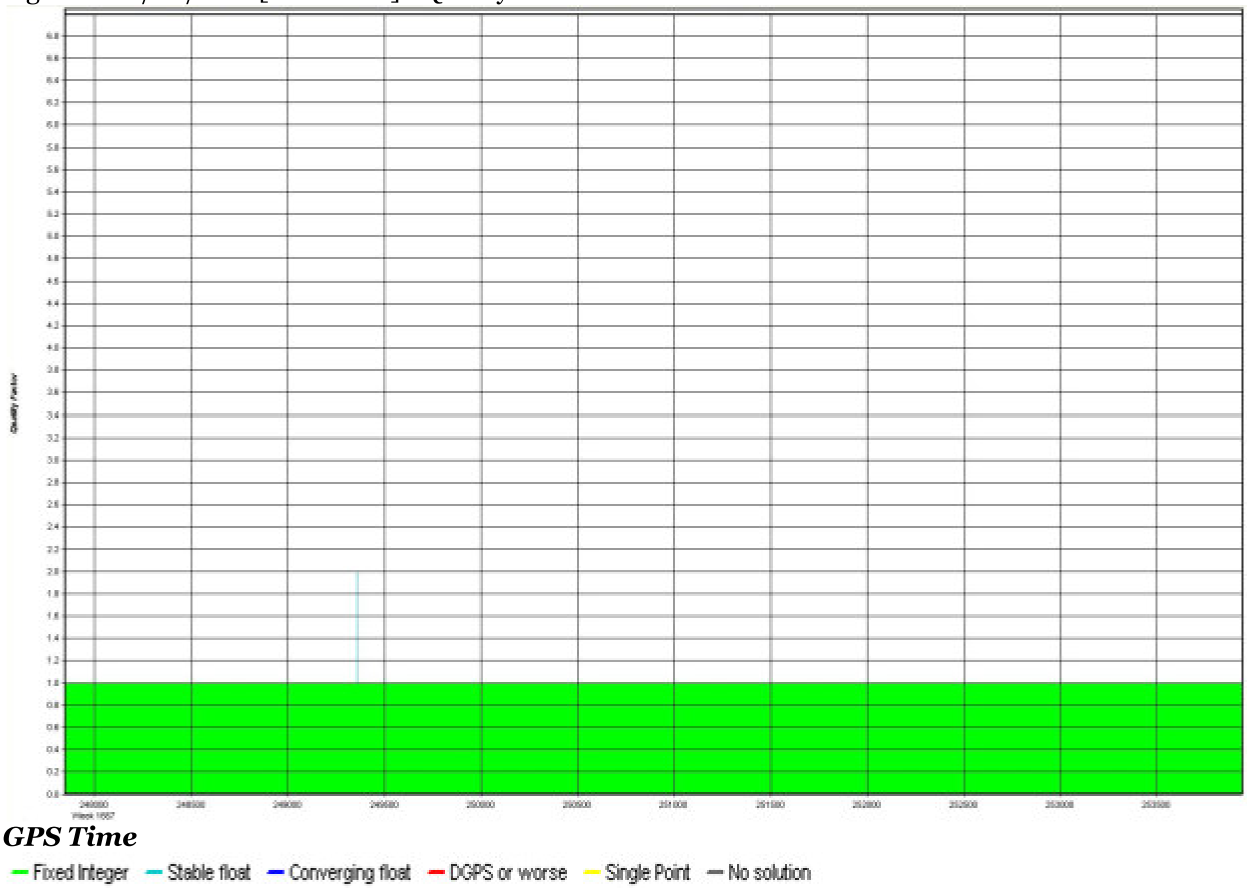
POSPAC Version 4.31

Figure 1: Combined - Map



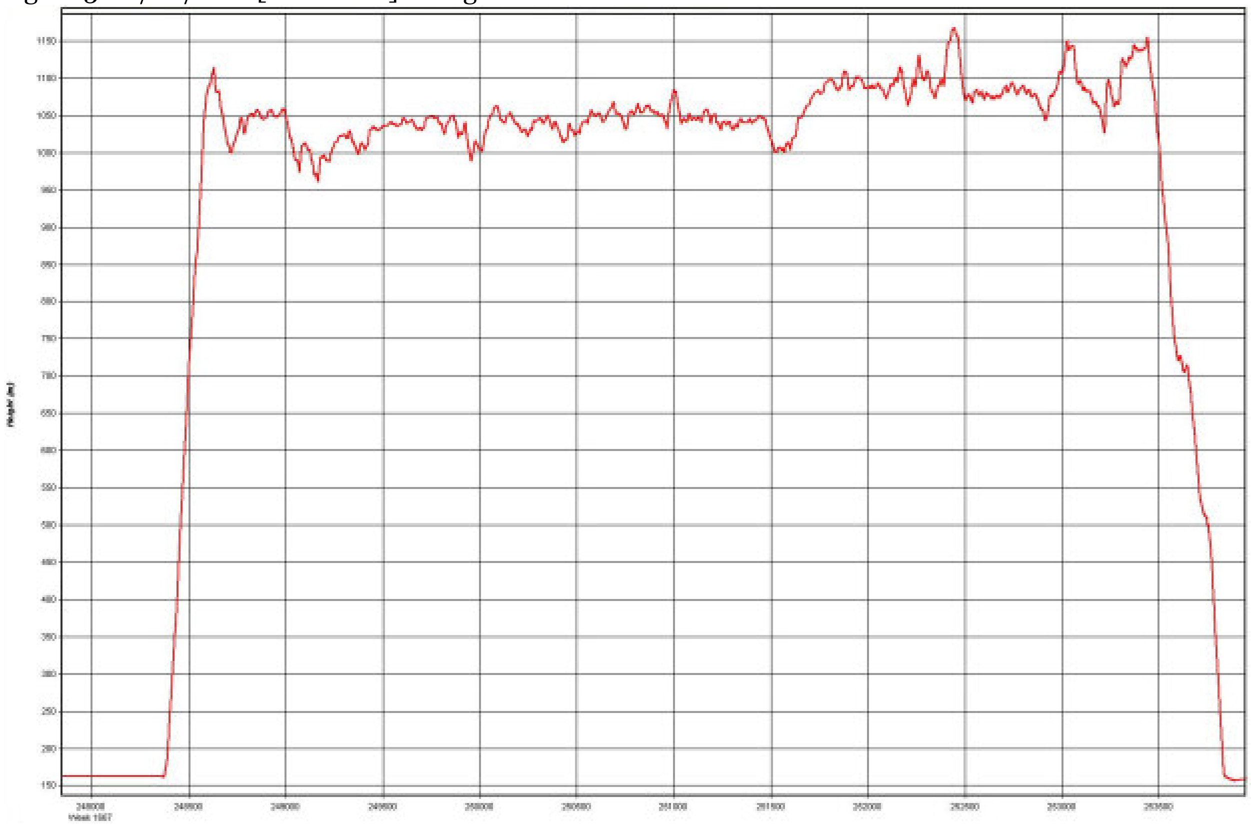
Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

Figure 2: 12/20/2011 [Combined] - Quality Factor Plot



Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

Figure 3: 12/20/2011 [Combined] - Height Profile Plot

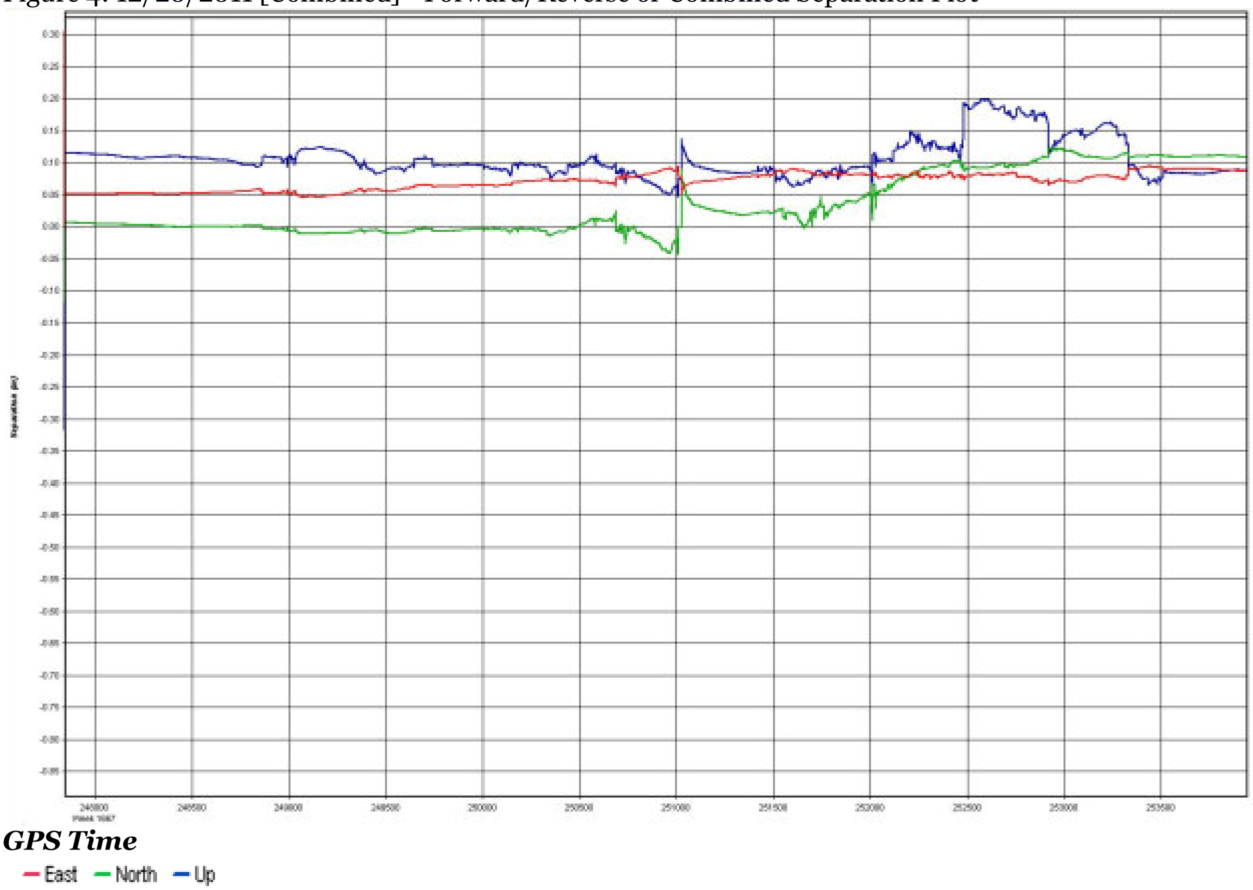


GPS Time

— Height

Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

Figure 4: 12/20/2011 [Combined] - Forward/Reverse or Combined Separation Plot

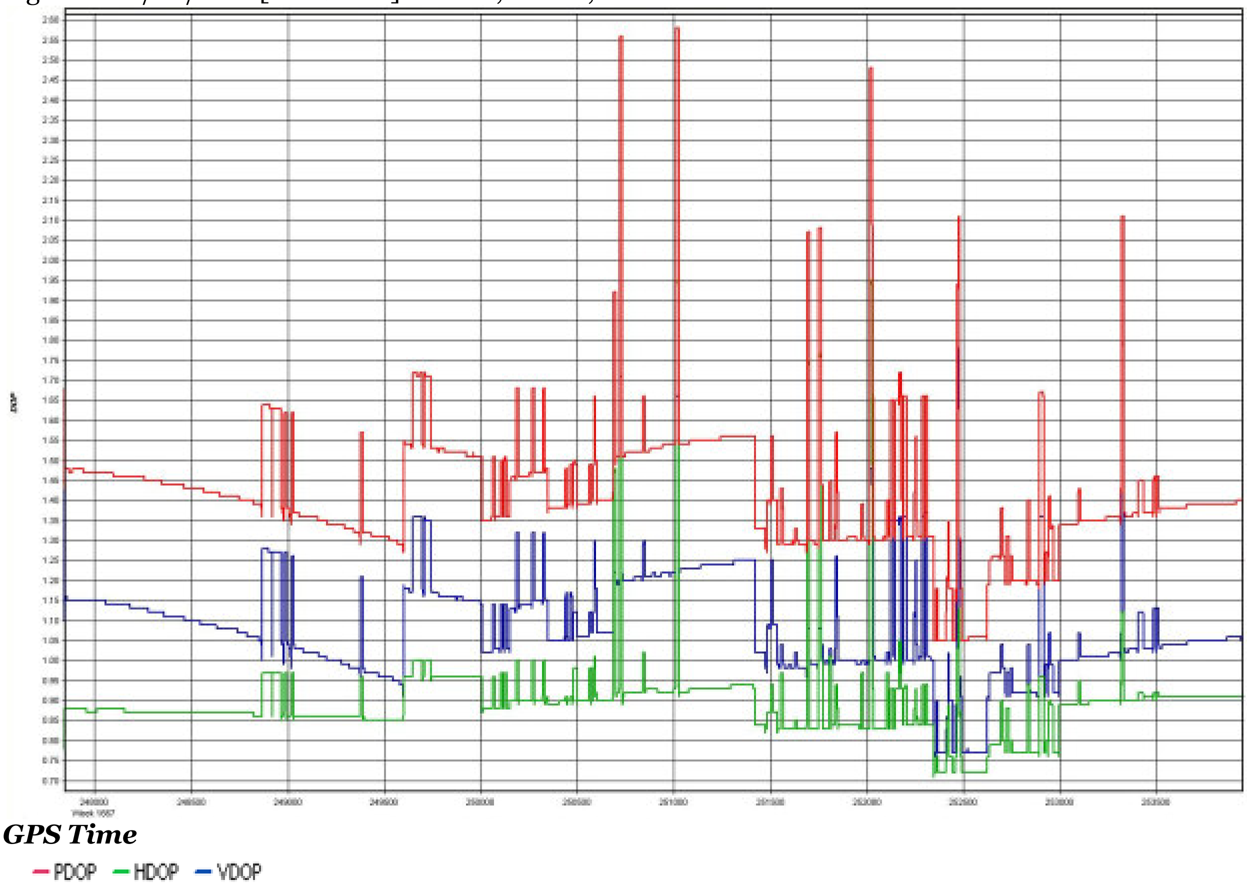


Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

Figure 5: 12/20/2011 [Combined] - Forward/Reverse or Combined Weighting Plot

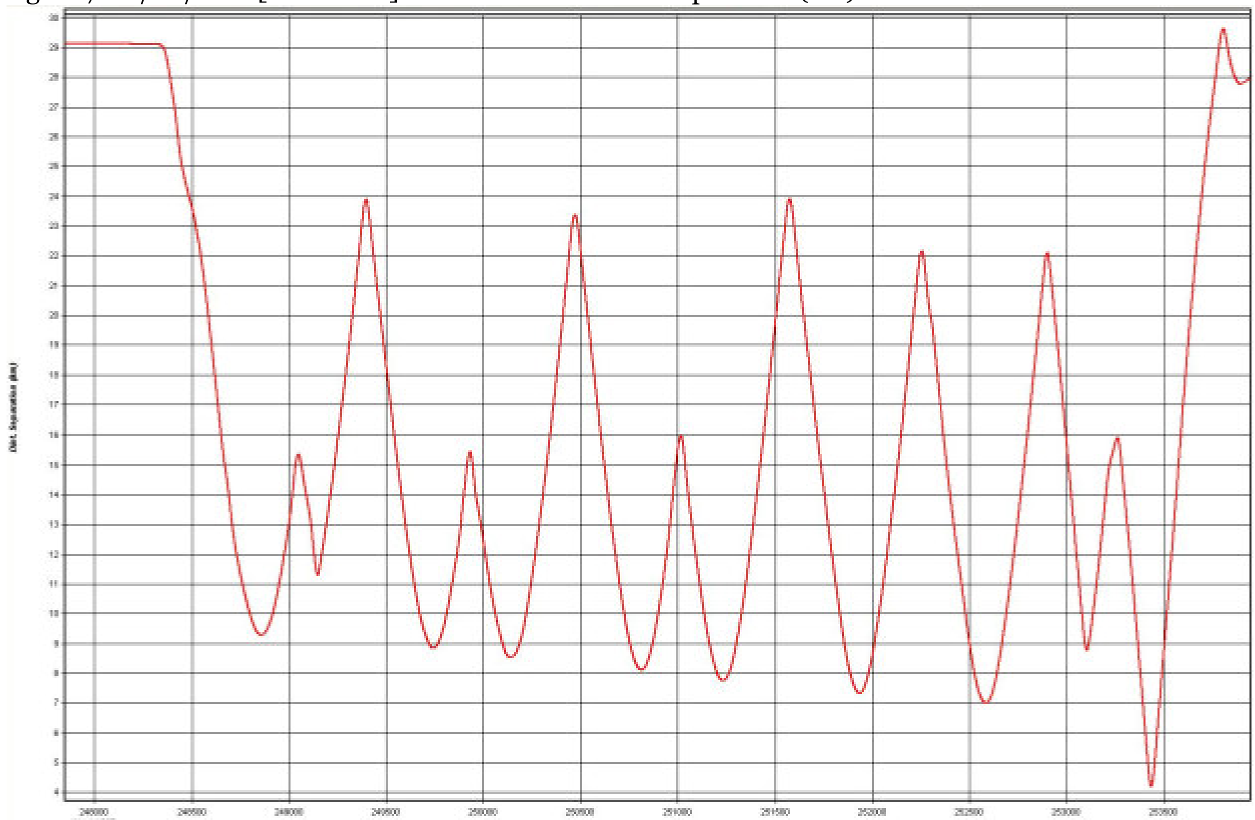
Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

Figure 6: 12/20/2011 [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

Figure 7: 12/20/2011 [Combined] - Horizontal Distance Separation (km)

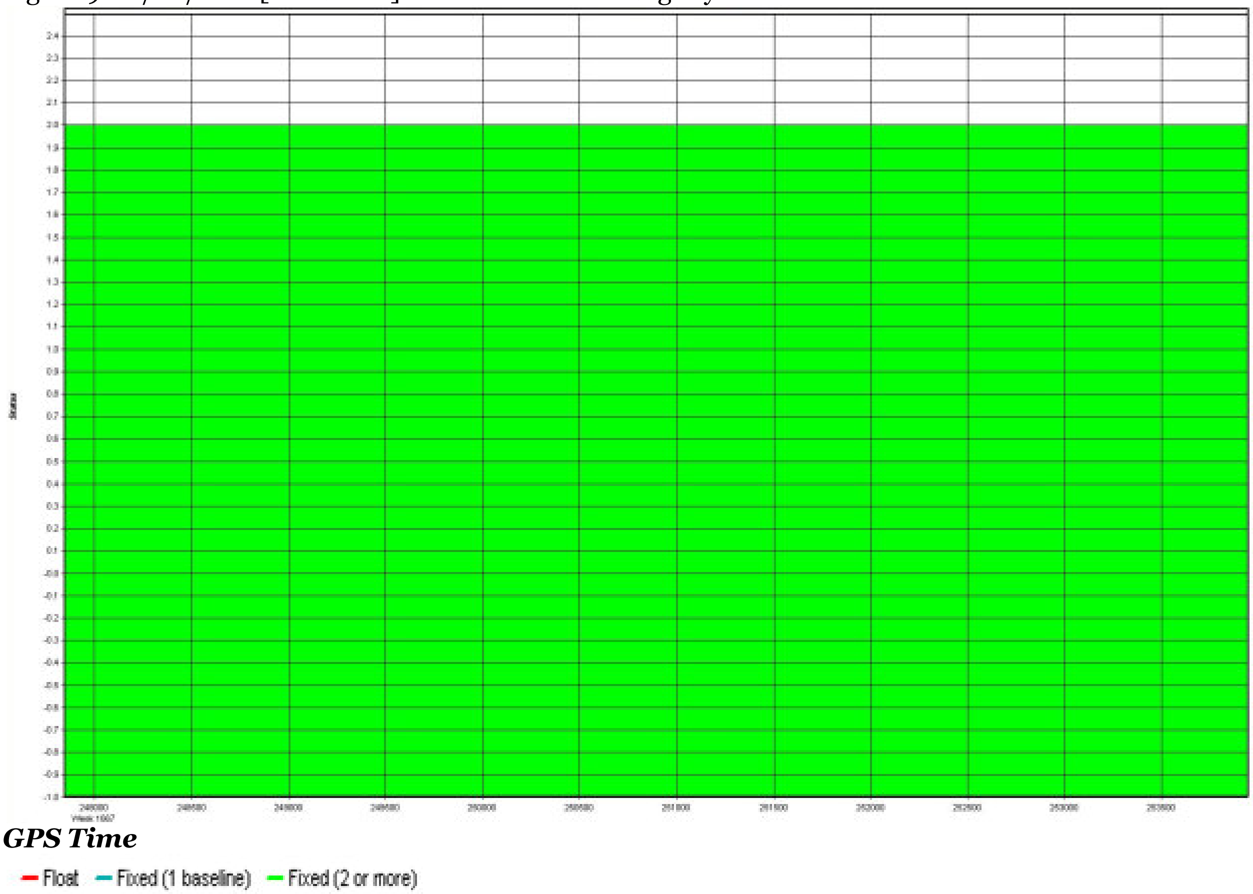


Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

Figure 8: 12/20/2011 [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

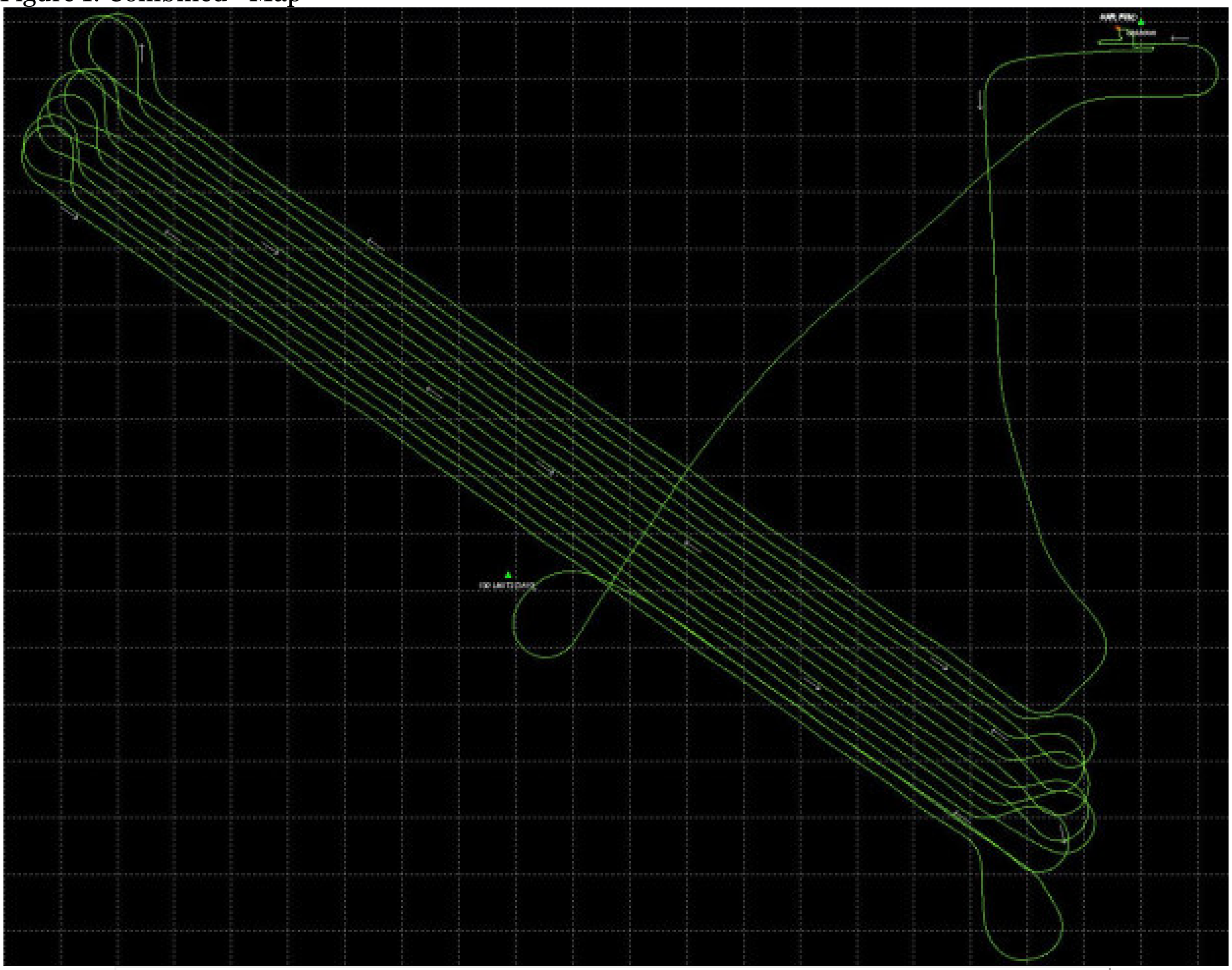
Figure 9: 12/20/2011 [Combined] - Float or Fixed Ambiguity



Process	Run (10)	by Unknown	on 12/20/2011	at 12:45

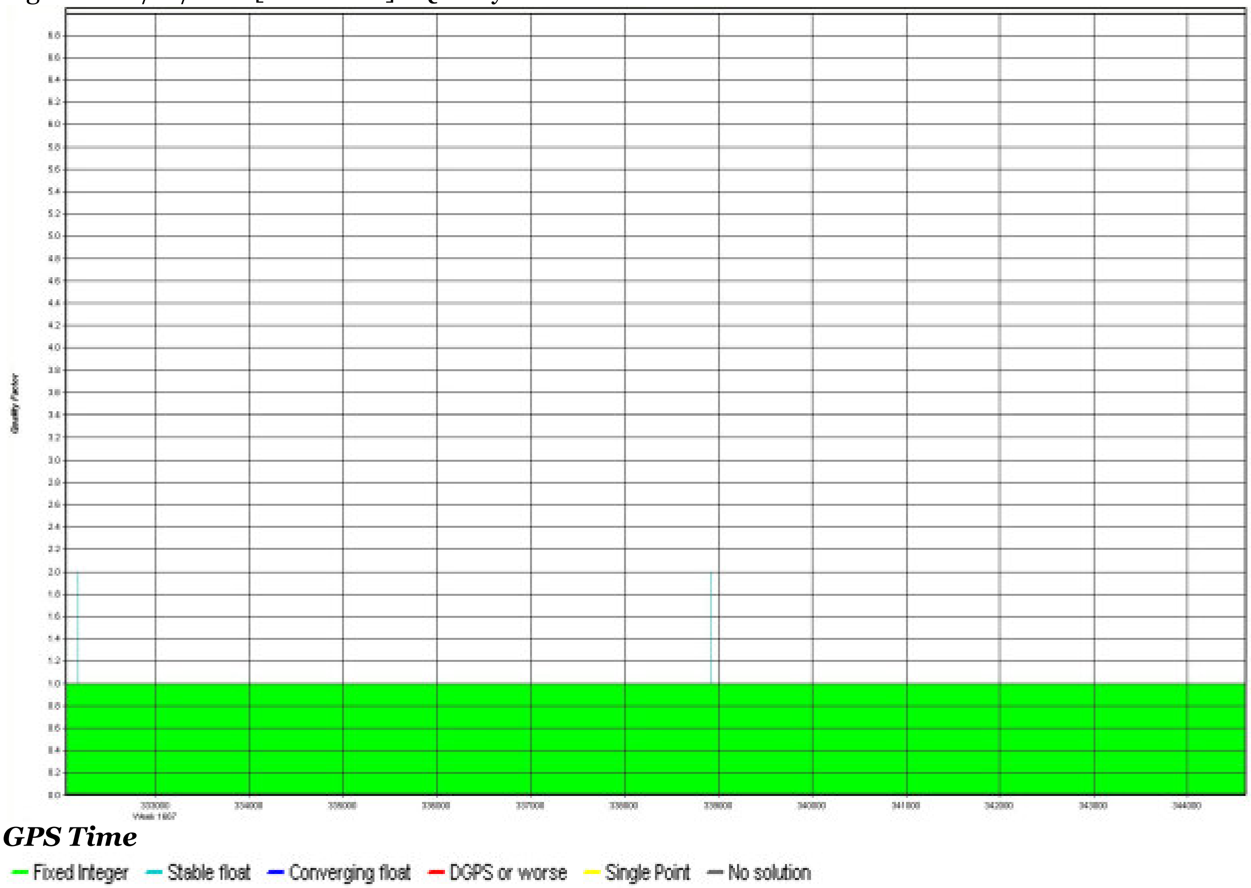
Output Results for 12/21/2011
POSPAC Version 4.31

Figure 1: Combined - Map



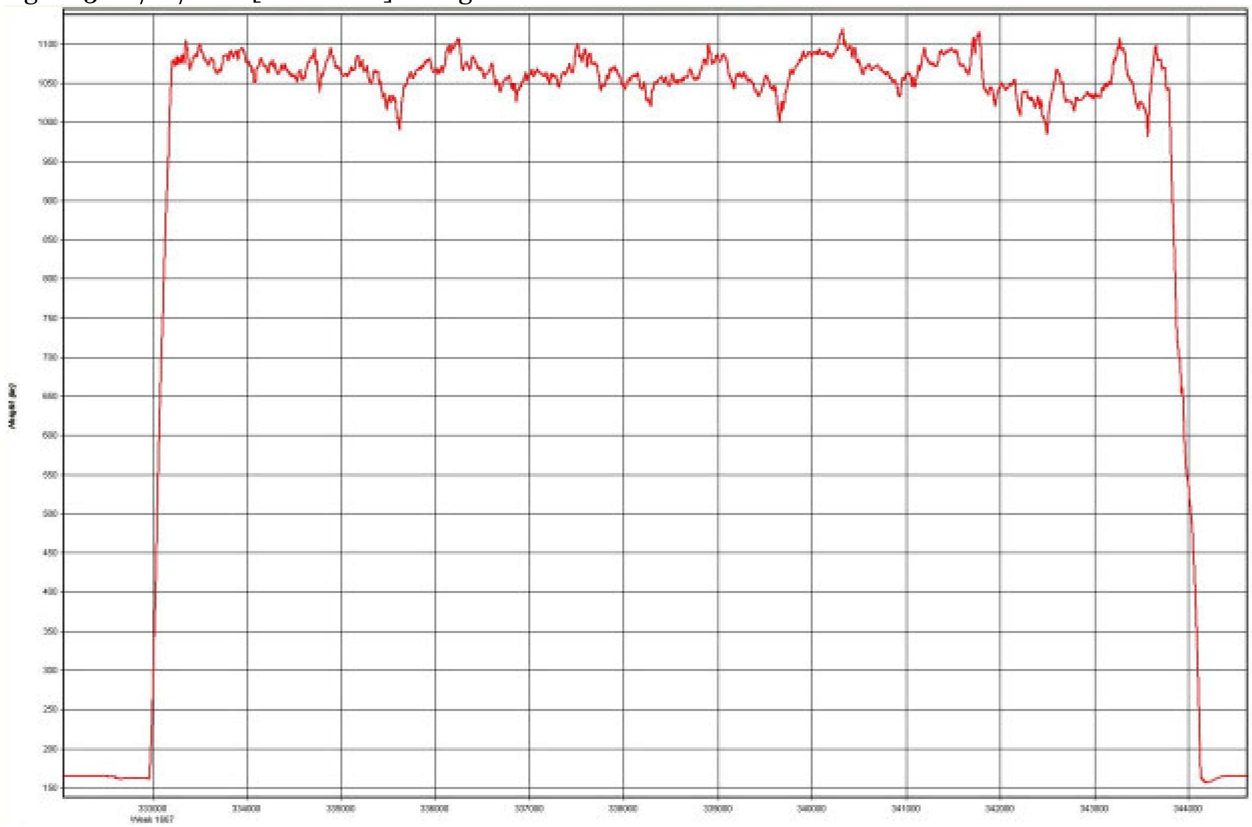
Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

Figure 2: 12/21/2011 [Combined] - Quality Factor Plot



Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

Figure 3: 12/21/2011 [Combined] - Height Profile Plot

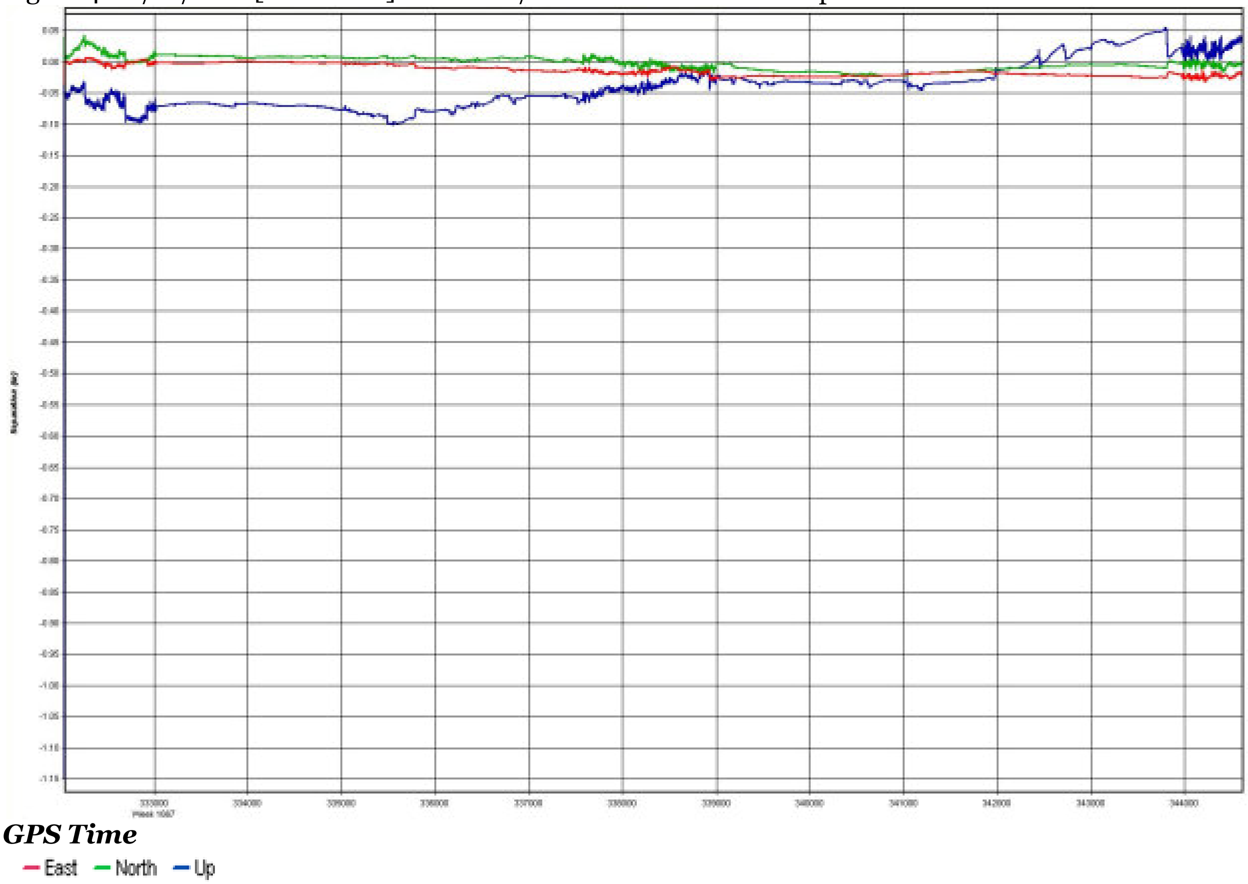


GPS Time

— Height

Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

Figure 4: 12/21/2011 [Combined] - Forward/Reverse or Combined Separation Plot

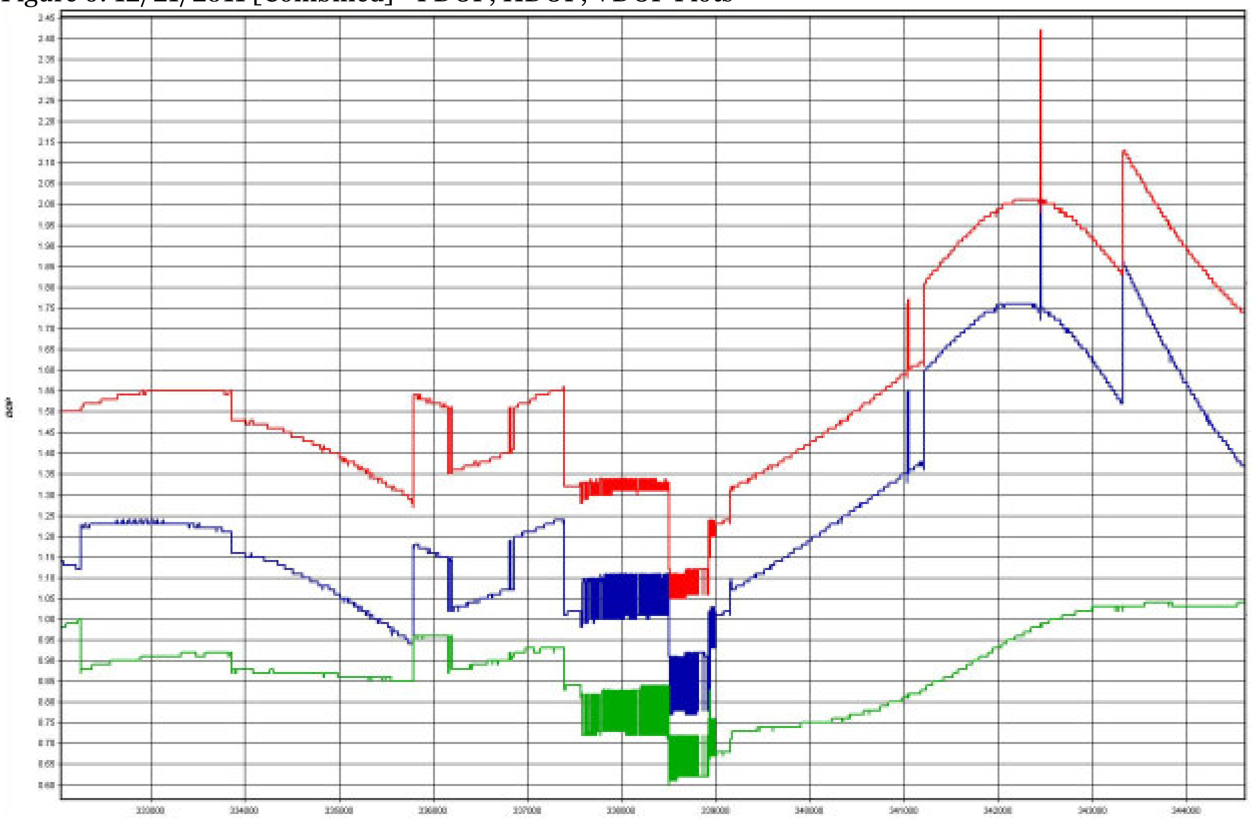


Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

Figure 5: 12/21/2011 [Combined] - Forward/Reverse or Combined Weighting Plot

Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

Figure 6: 12/21/2011 [Combined] - PDOP, HDOP, VDOP Plots

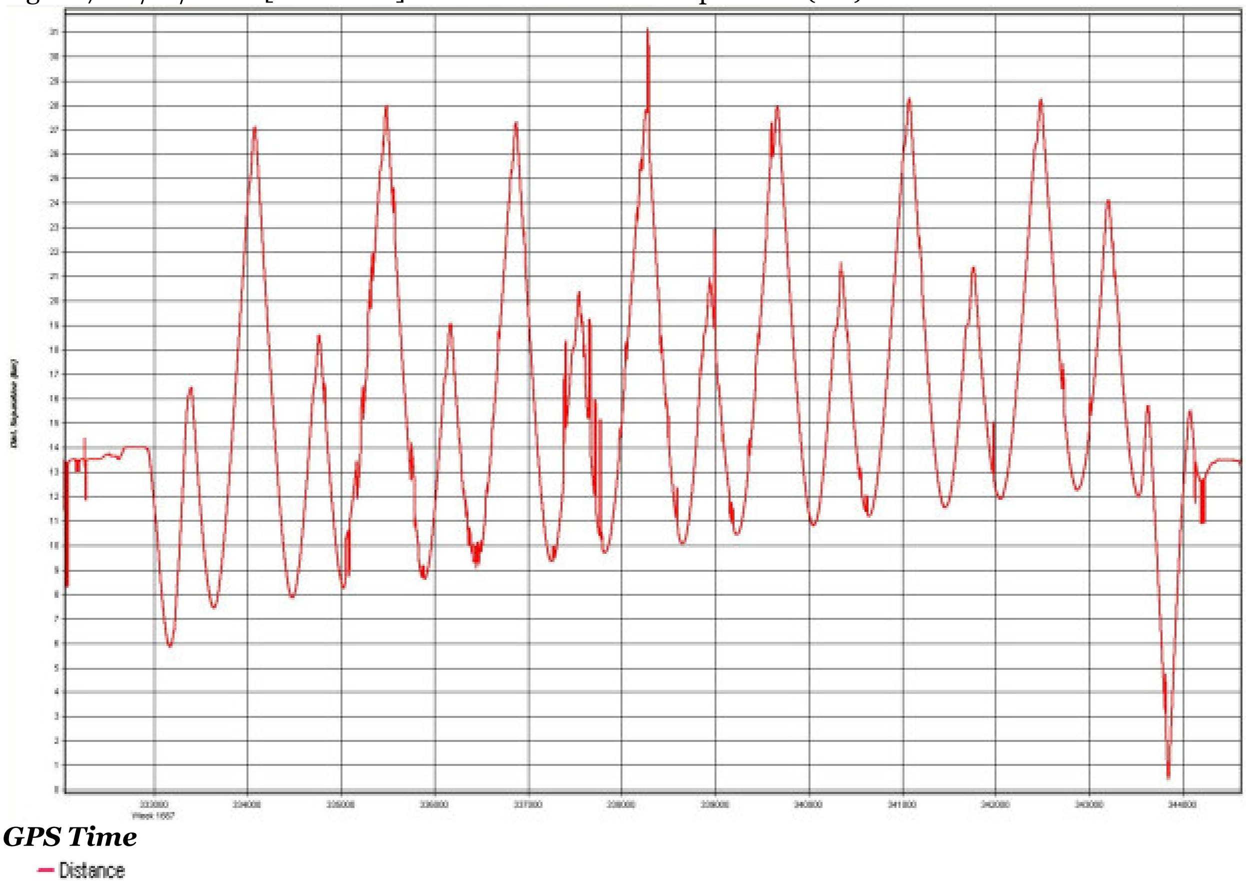


GPS Time

PDOP HDOP VDOP

Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

Figure 7: 12/21/12011 [Combined] - Horizontal Distance Separation (km)

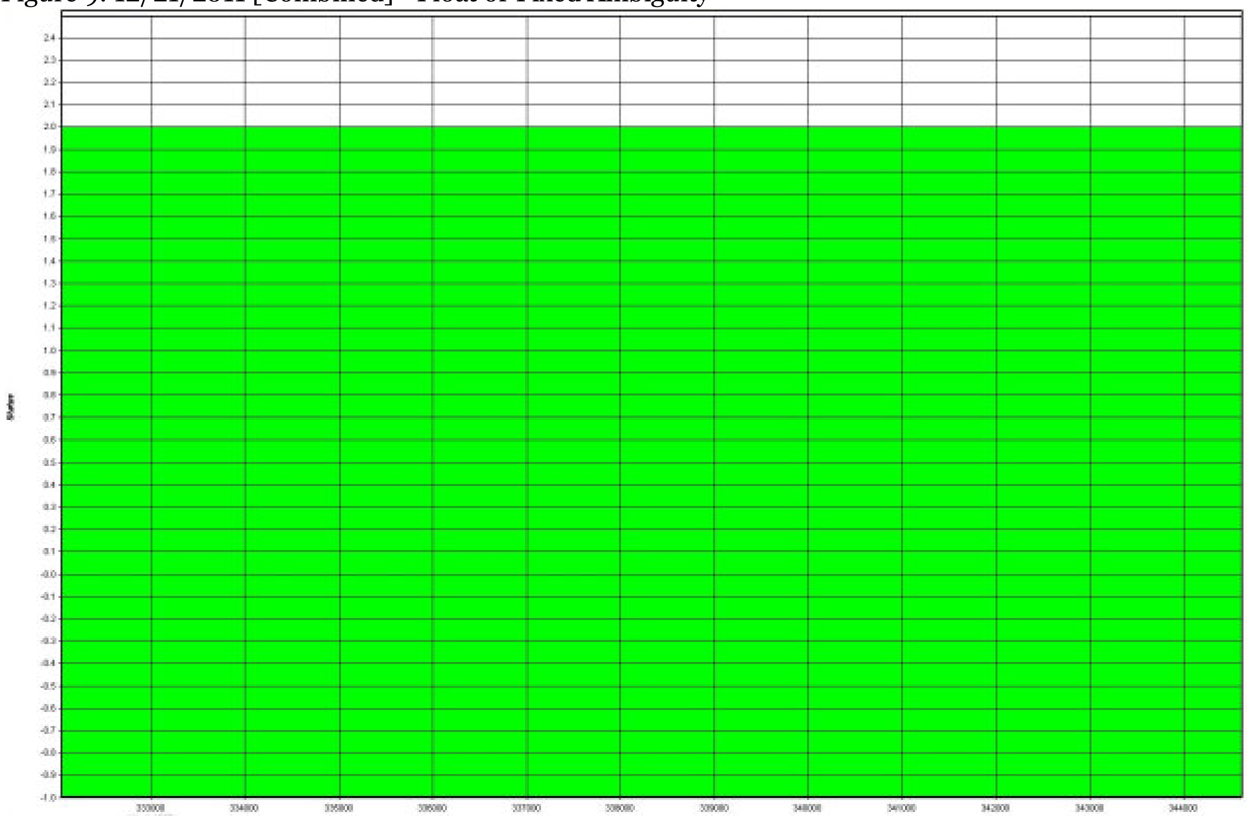


Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

Figure 8: 12/21/2011 [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

Figure 9: 12/21/2011 [Combined] - Float or Fixed Ambiguity



GPS Time

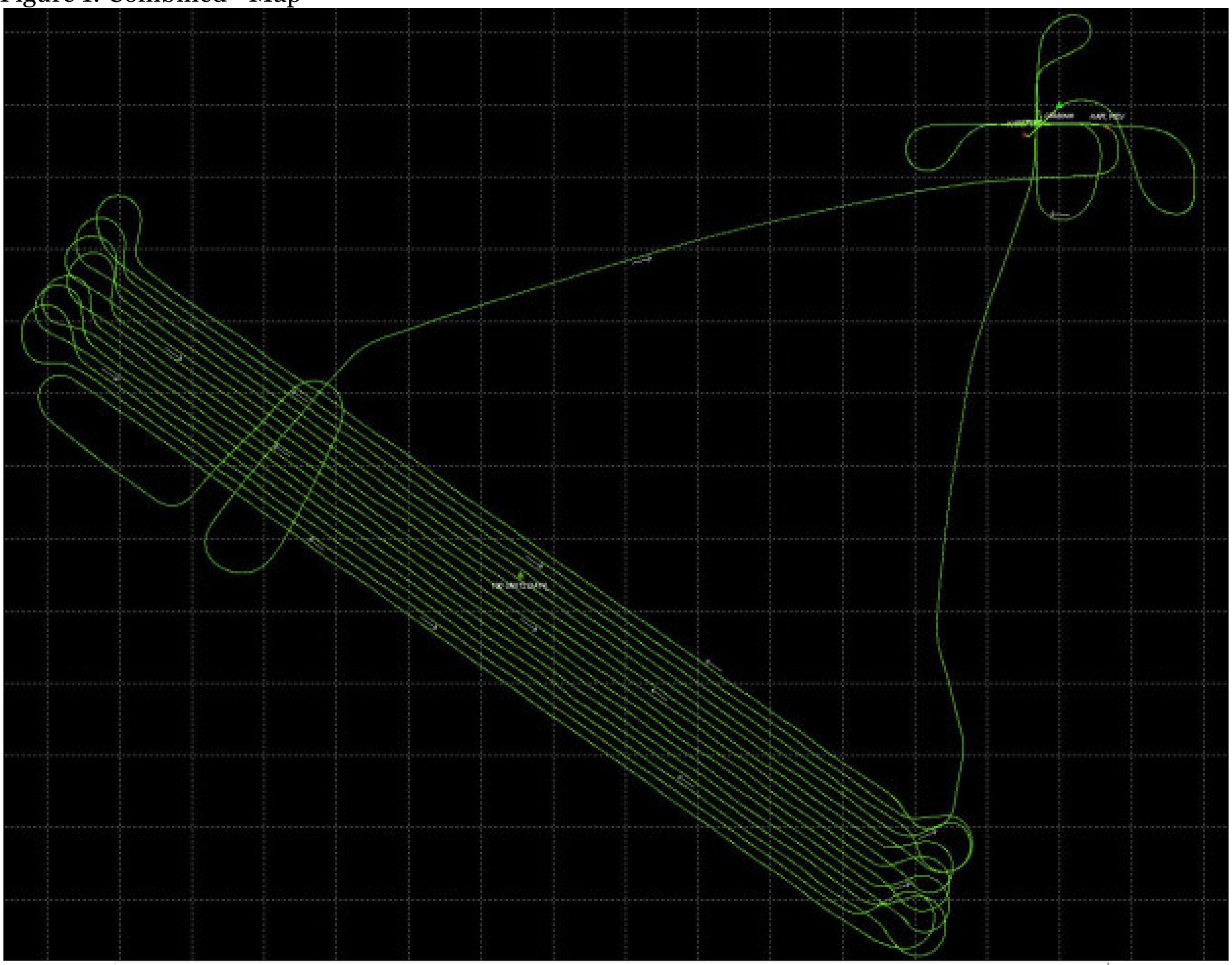
Float Fixed (1 baseline) Fixed (2 or more)

Process	Run (16)	by Unknown	on 12/21/2011	at 12:20

2.7 Output Results for 12/23/2011

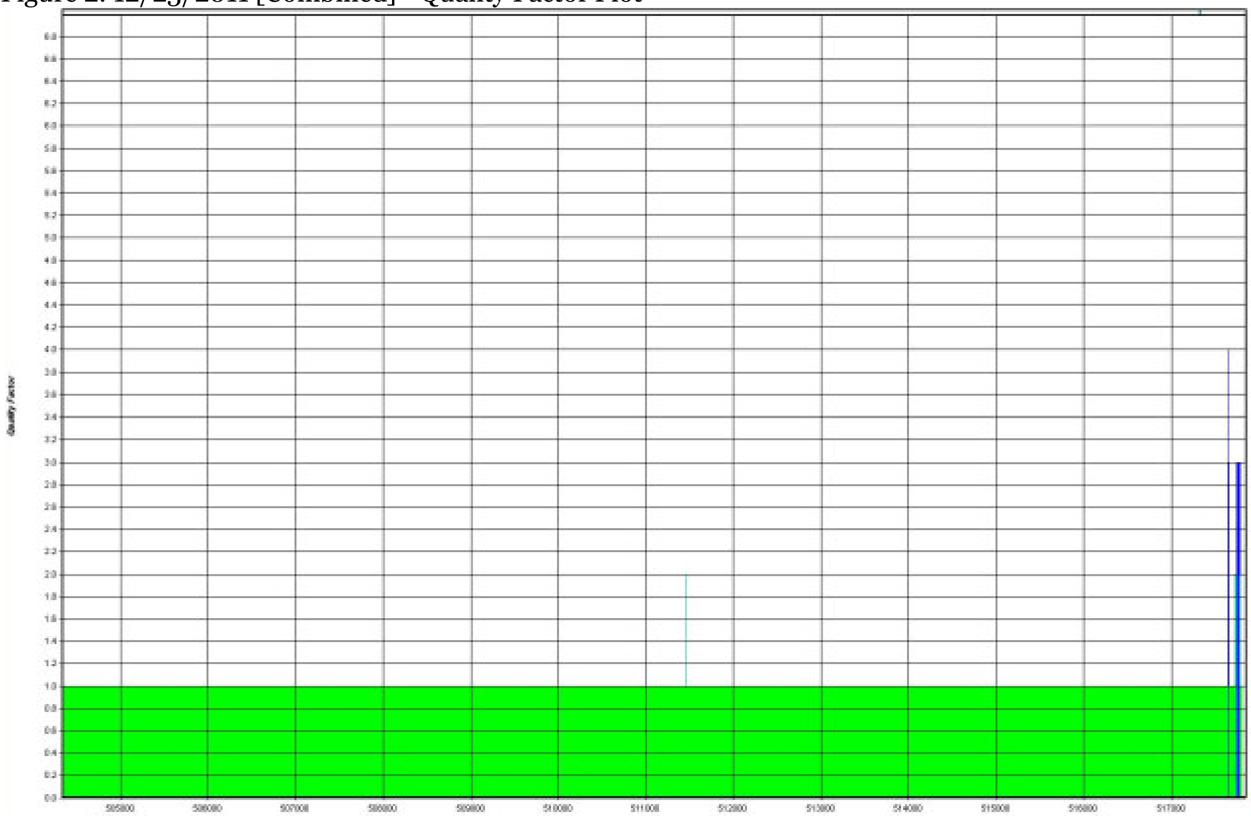
POSPAC Version 4.31

Figure 1: Combined - Map



Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

Figure 2: 12/23/2011 [Combined] - Quality Factor Plot

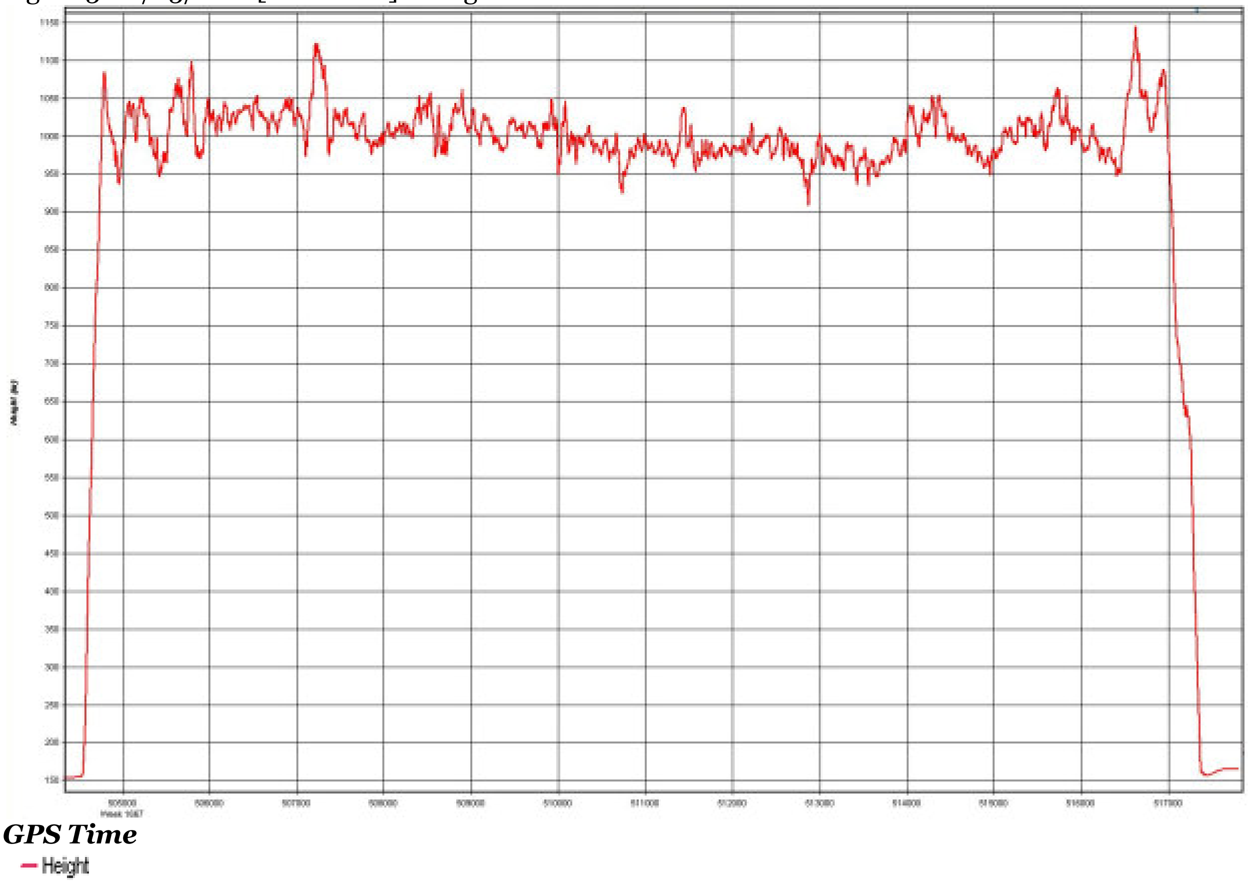


GPS Time

— Fixed Integer — Stable float — Converging float — DGPS or worse — Single Point — No solution

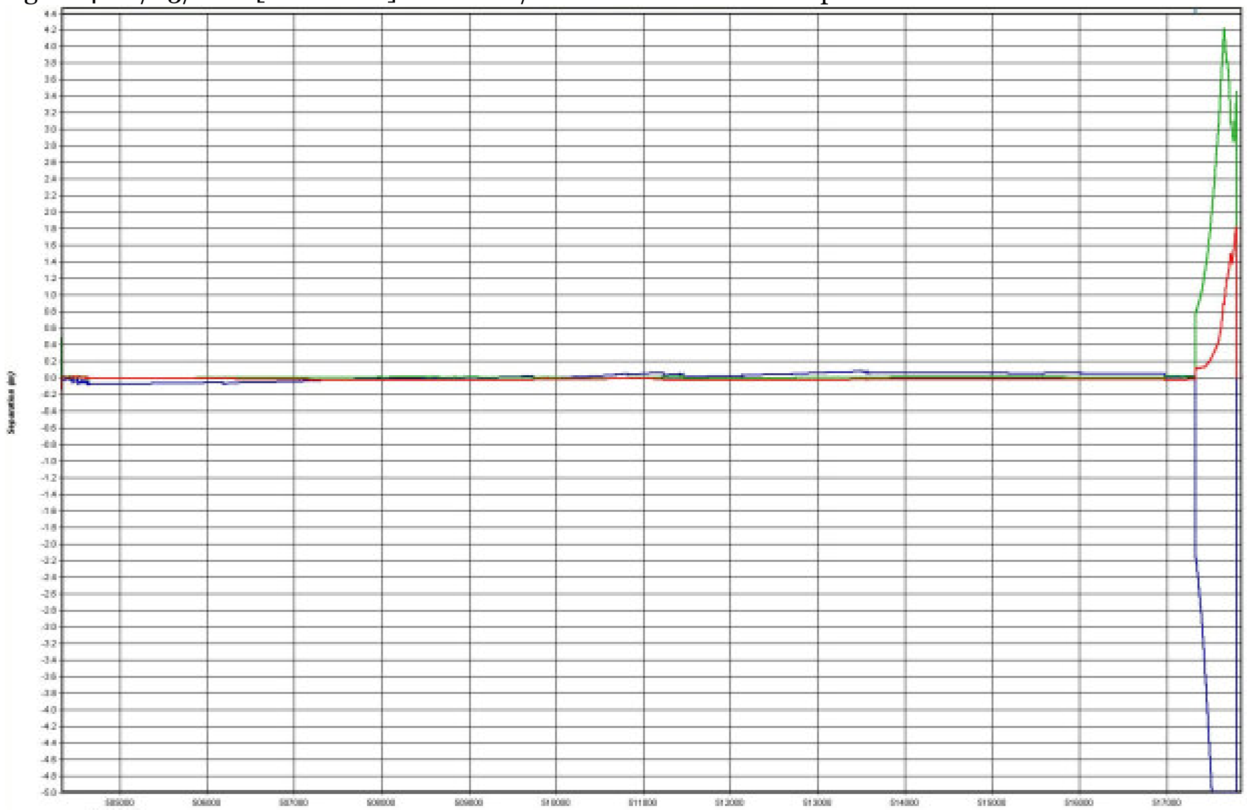
Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

Figure 3: 12/23/2011 [Combined] - Height Profile Plot



Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

Figure 4: 12/23/2011 [Combined] - Forward/Reverse or Combined Separation Plot

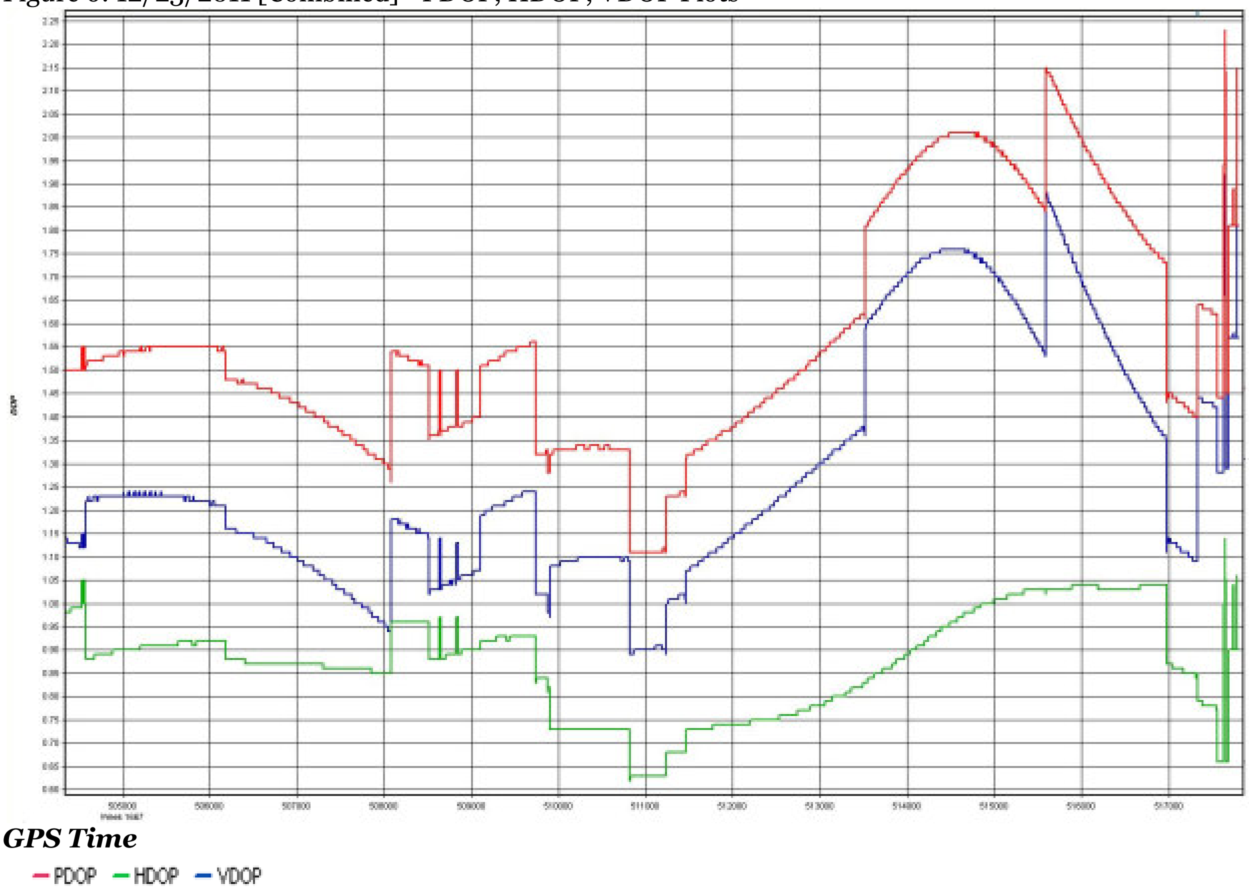


Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

Figure 5: 12/23/2011 [Combined] - Forward/Reverse or Combined Weighting Plot

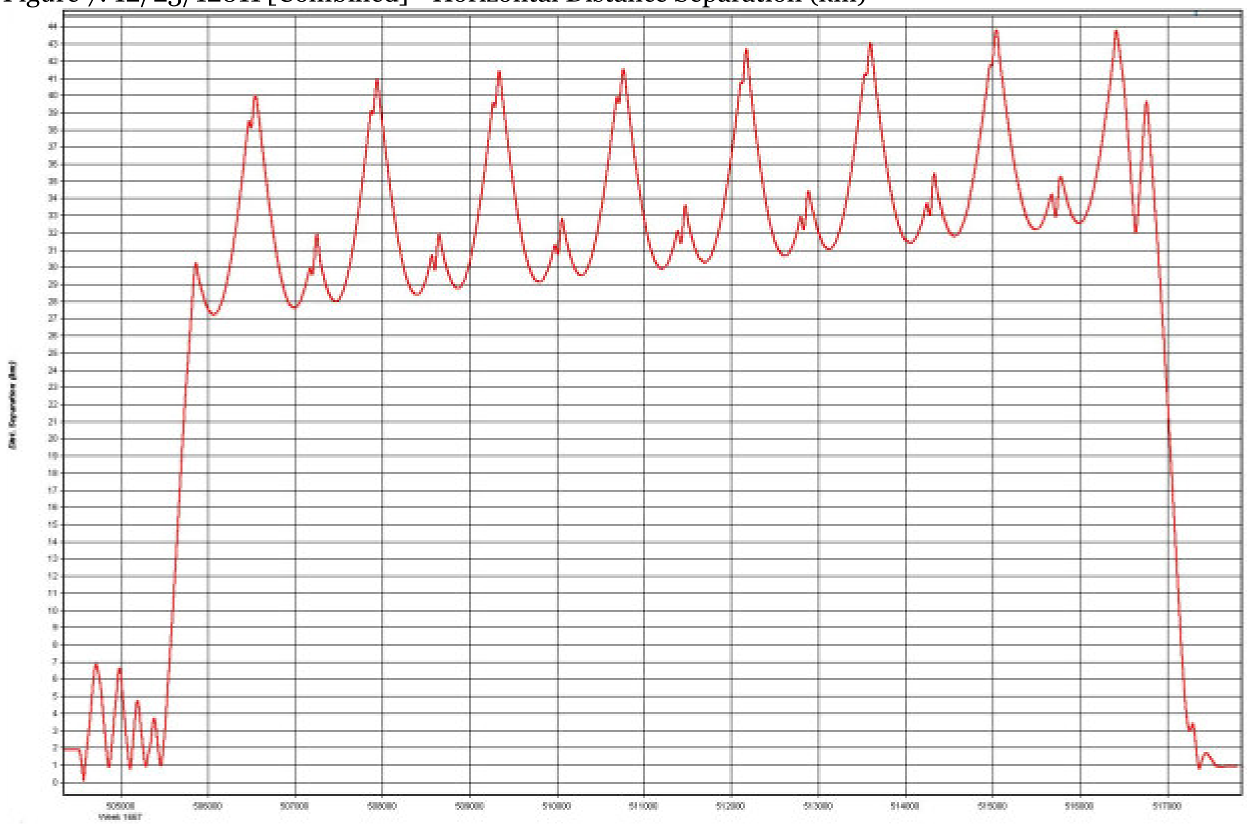
Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

Figure 6: 12/23/2011 [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

Figure 7: 12/23/12011 [Combined] - Horizontal Distance Separation (km)



GPS Time

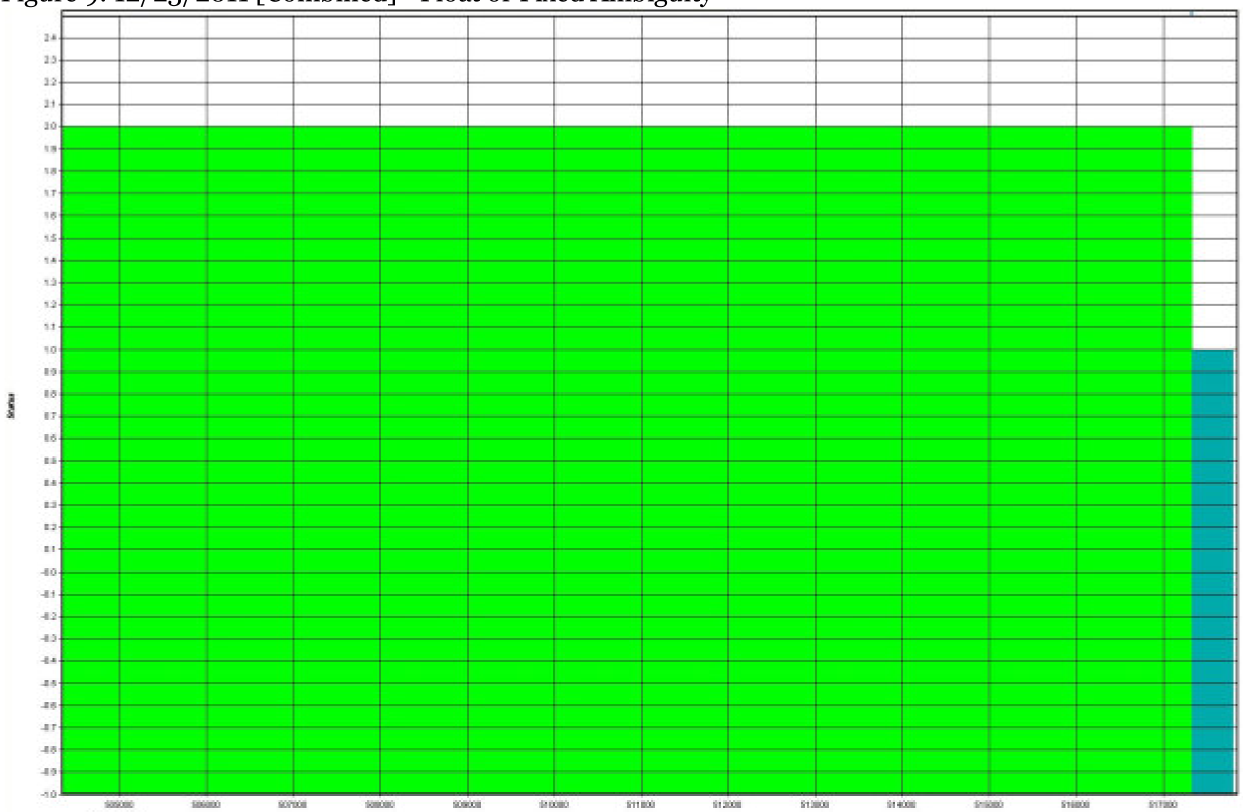
Distance

Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

Figure 8: 12/23/2011 [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

Figure 9: 12/23/2011 [Combined] - Float or Fixed Ambiguity



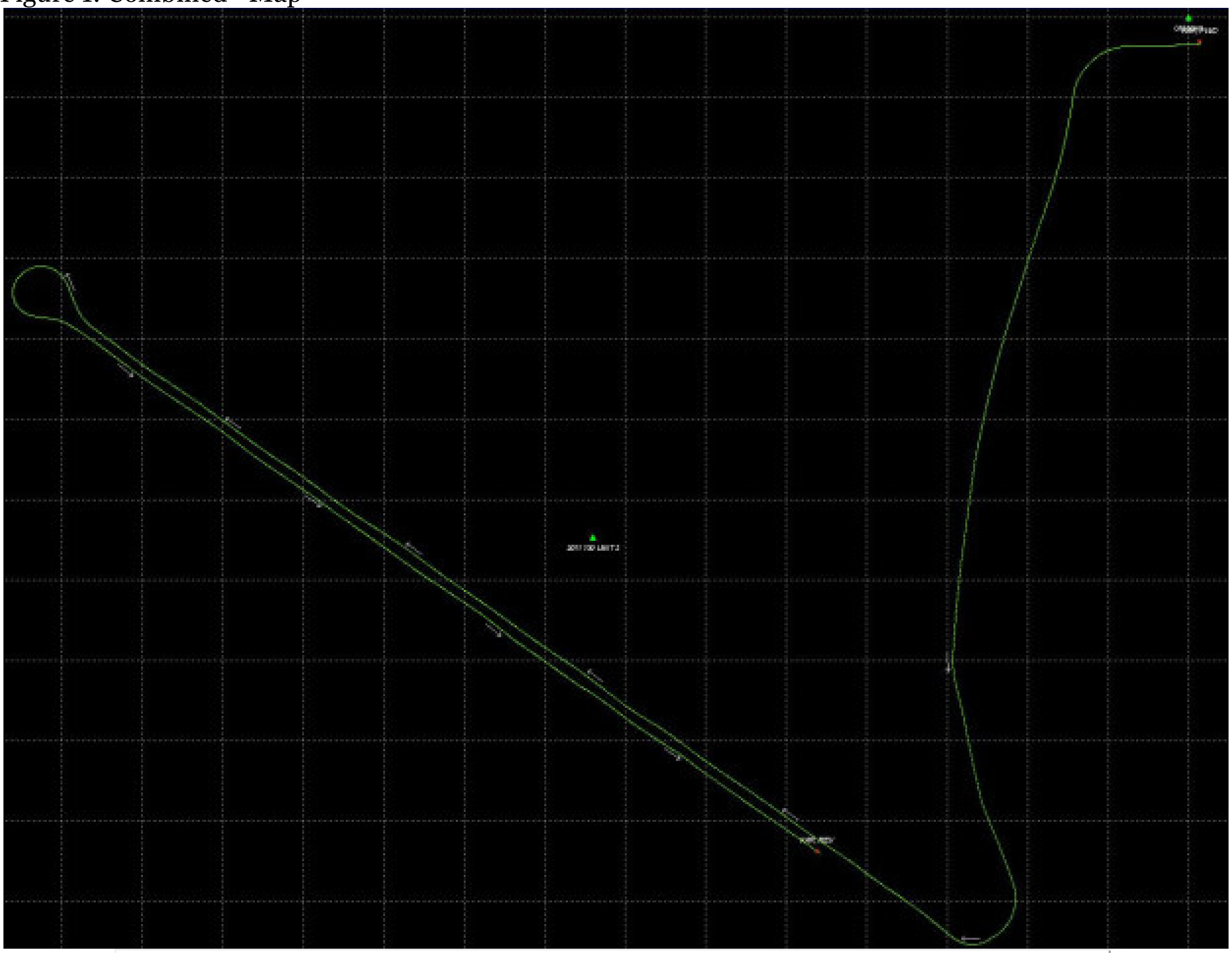
GPS Time

Process	Run (17)	by Unknown	on 12/23/2011	at 12:05

2.8 Output Results for 12/24/2011AM

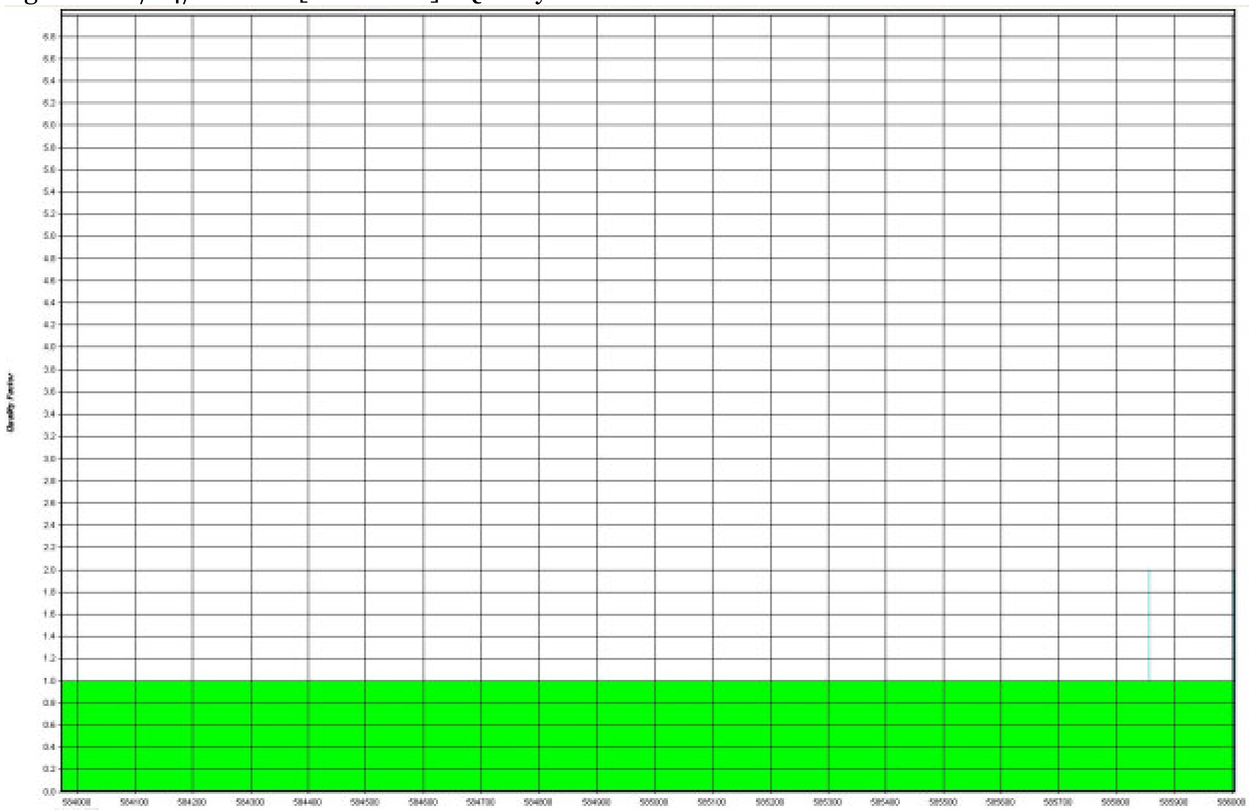
POSPAC Version 4.31

Figure 1: Combined - Map



Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

Figure 2: 12/24/2011AM [Combined] - Quality Factor Plot

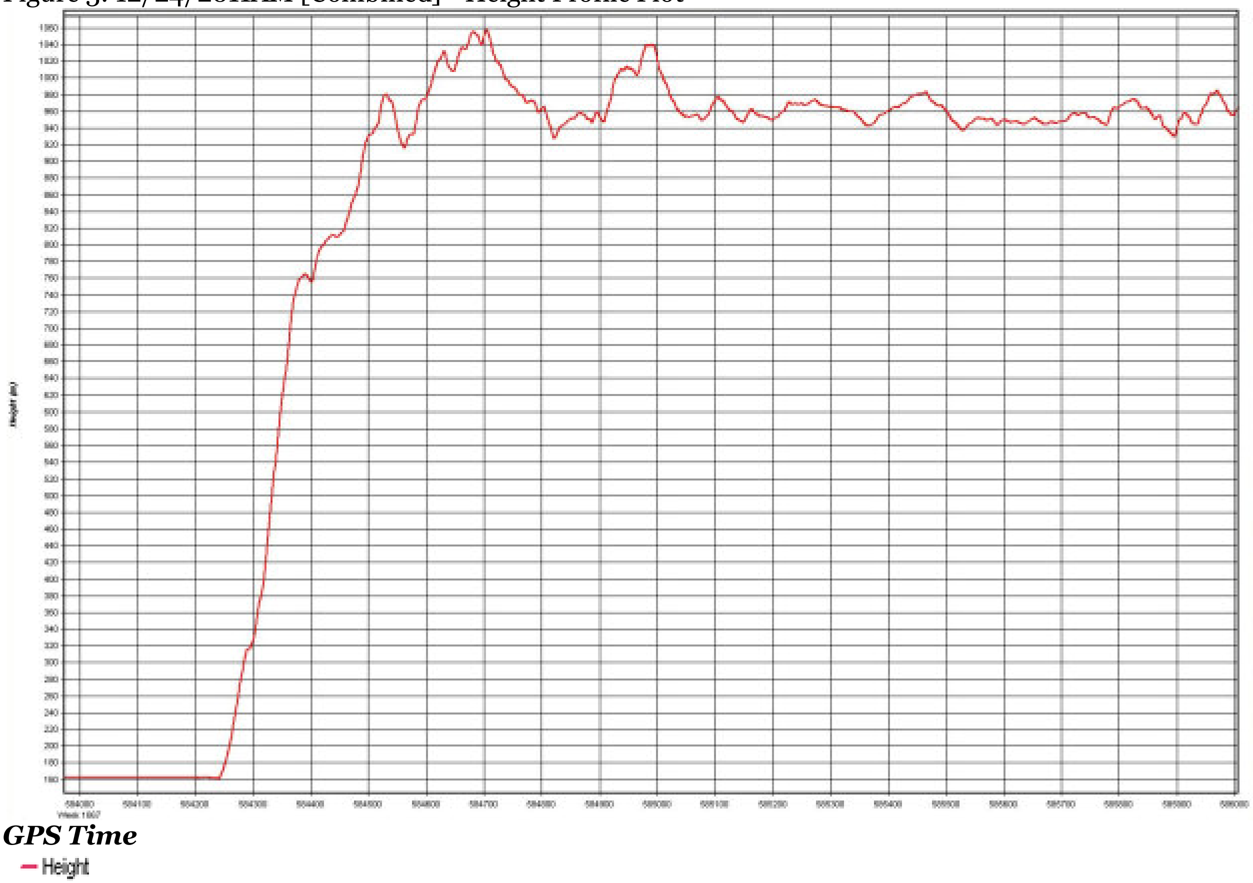


GPS Time

— Fixed Integer — Stable float — Converging float — DGPS or worse — Single Point — No solution

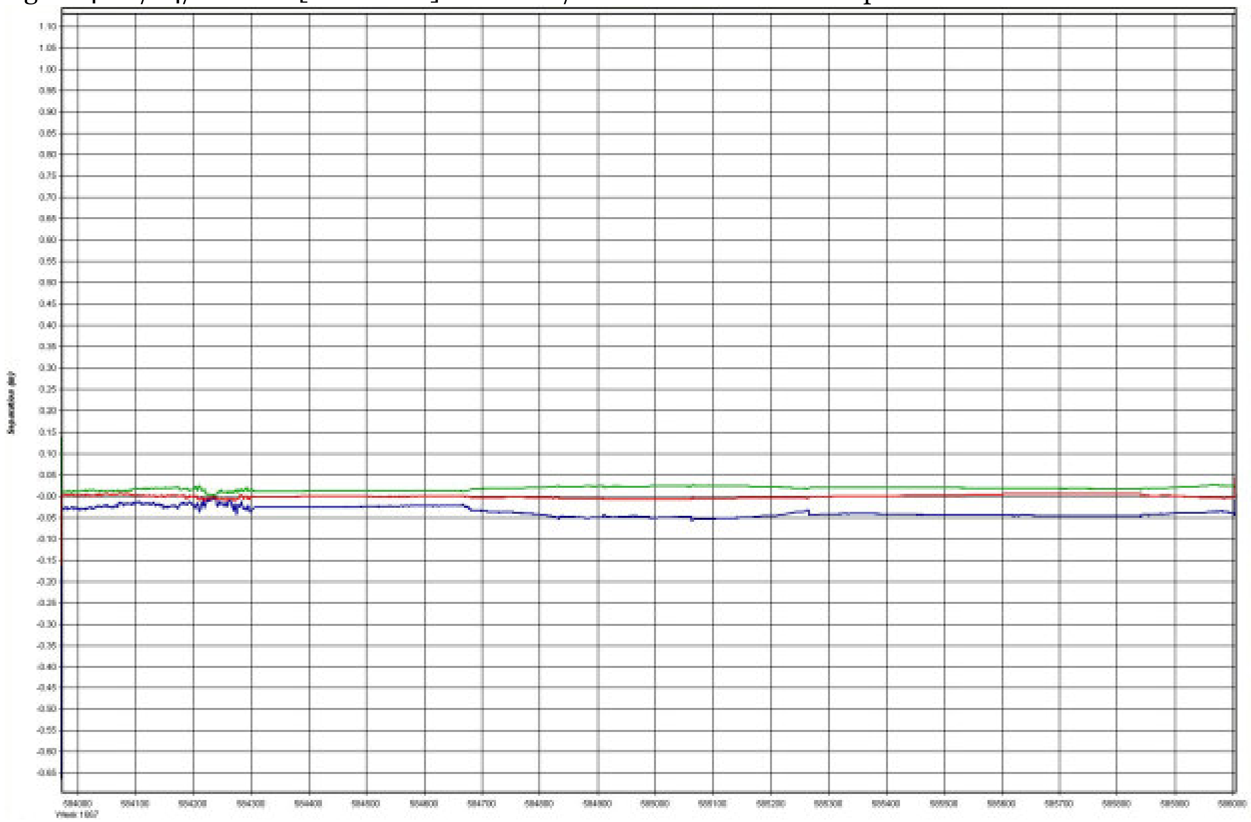
Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

Figure 3: 12/24/2011AM [Combined] - Height Profile Plot



Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

Figure 4: 12/24/2011AM [Combined] - Forward/Reverse or Combined Separation Plot



GPS Time

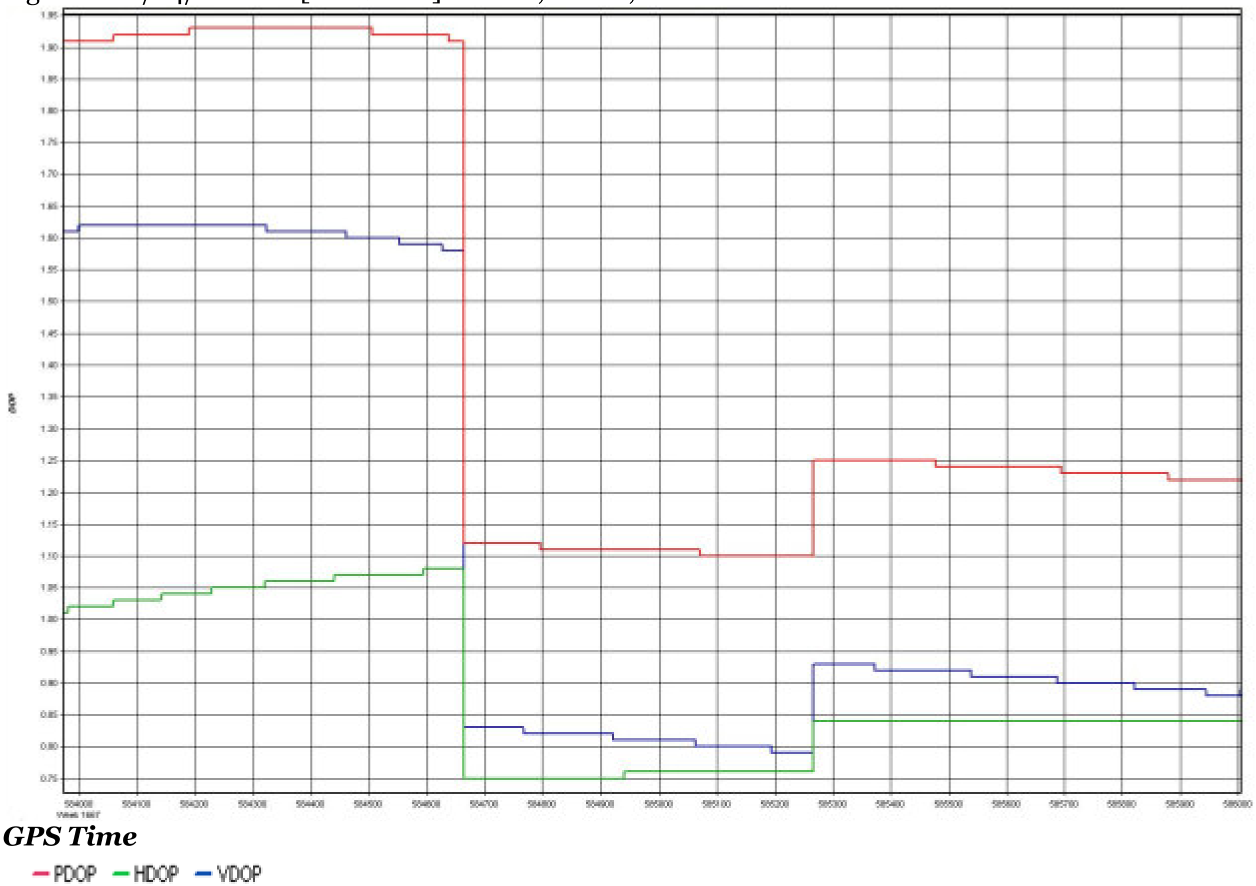
— East — North — Up

Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

Figure 5: 12/24/2011AM [Combined] - Forward/Reverse or Combined Weighting Plot

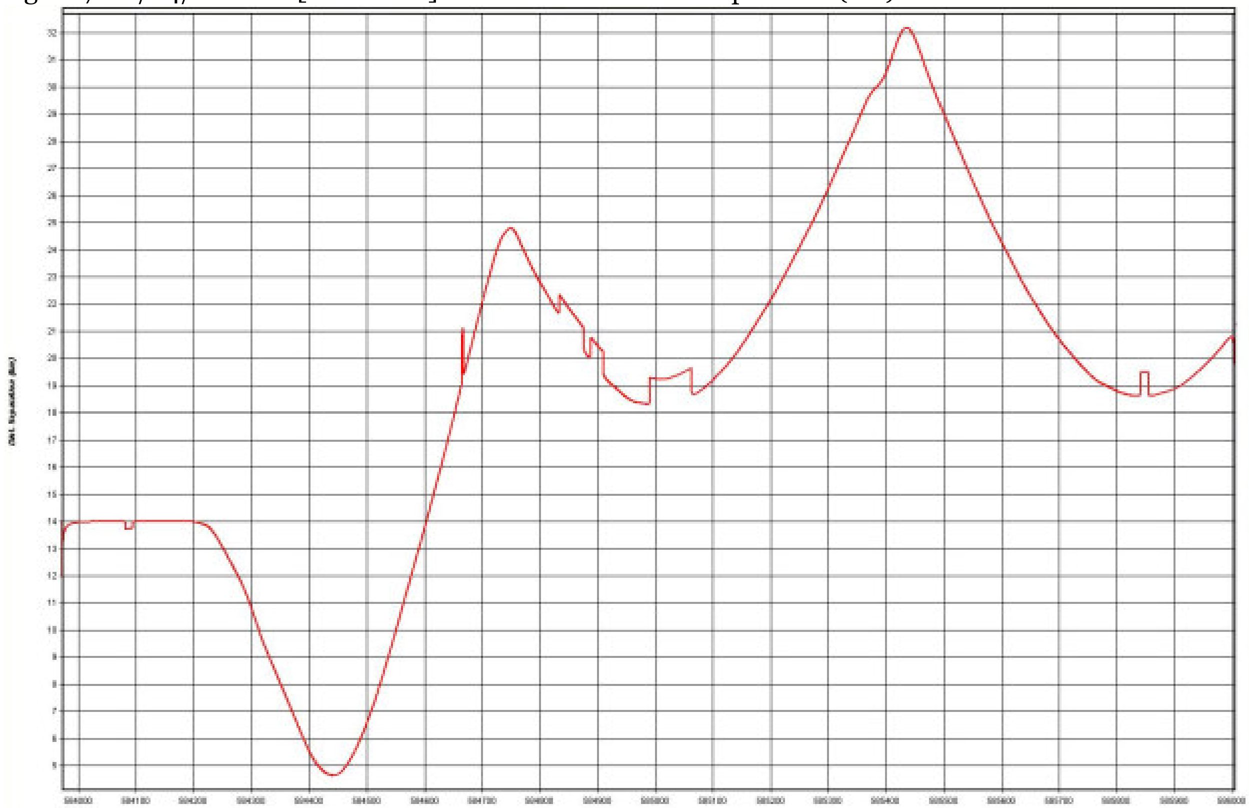
Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

Figure 6: 12/24/2011AM [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

Figure 7: 12/24/2011AM [Combined] - Horizontal Distance Separation (km)



GPS Time

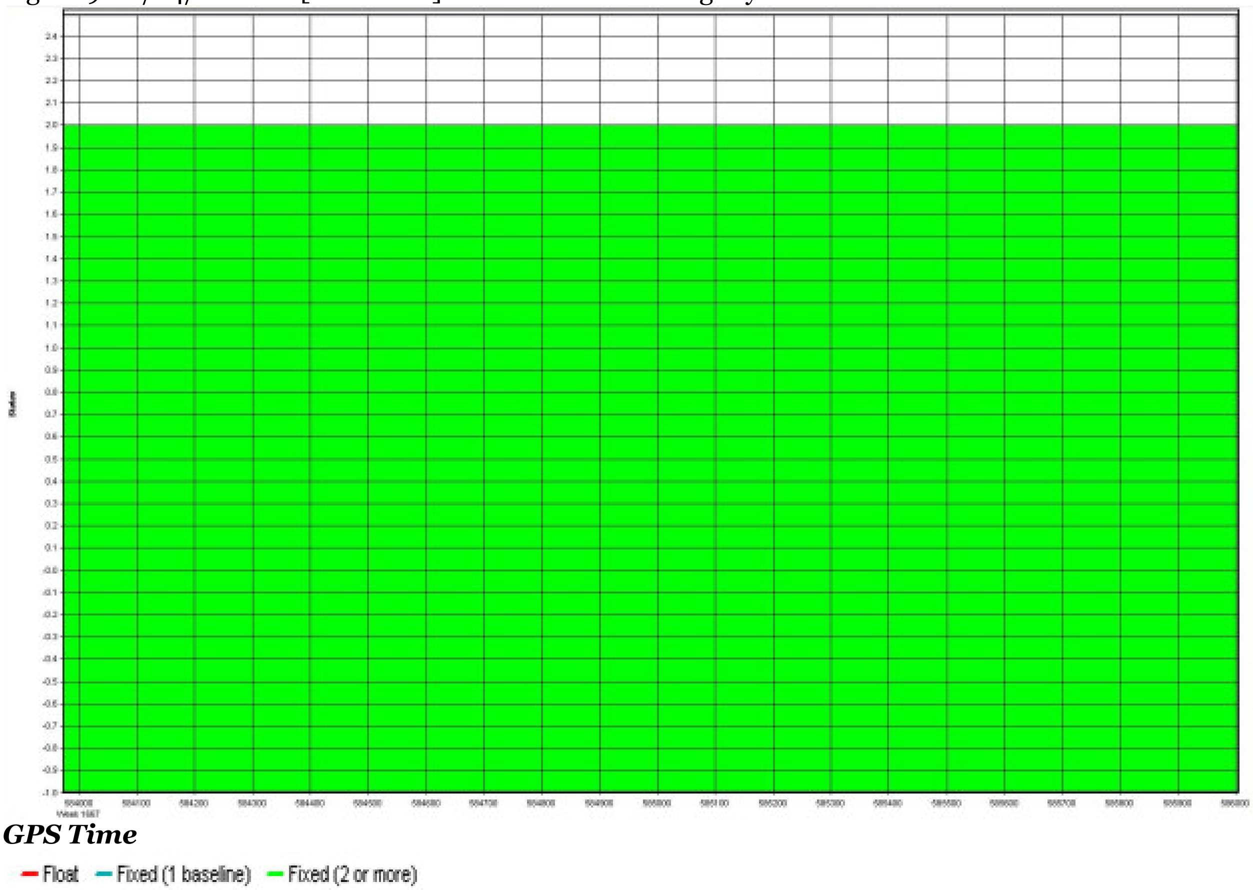
Distance

Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

Figure 8: 12/24/2011AM [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

Figure 9: 12/24/2011AM [Combined] - Float or Fixed Ambiguity

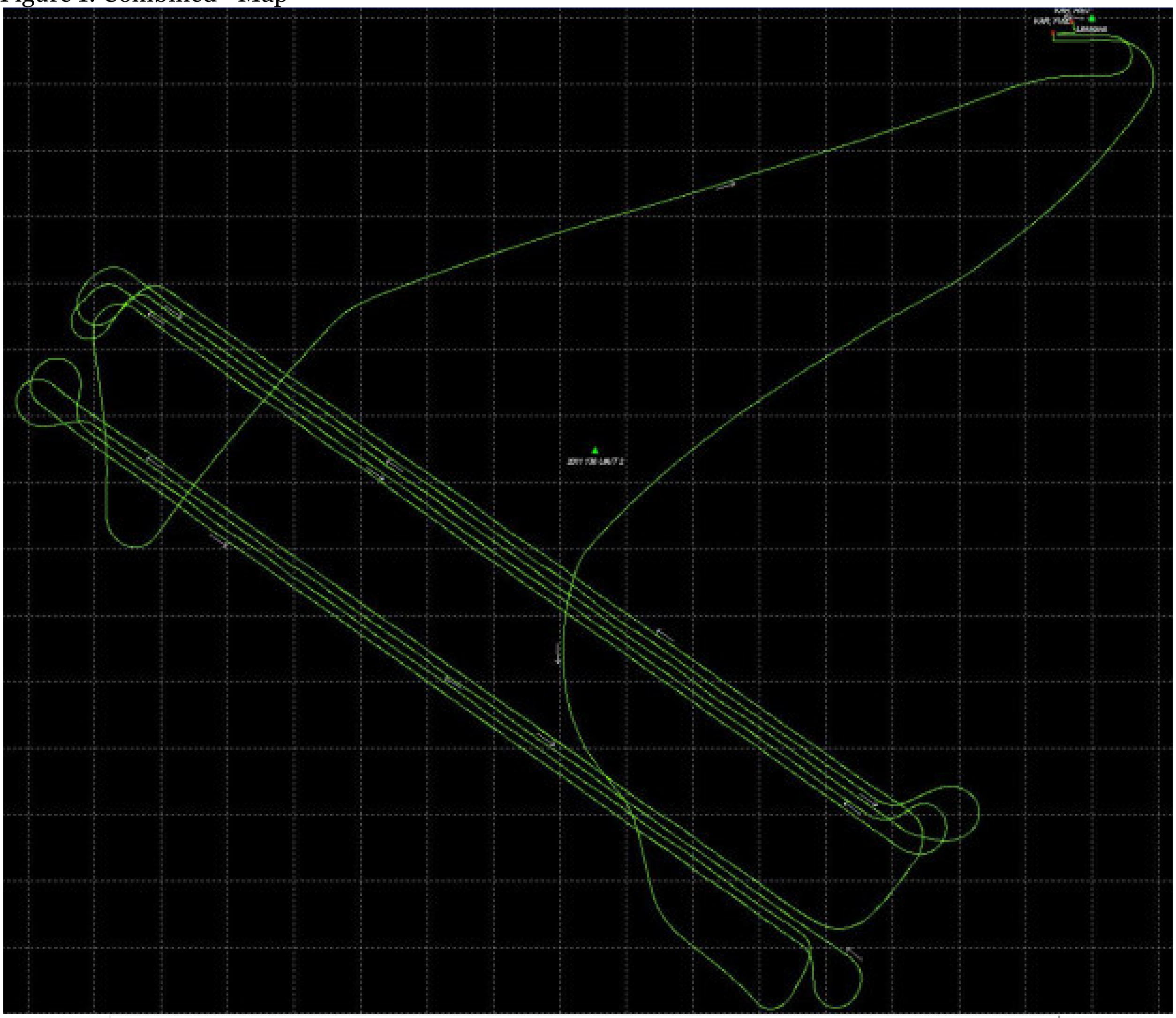


Process	Run (2)	by Unknown	on 12/24/2011	at 10:20

2.9 Output Results for 12/24/2011PM

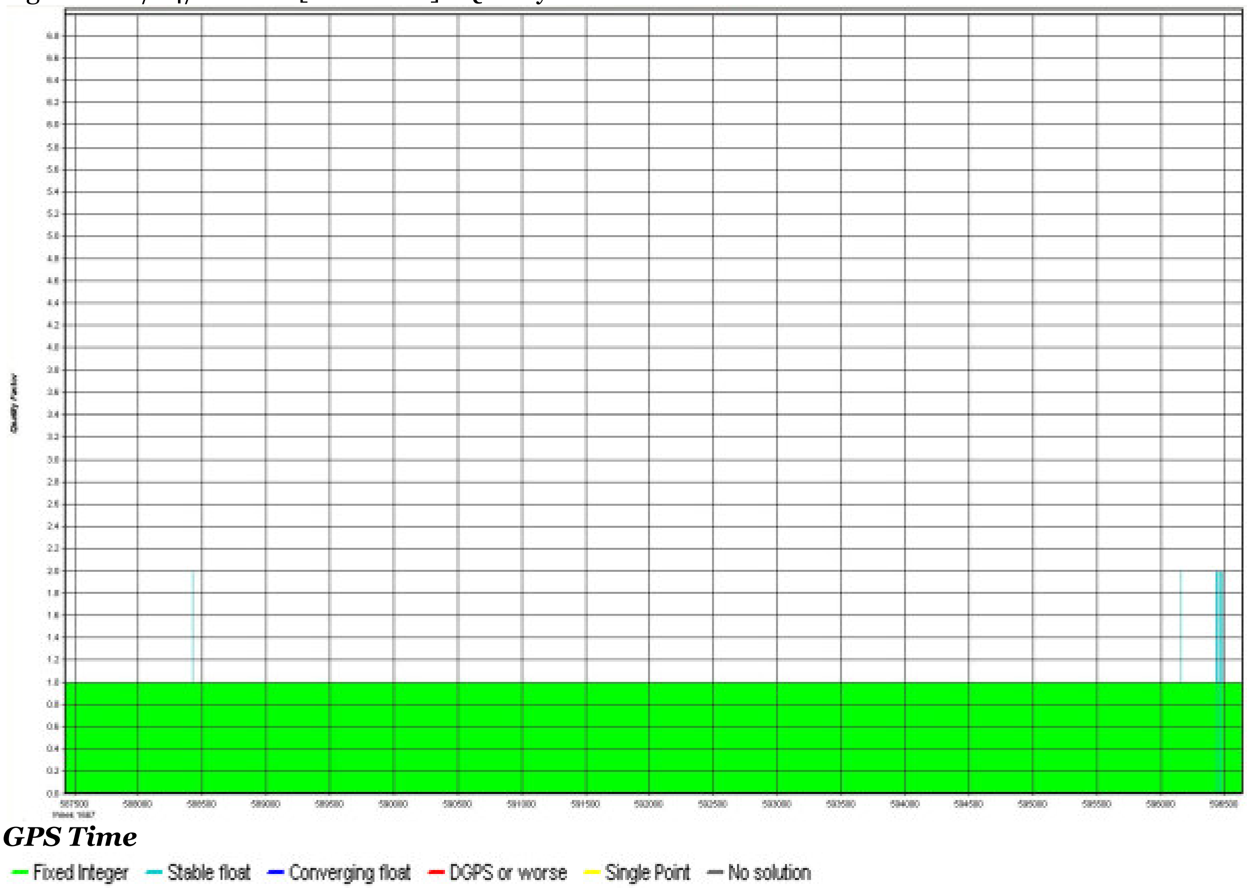
POSPAC Version 4.31

Figure 1: Combined - Map



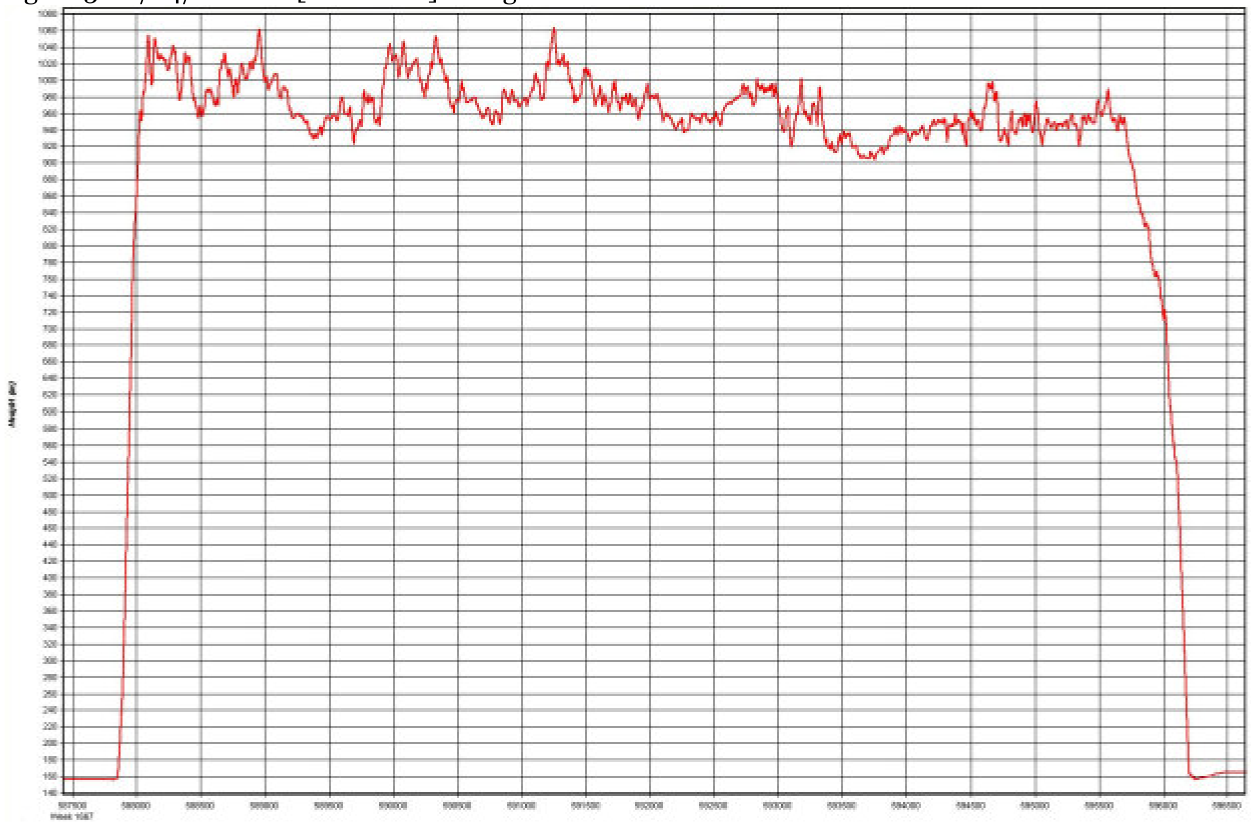
Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

Figure 2: 12/24/2011PM [Combined] - Quality Factor Plot



Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

Figure 3: 12/24/2011PM [Combined] - Height Profile Plot

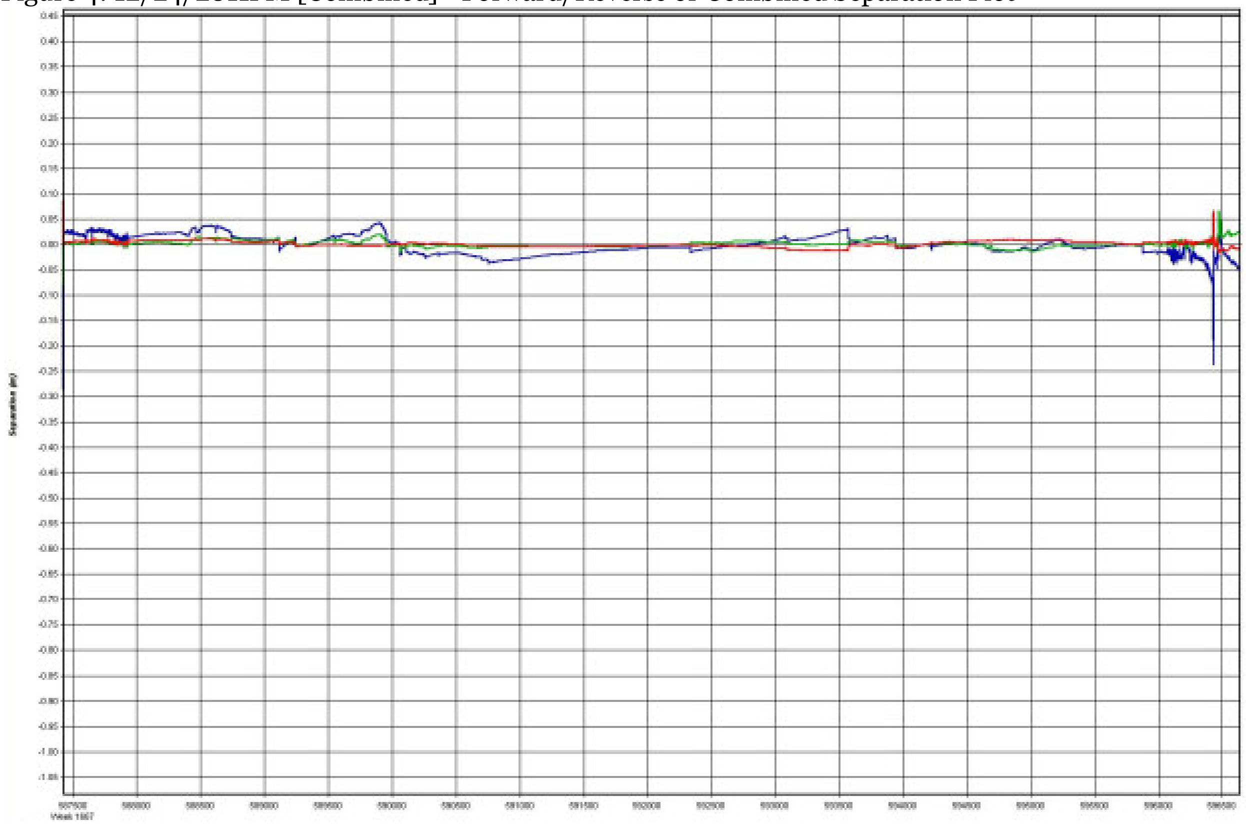


GPS Time

— Height

Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

Figure 4: 12/24/2011PM [Combined] - Forward/Reverse or Combined Separation Plot



GPS Time

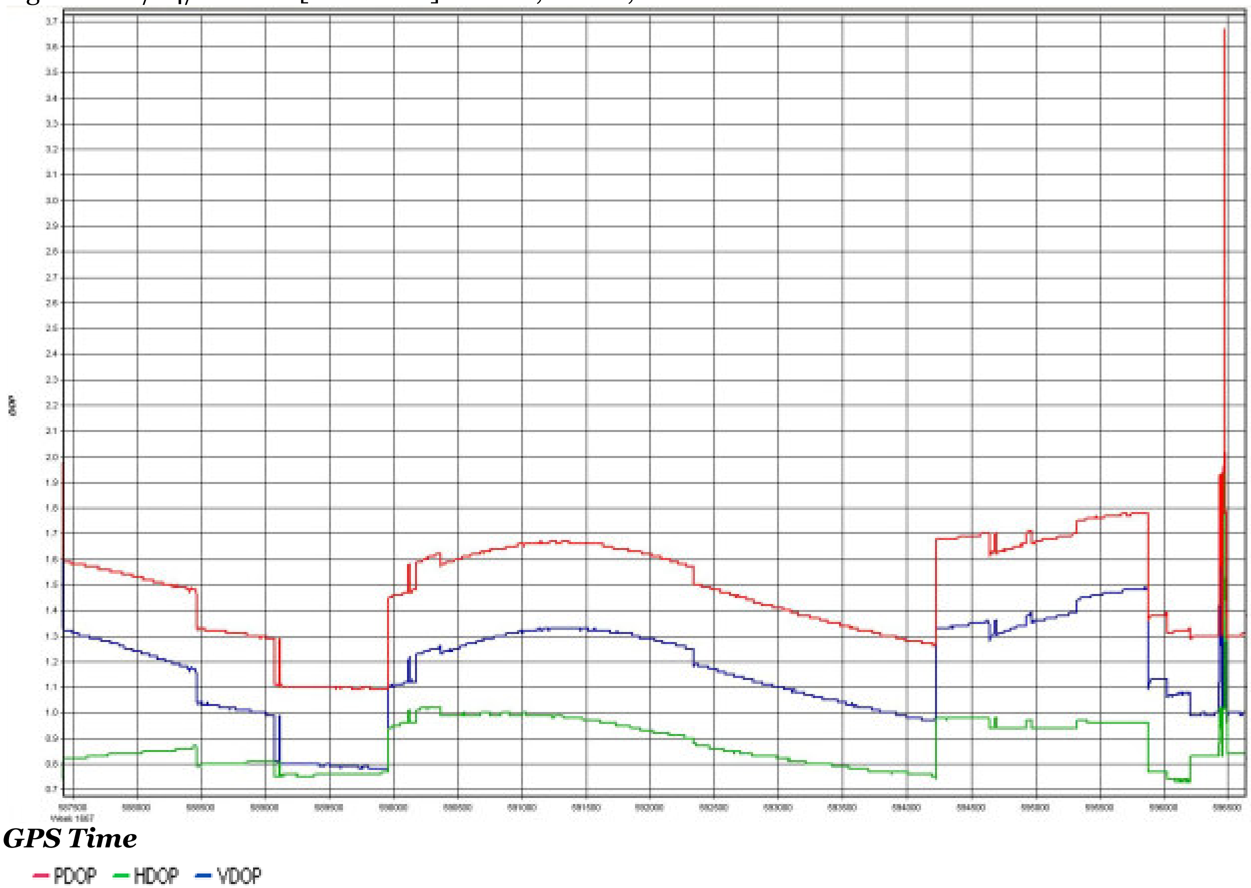
East North Up

Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

Figure 5: 12/24/2011PM [Combined] - Forward/Reverse or Combined Weighting Plot

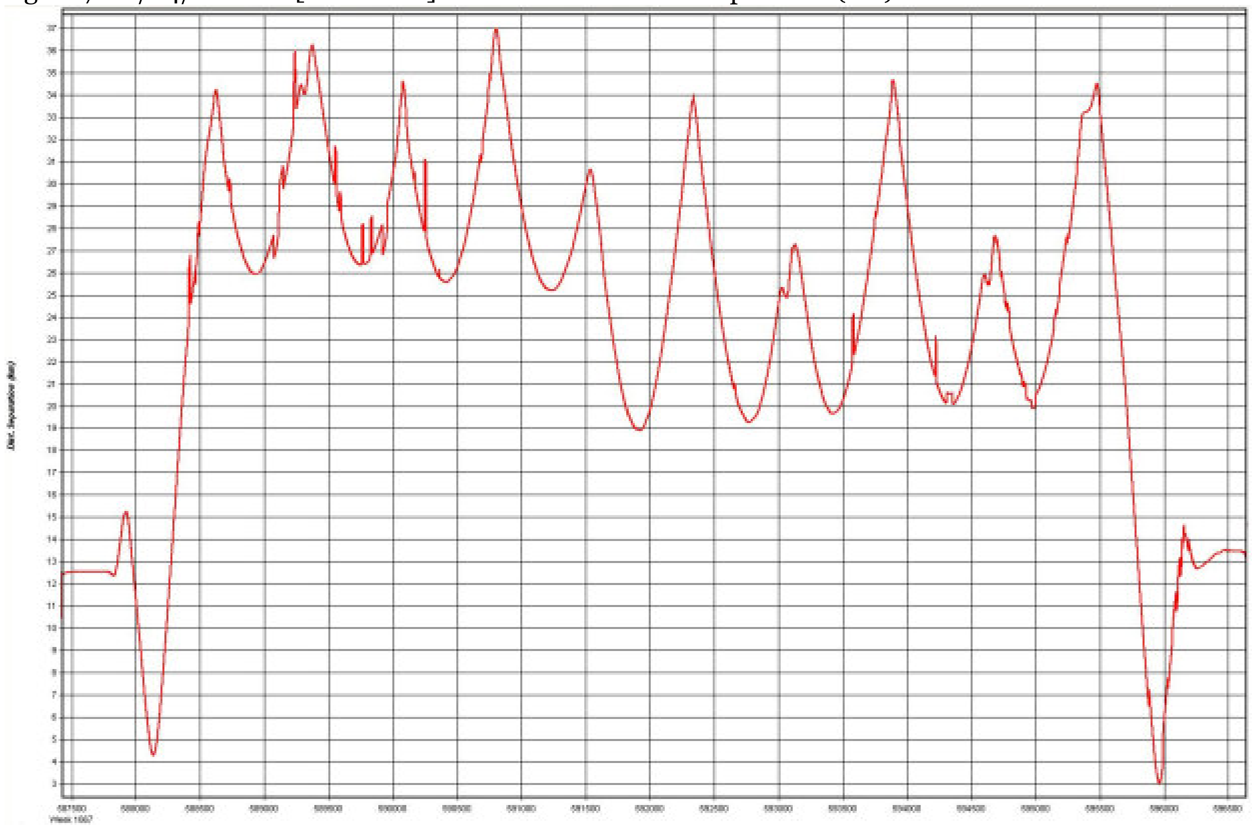
Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

Figure 6: 12/24/2011PM [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

Figure 7: 12/24/2011PM [Combined] - Horizontal Distance Separation (km)



GPS Time

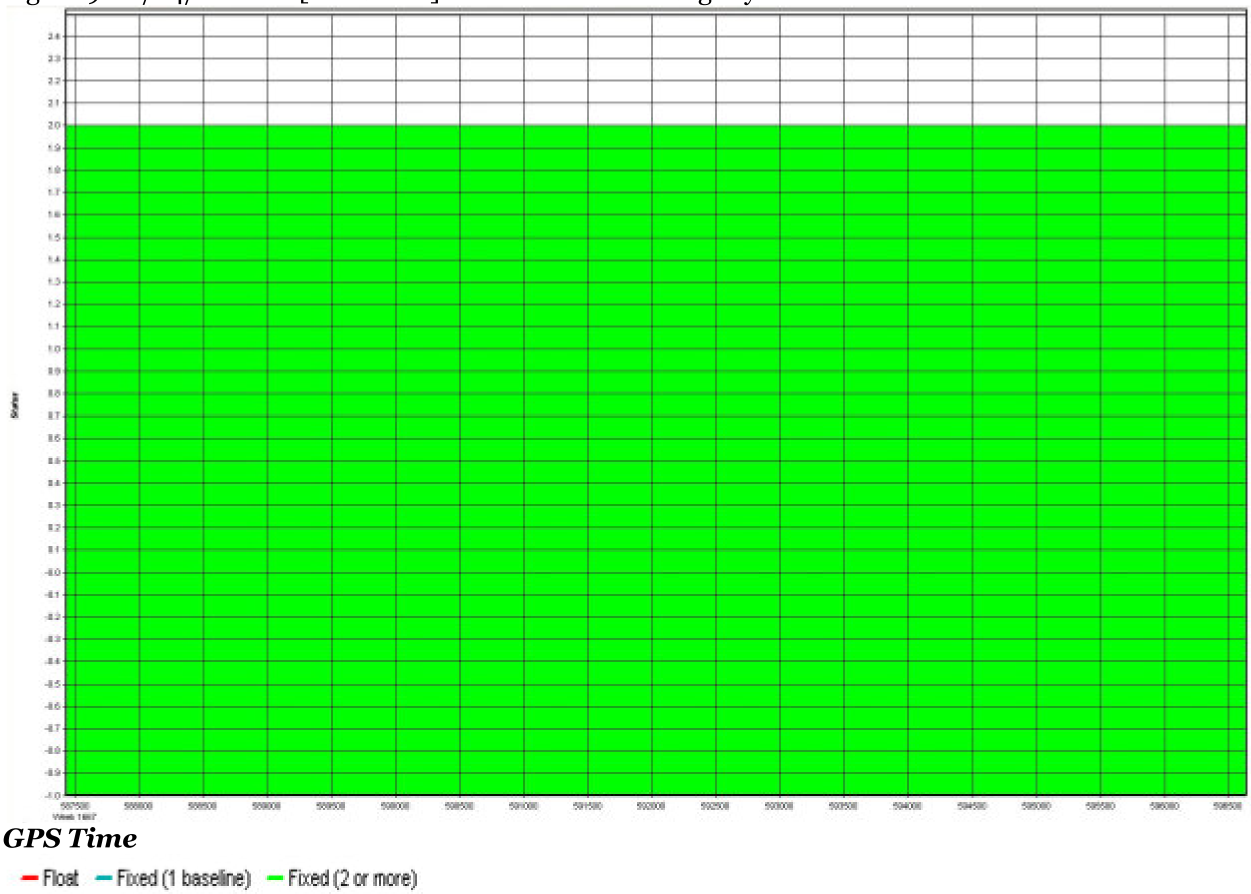
— Distance

Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

Figure 8: 12/24/2011PM [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

Figure 9: 12/24/2011PM [Combined] - Float or Fixed Ambiguity

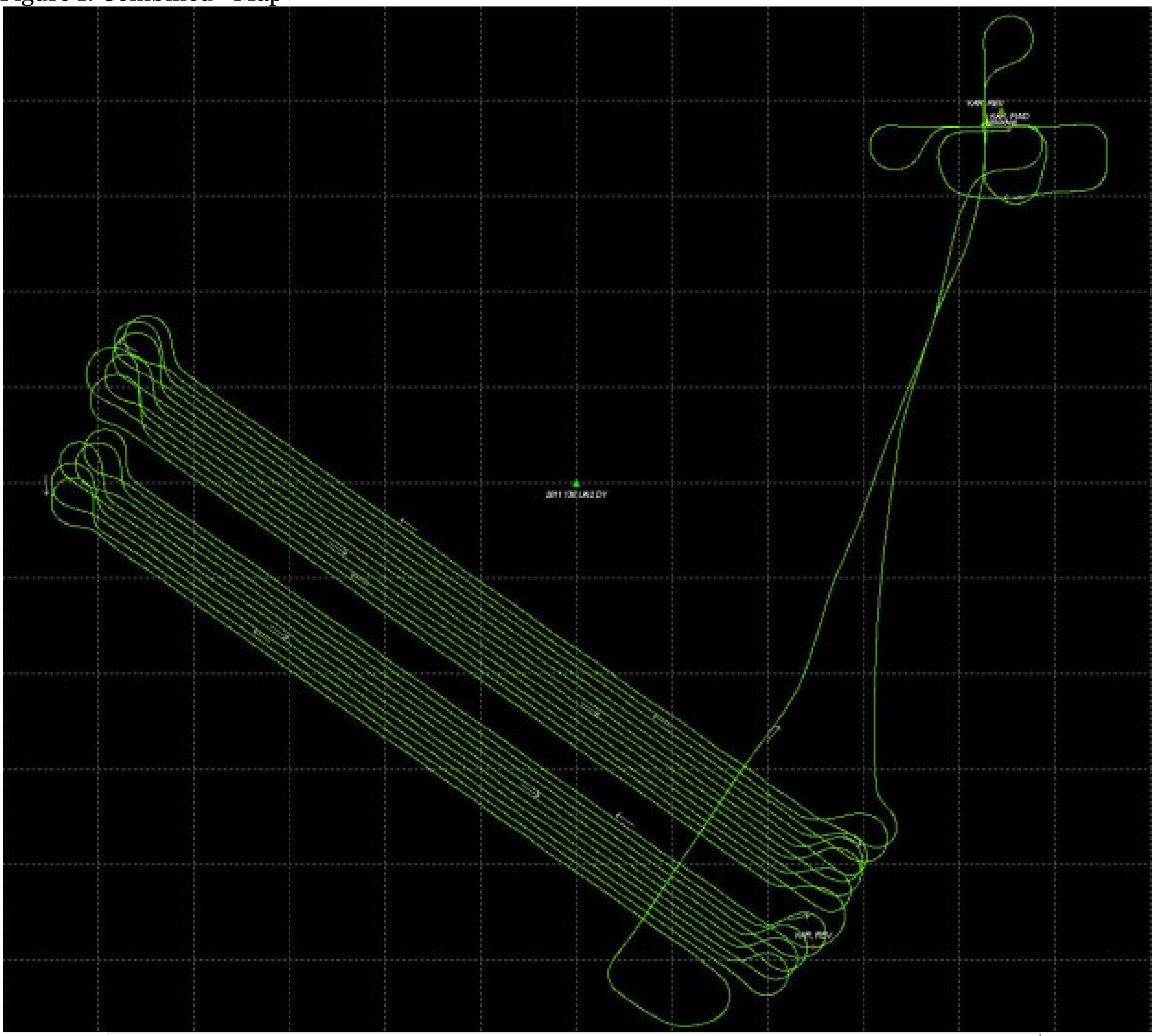


Process	Run (10)	by Unknown	on 12/24/2011	at 13:55

2.10 Output Results for 12/26/2011

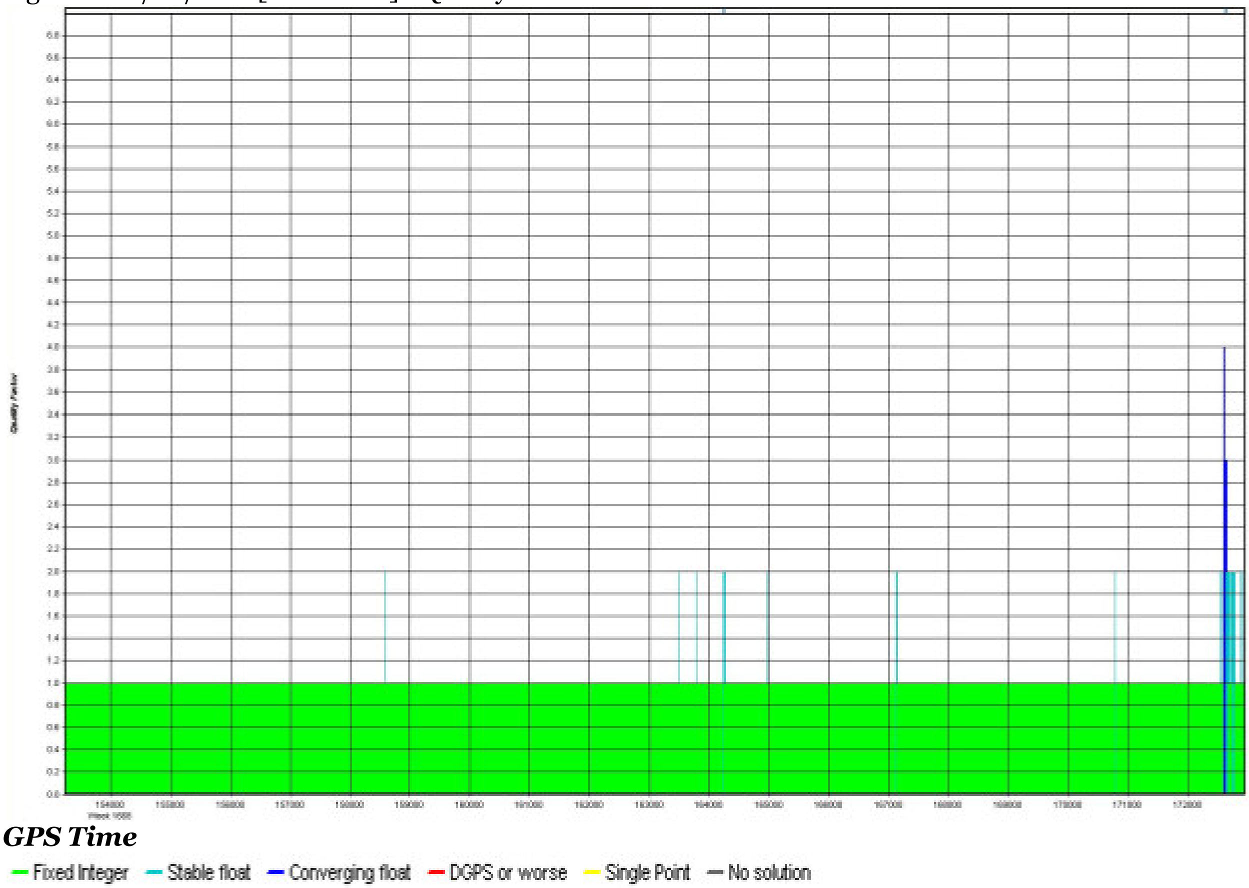
POSPAC Version 4.31

Figure 1: Combined - Map



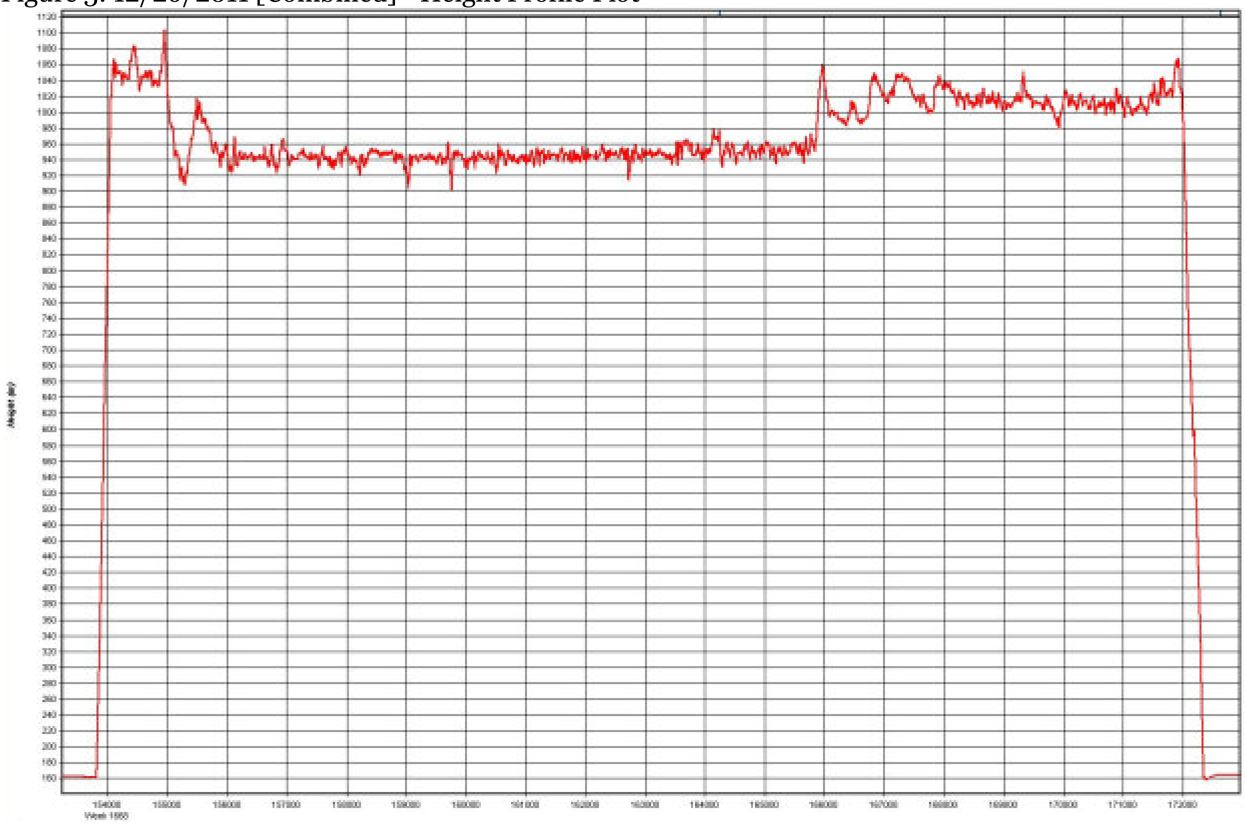
Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

Figure 2: 12/26/2011 [Combined] - Quality Factor Plot



Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

Figure 3: 12/26/2011 [Combined] - Height Profile Plot

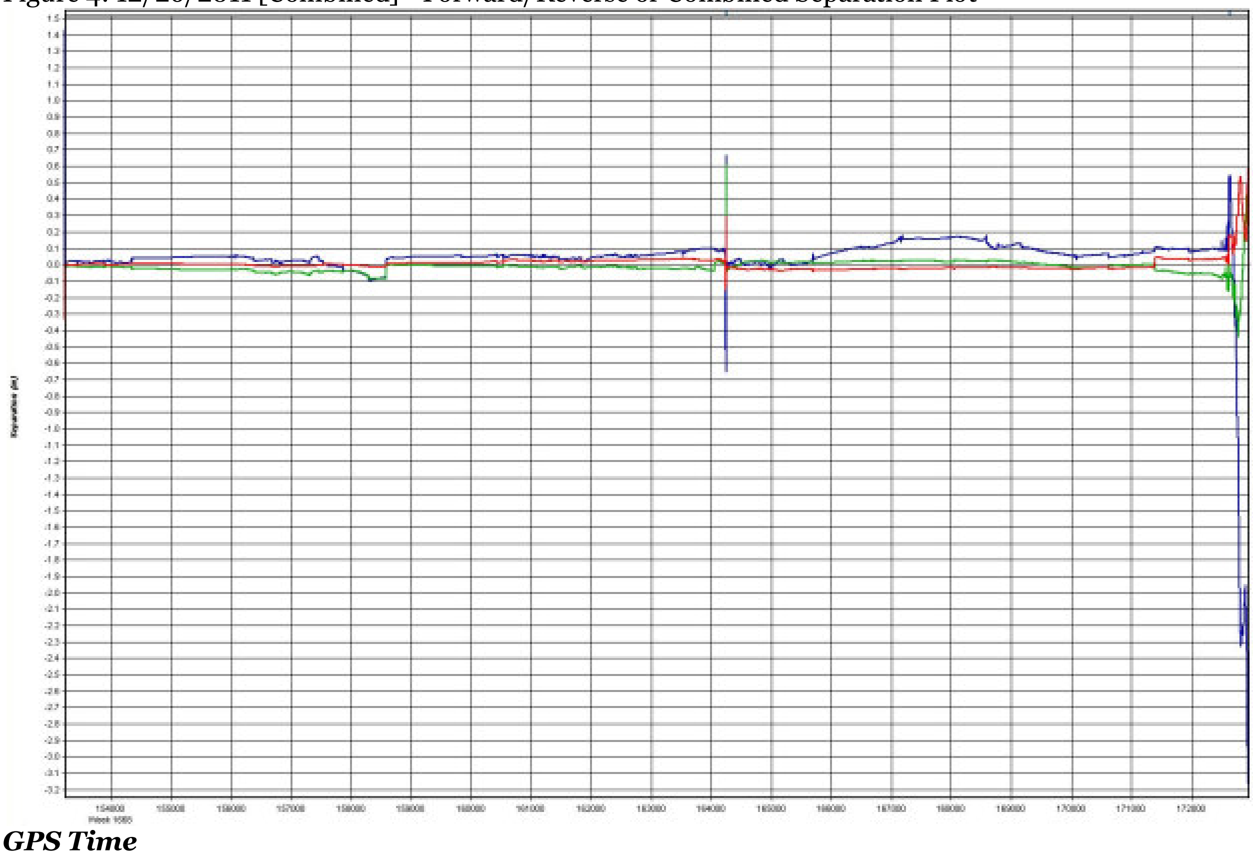


GPS Time

— Height

Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

Figure 4: 12/26/2011 [Combined] - Forward/Reverse or Combined Separation Plot

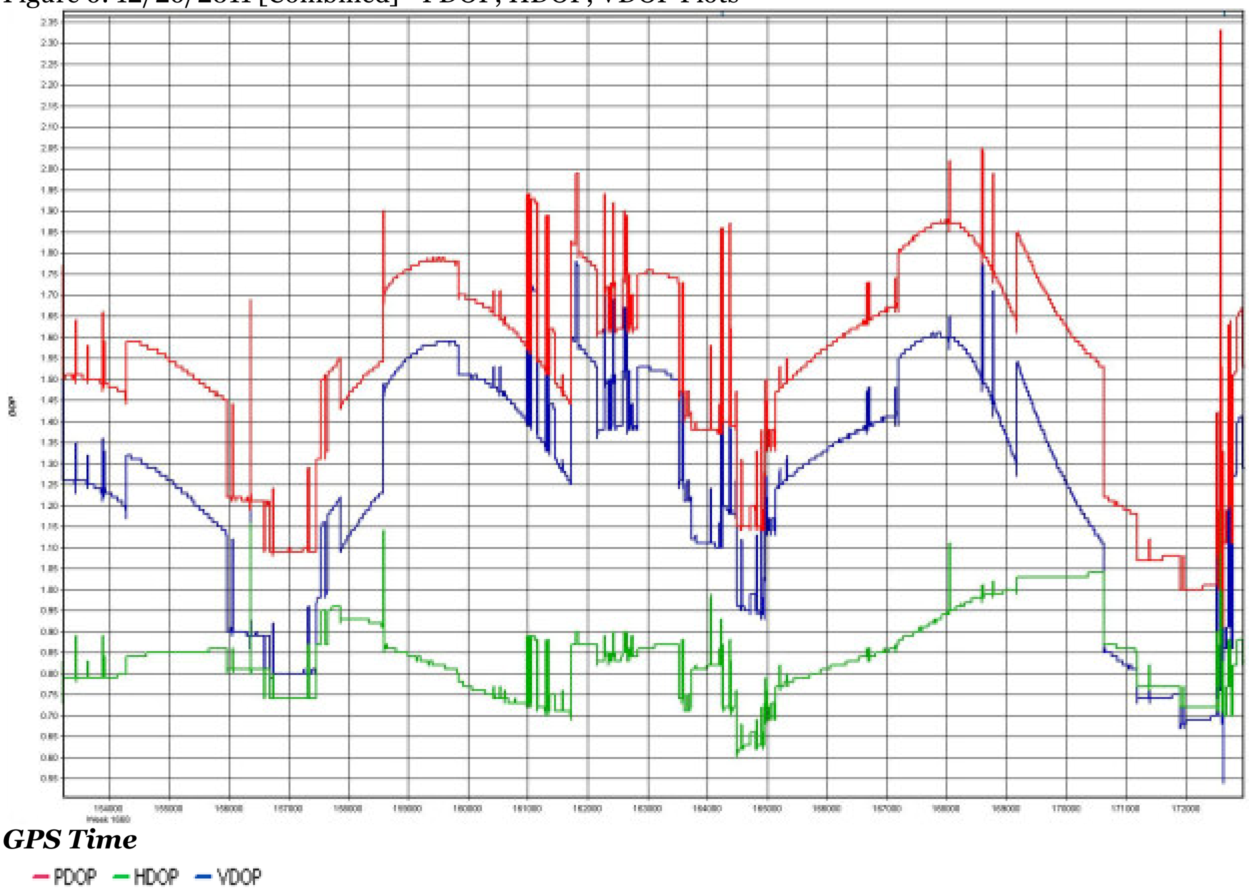


Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

Figure 5: 12/26/2011 [Combined] - Forward/Reverse or Combined Weighting Plot

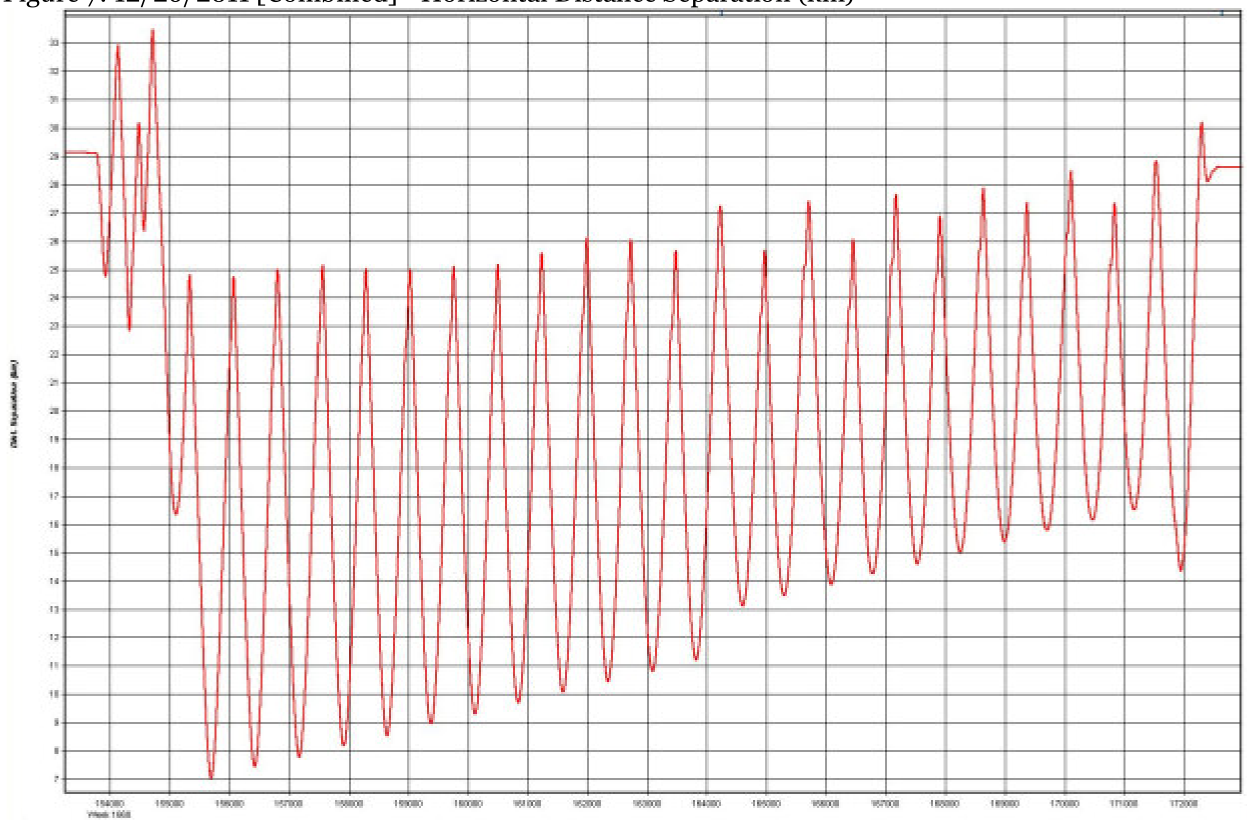
Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

Figure 6: 12/26/2011 [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

Figure 7: 12/26/2011 [Combined] - Horizontal Distance Separation (km)



GPS Time

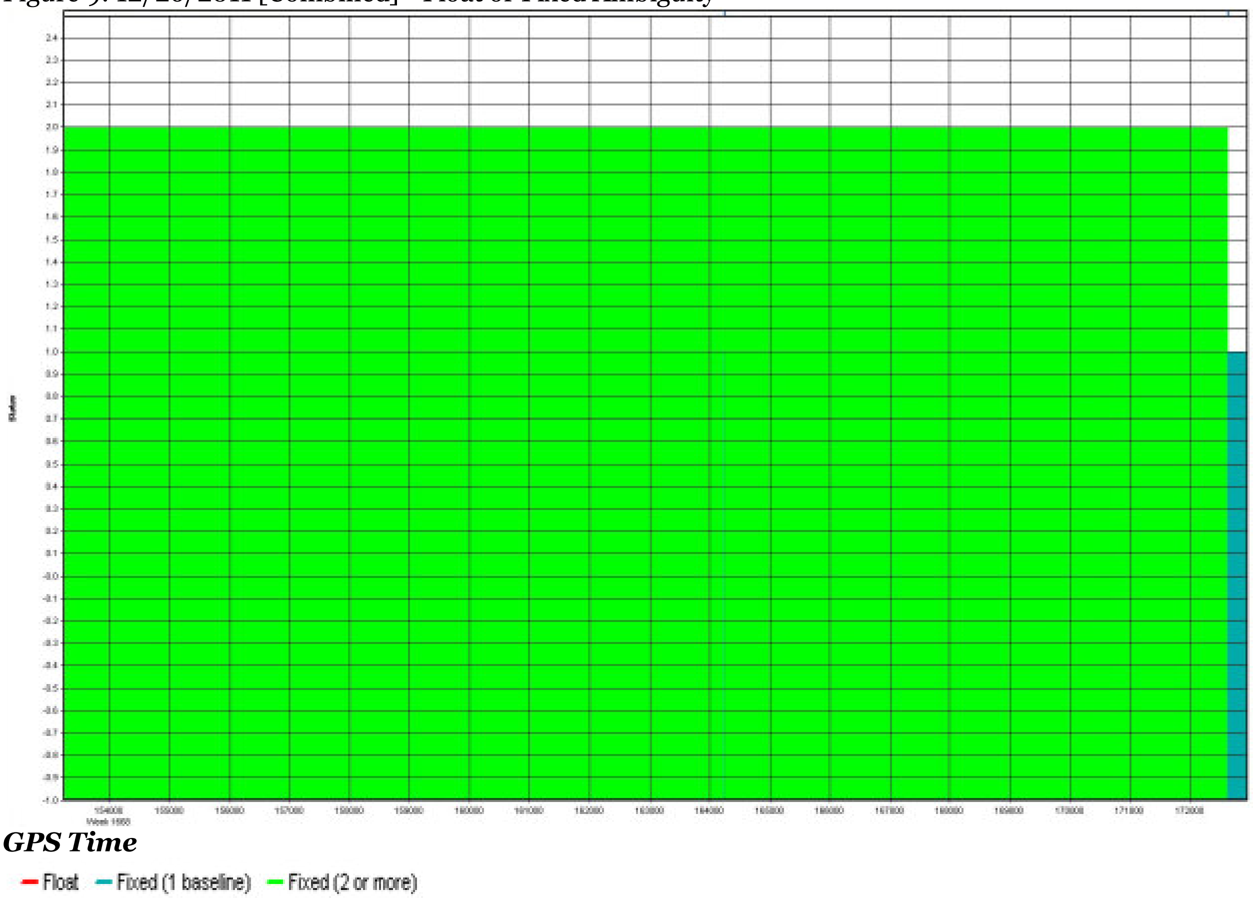
Distance

Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

Figure 8: 12/26/2011 [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

Figure 9: 12/26/2011 [Combined] - Float or Fixed Ambiguity

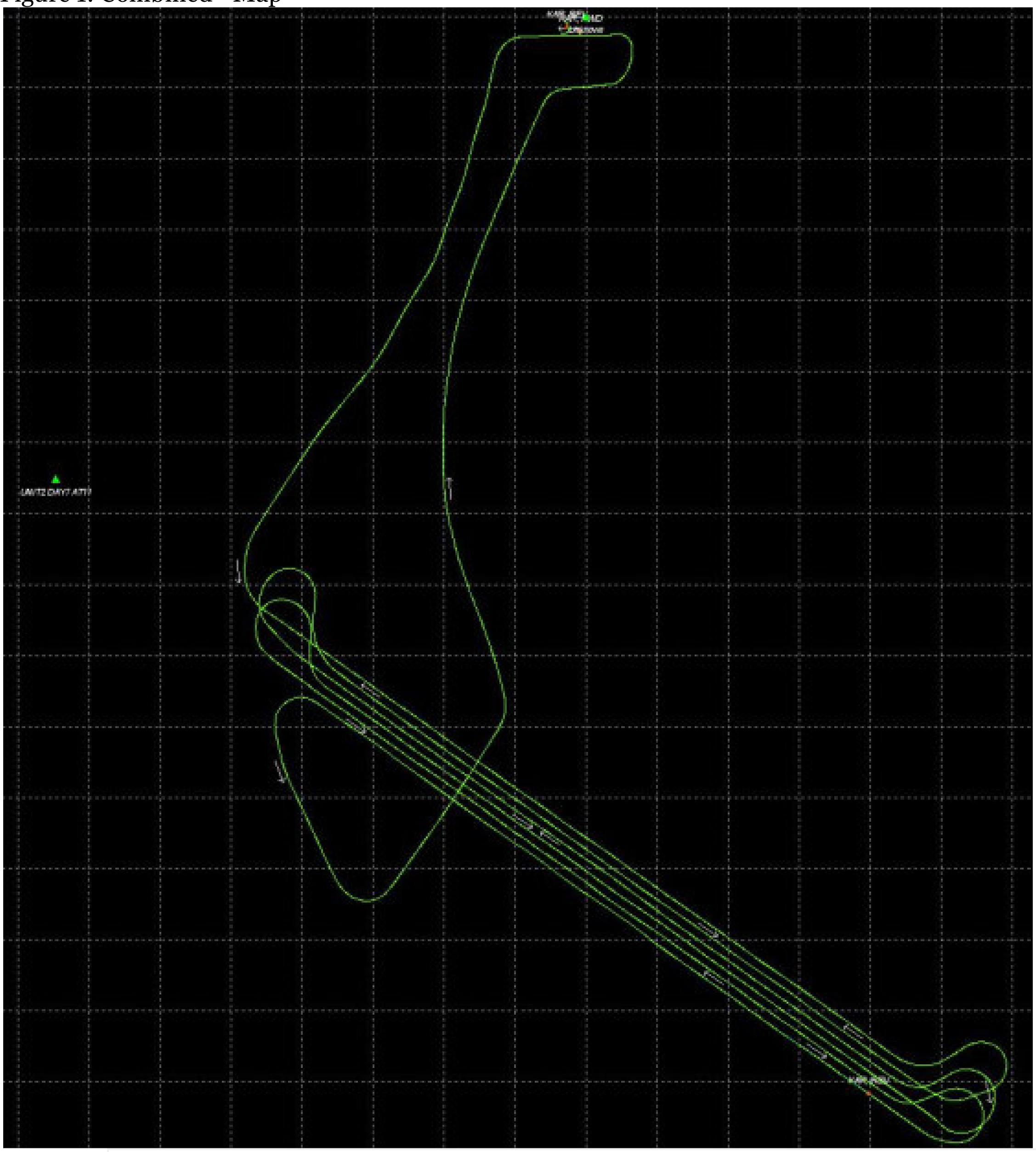


Process	Run (23)	by Unknown	on 12/26/2011	at 10:40

2.11 Output Results for 12/27/2011AM

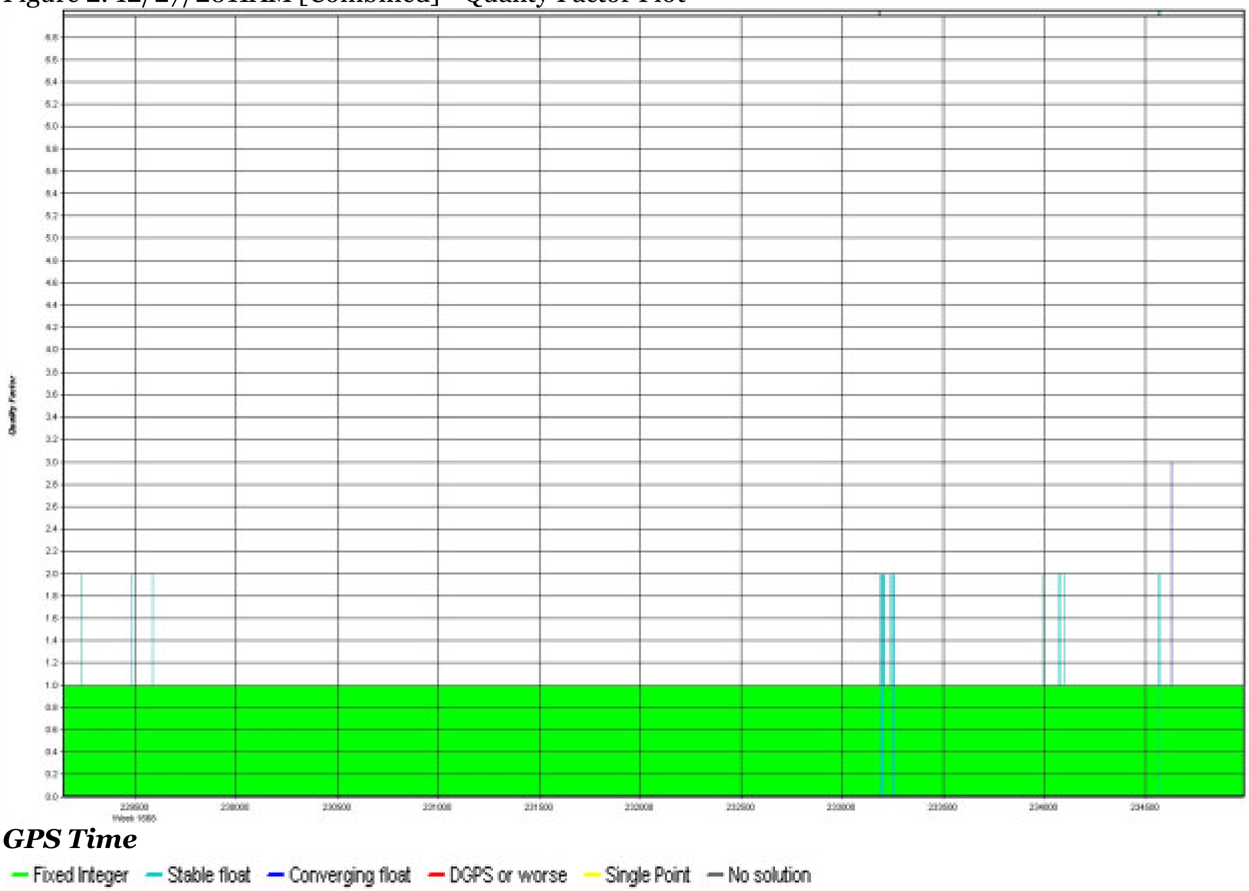
POSPAC Version 4.31

Figure 1: Combined - Map



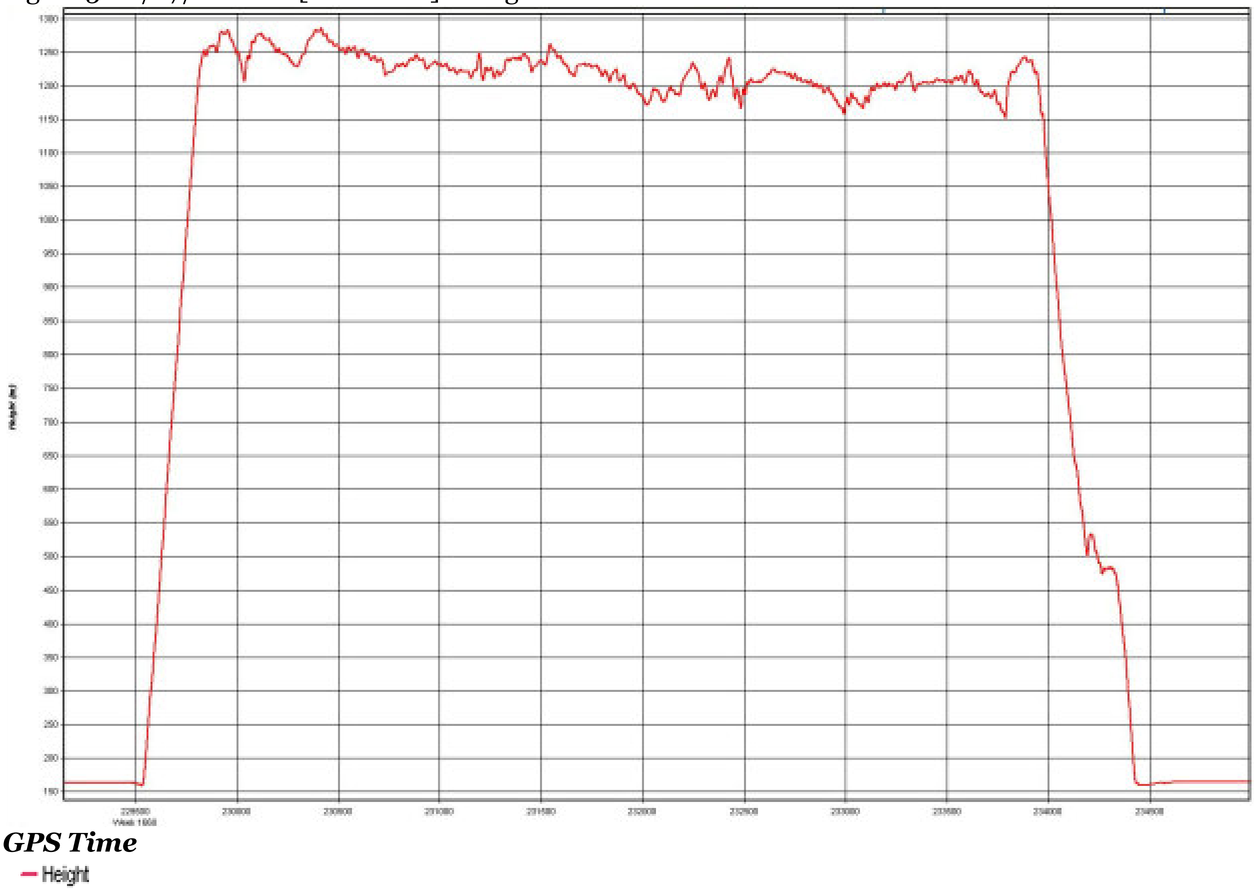
Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

Figure 2: 12/27/2011AM [Combined] - Quality Factor Plot



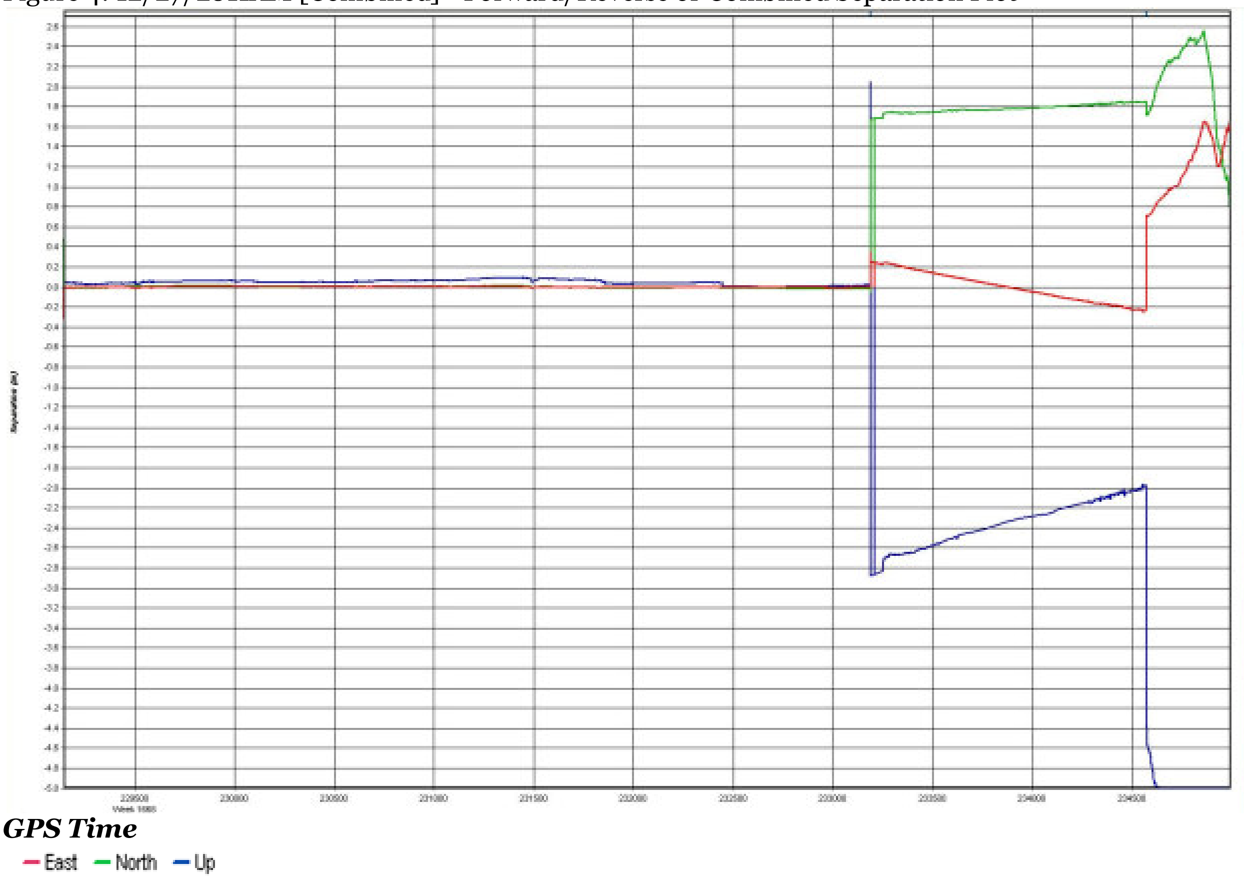
Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

Figure 3: 12/27/2011AM [Combined] - Height Profile Plot



Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

Figure 4: 12/27/2011AM [Combined] - Forward/Reverse or Combined Separation Plot

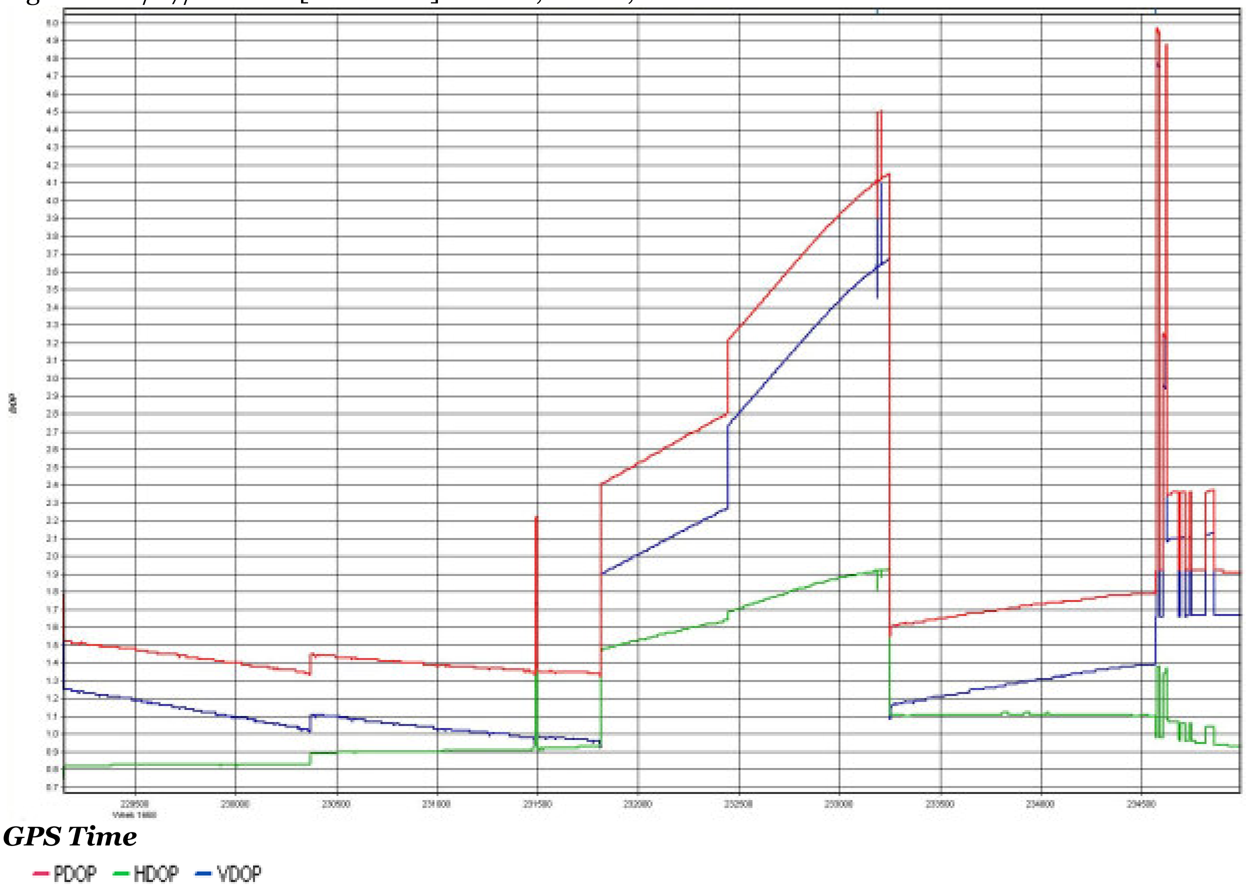


Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

Figure 5: 12/27/2011AM [Combined] - Forward/Reverse or Combined Weighting Plot

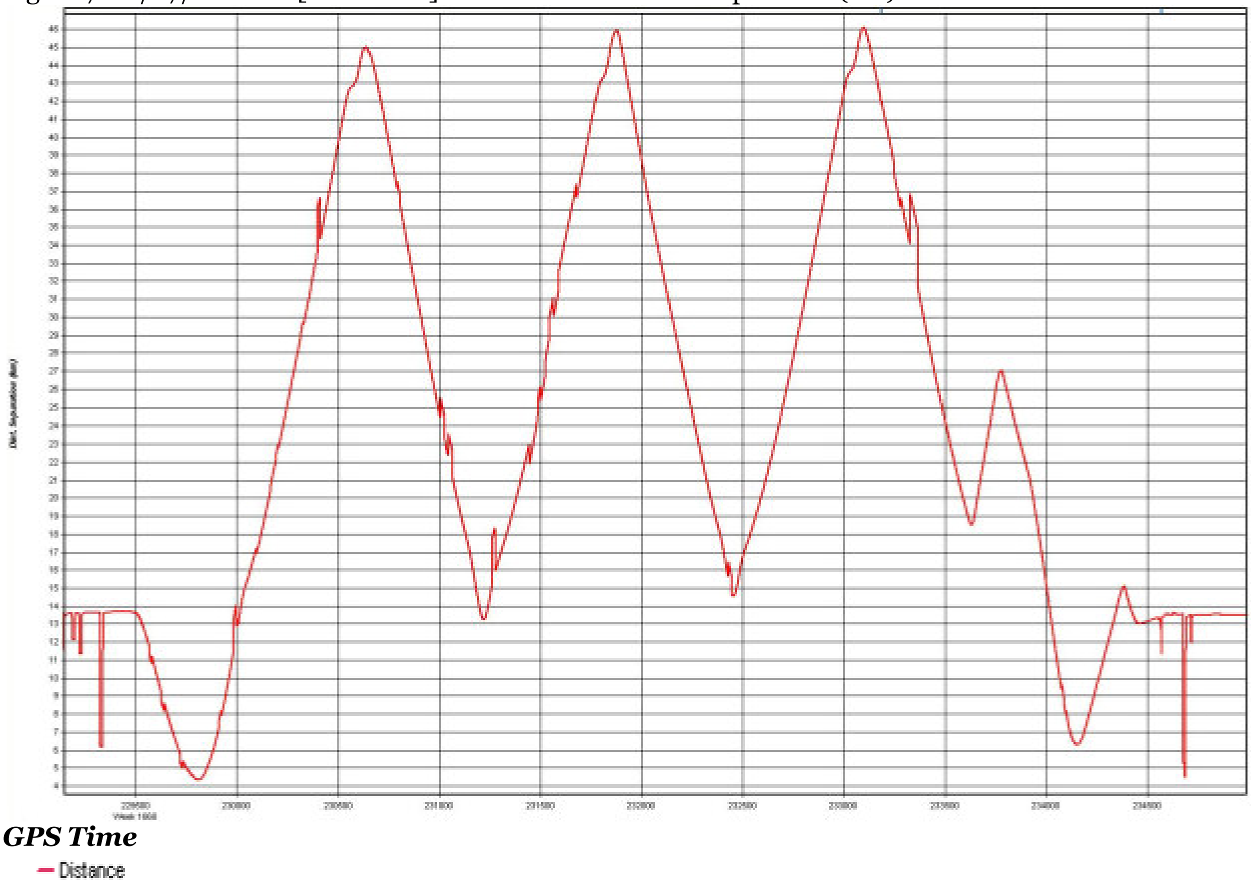
Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

Figure 6: 12/27/2011AM [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

Figure 7: 12/27/2011AM [Combined] - Horizontal Distance Separation (km)

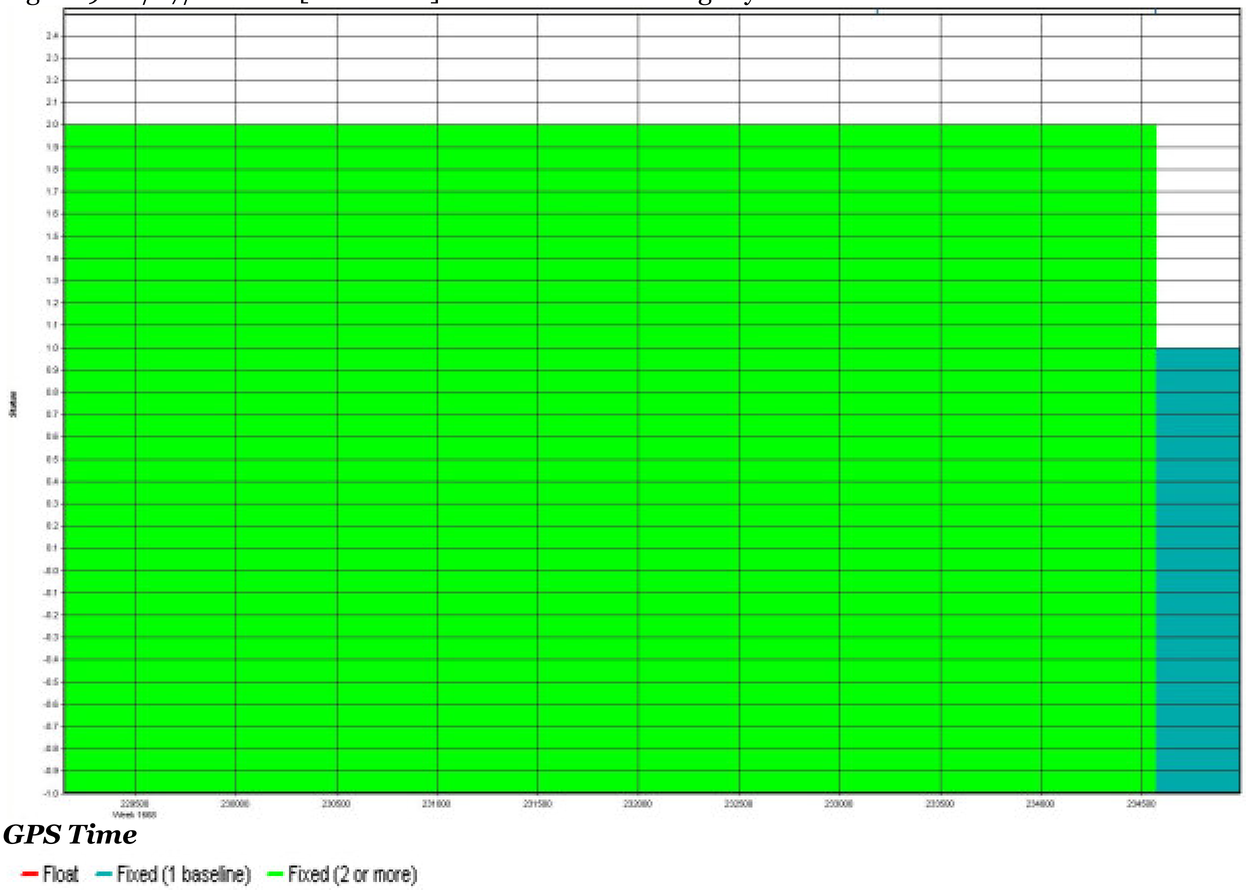


Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

Figure 8: 12/27/2011AM [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

Figure 9: 12/27/2011AM [Combined] - Float or Fixed Ambiguity



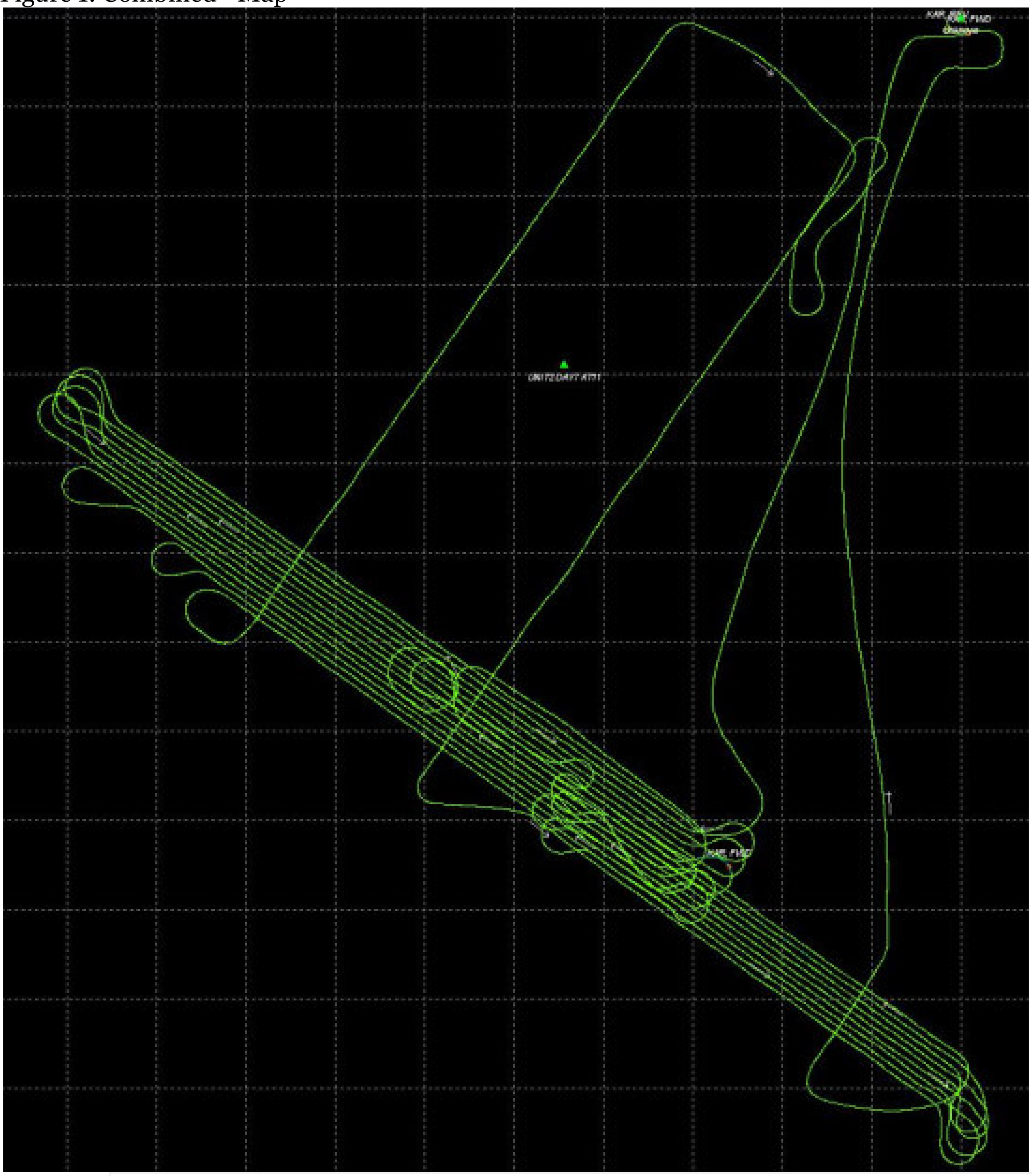
GPS Time

Process	Run (7)	by Unknown	on 12/27/2011	at 06:50

2.12 Output Results for 12/27/2011PM

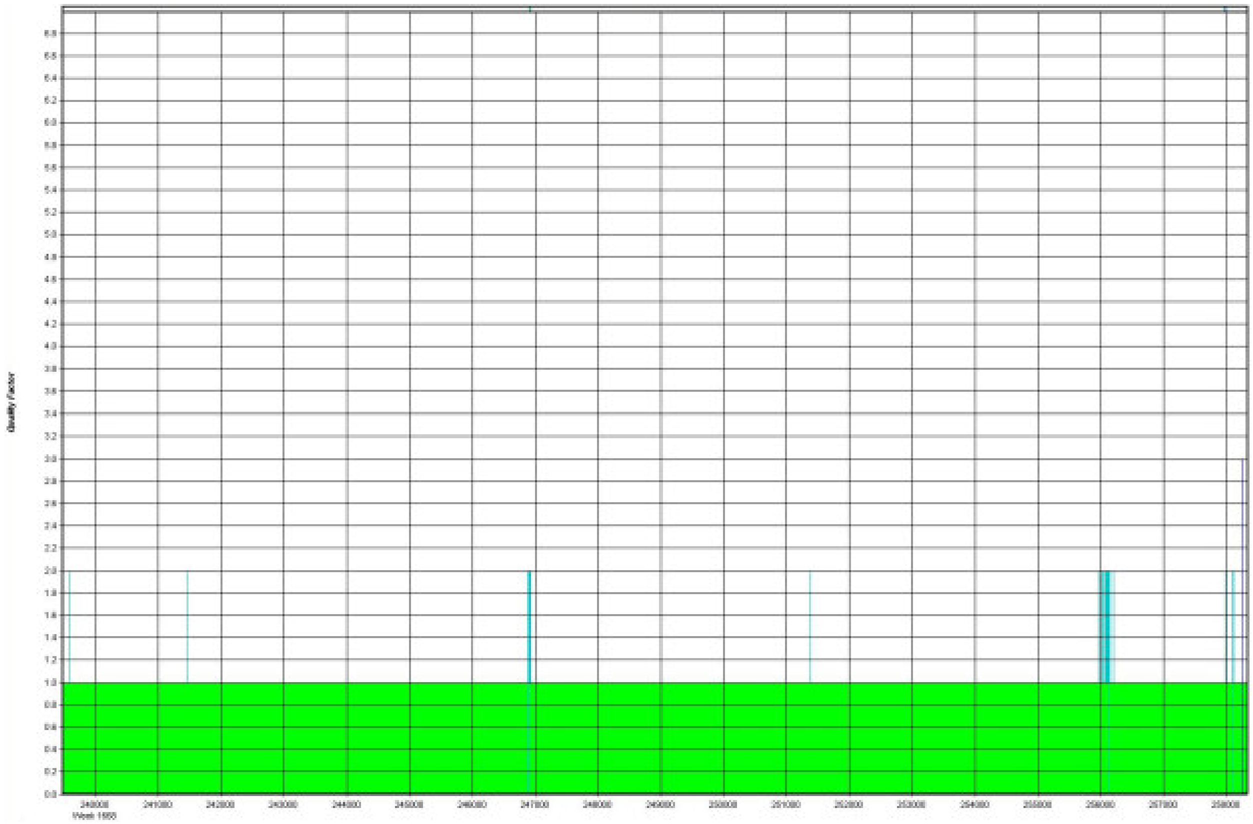
POSPAC Version 4.31

Figure 1: Combined - Map



Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

Figure 2: 12/27/2011PM [Combined] - Quality Factor Plot

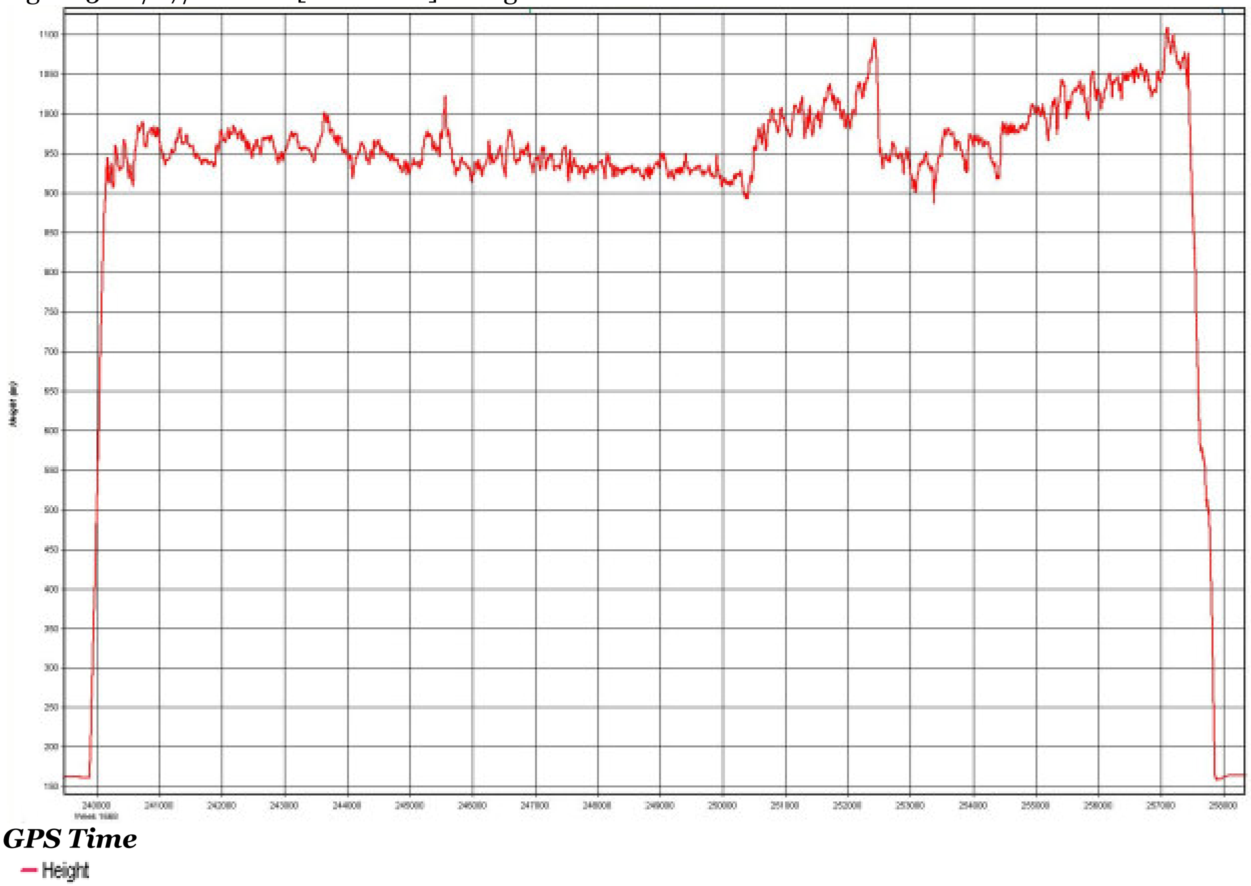


GPS Time

— Fixed Integer — Stable float — Converging float — DGPS or worse — Single Point — No solution

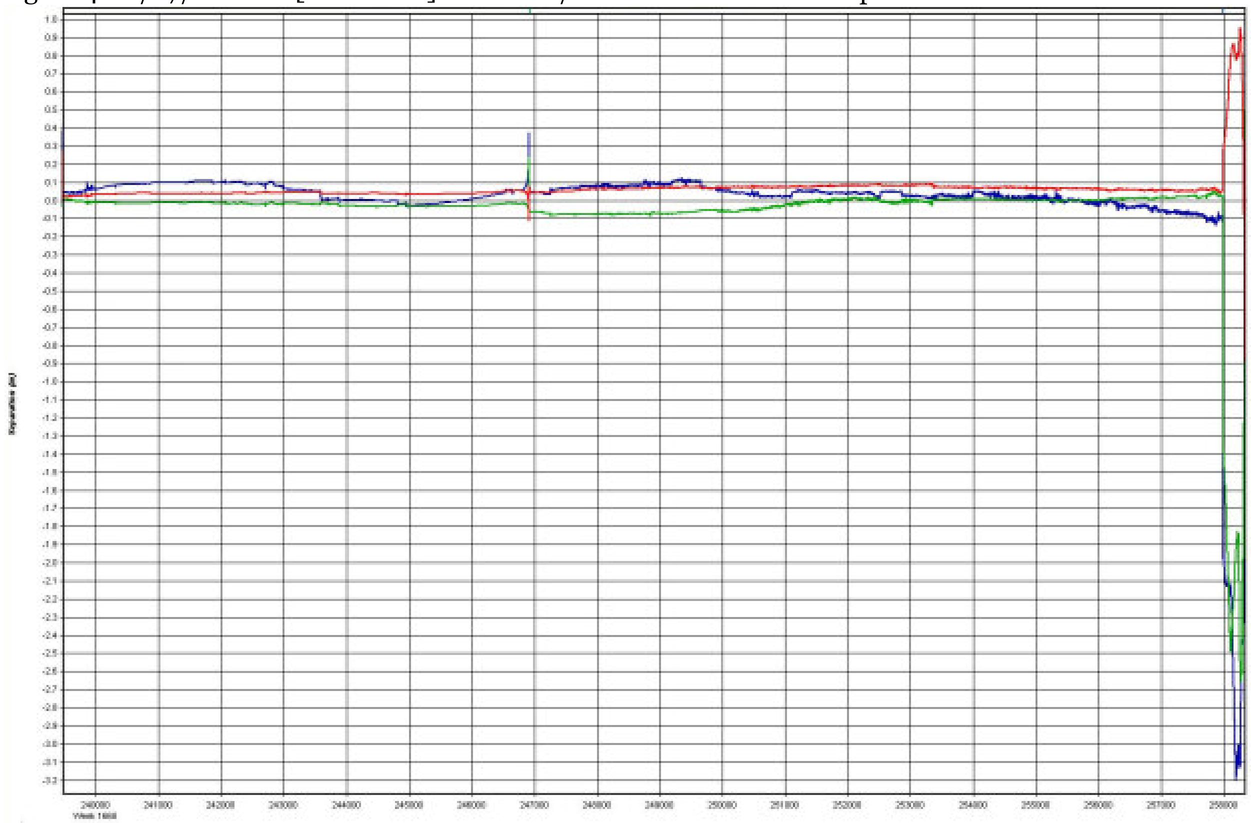
Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

Figure 3: 12/27/2011PM [Combined] - Height Profile Plot



Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

Figure 4: 12/27/2011PM [Combined] - Forward/Reverse or Combined Separation Plot



GPS Time

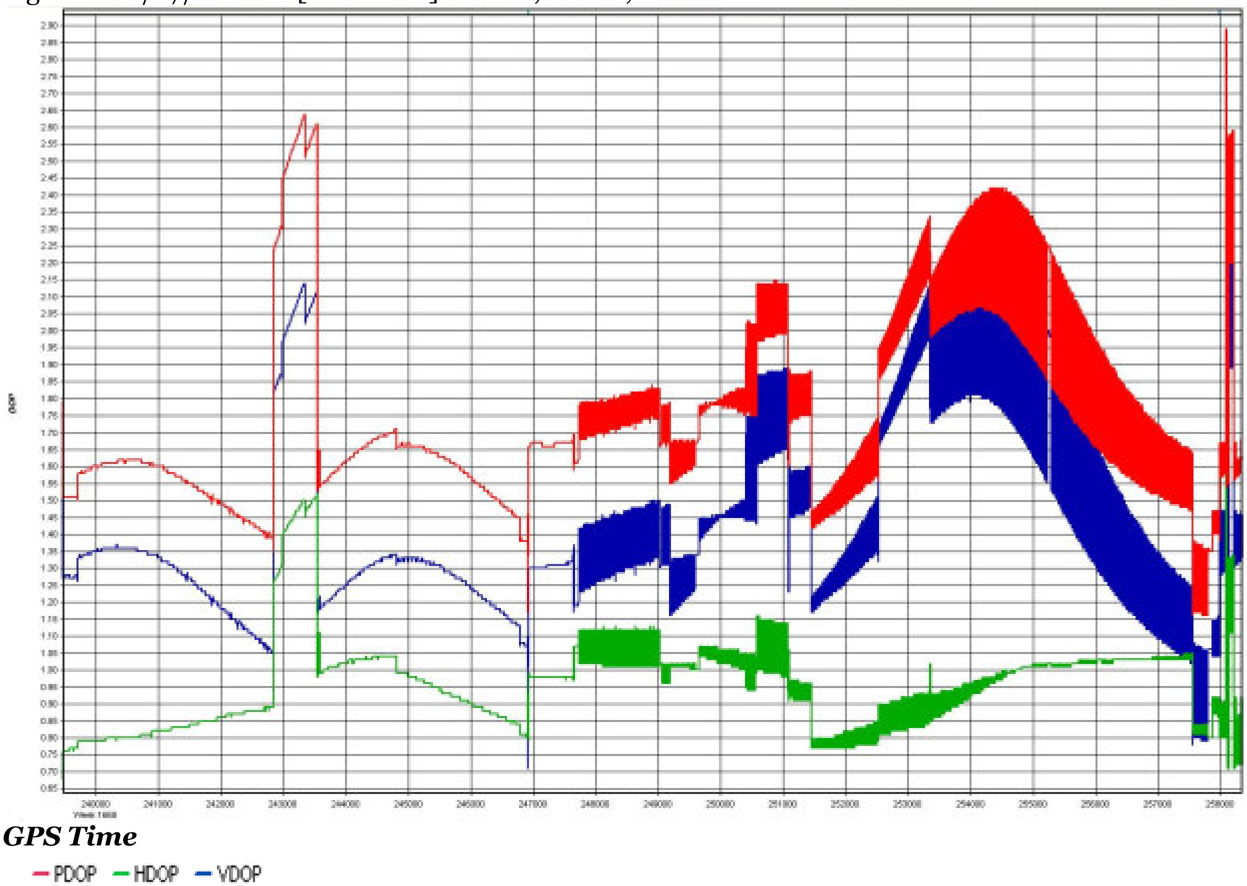
East North Up

Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

Figure 5: 12/27/2011PM [Combined] - Forward/Reverse or Combined Weighting Plot

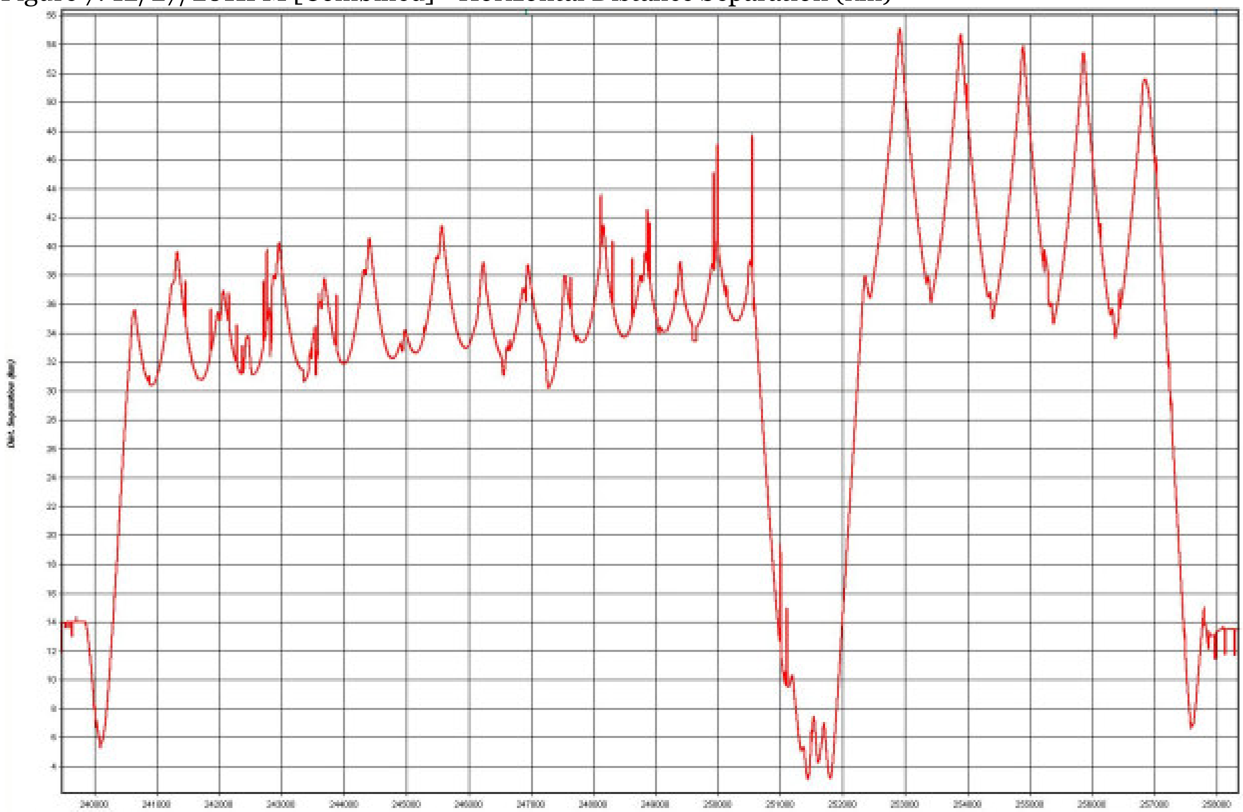
Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

Figure 6: 12/27/2011PM [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

Figure 7: 12/27/2011PM [Combined] - Horizontal Distance Separation (km)



GPS Time

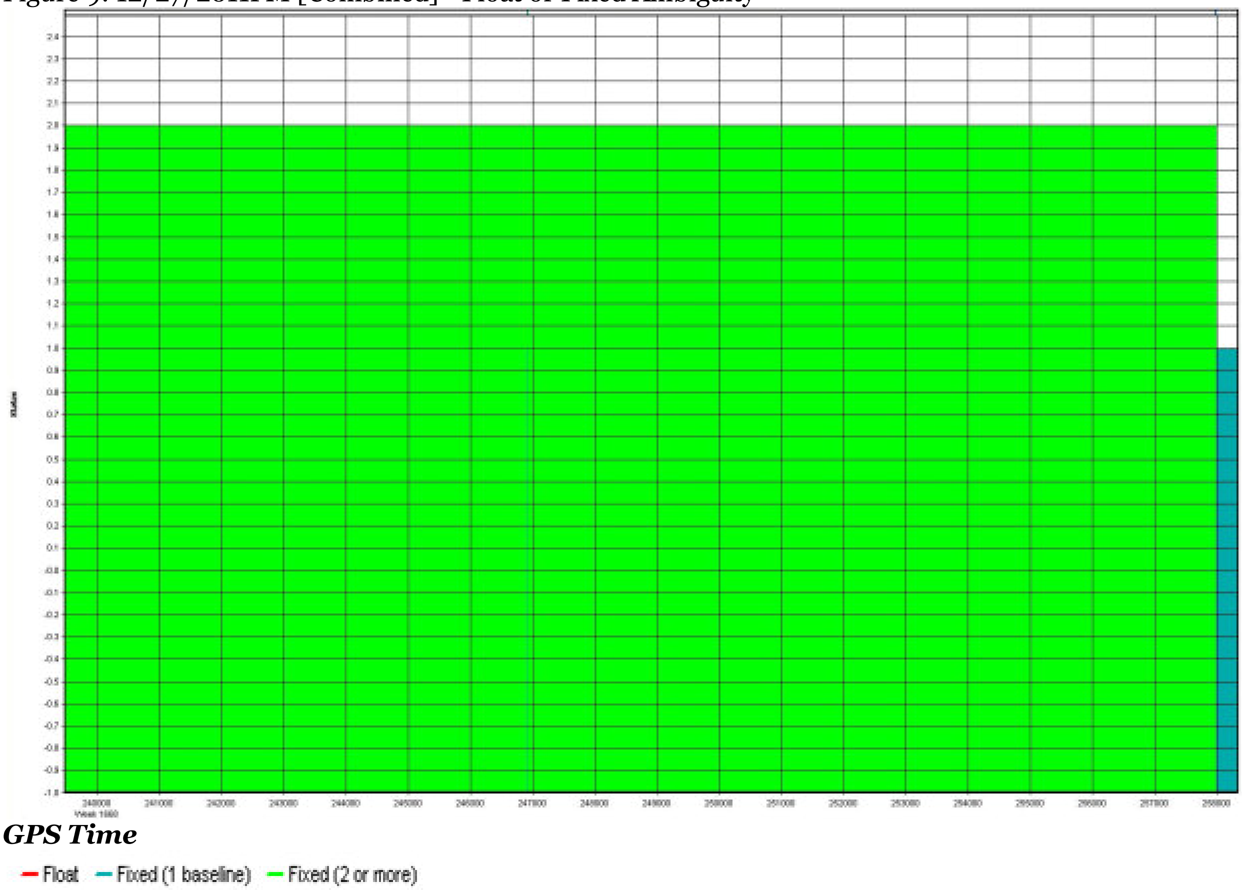
— Distance

Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

Figure 8: 12/27/2011PM [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

Figure 9: 12/27/2011PM [Combined] - Float or Fixed Ambiguity



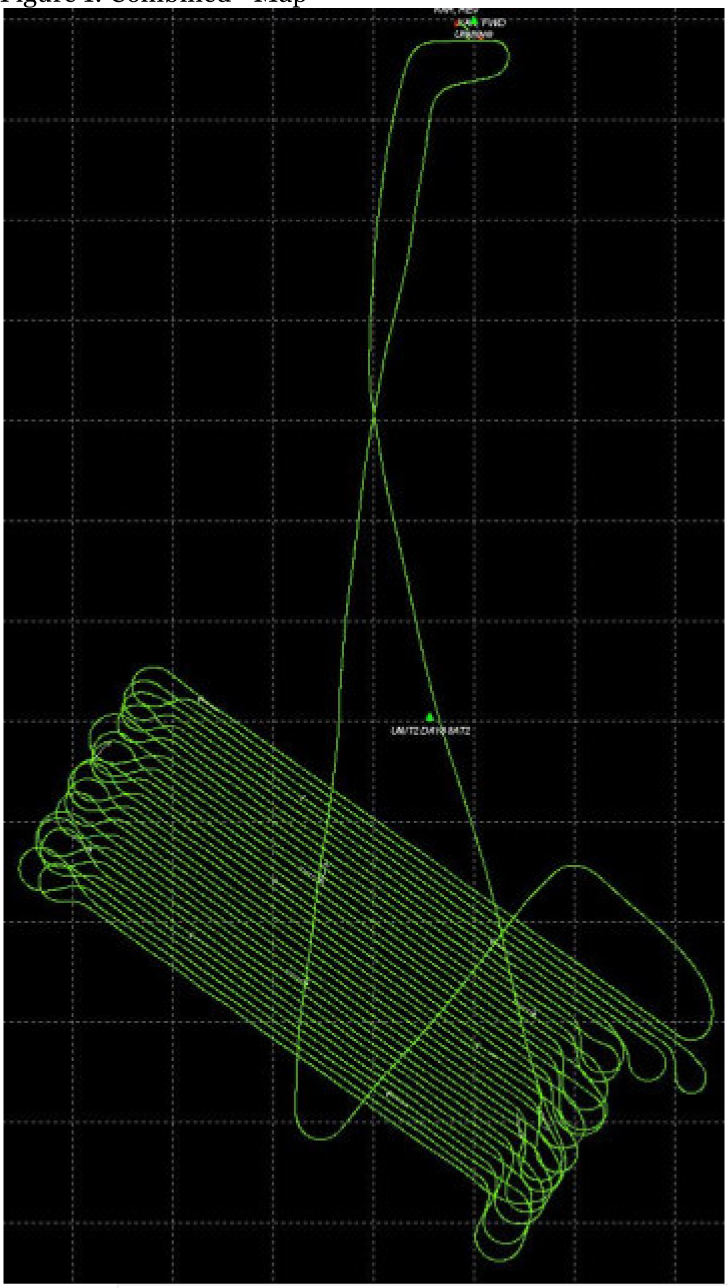
GPS Time

Process	Run (29)	by Unknown	on 12/27/2011	at 10:30

2.13 Output Results for 12/28/2011

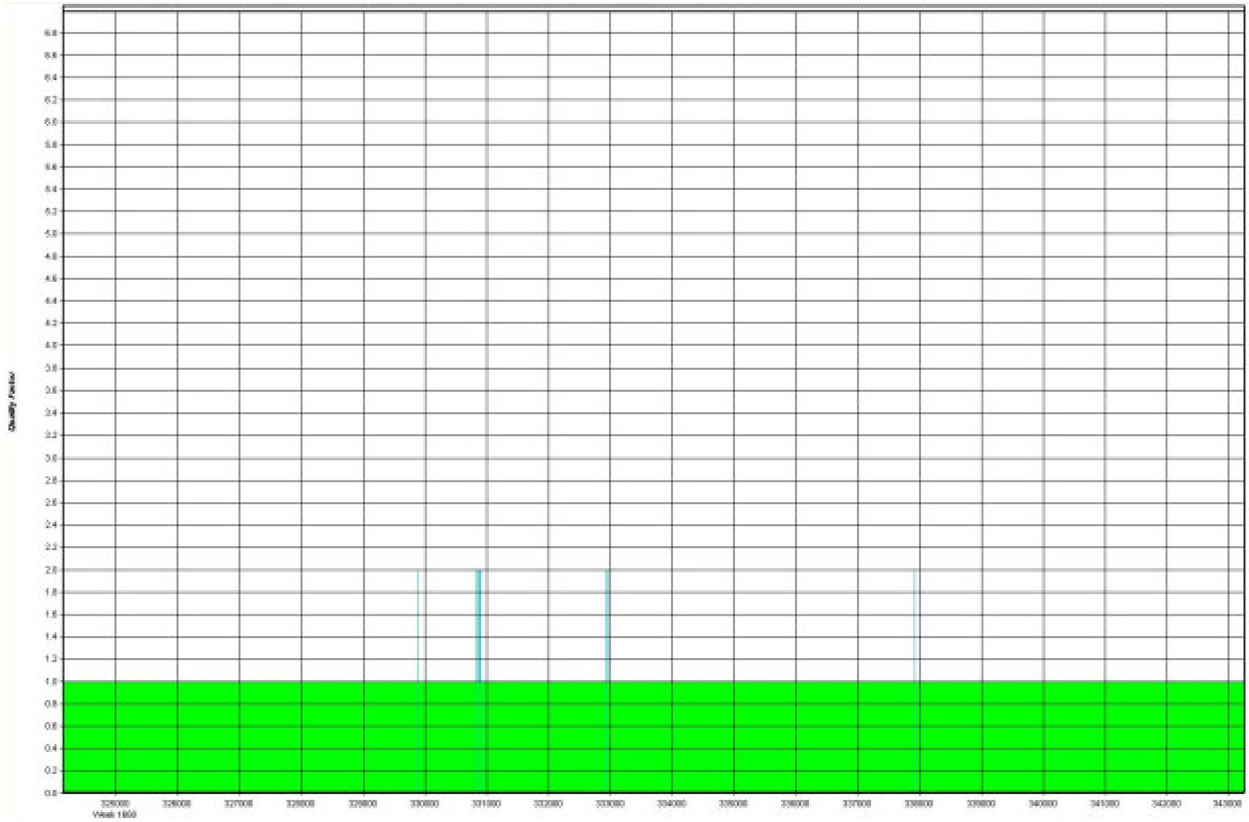
POSPAC Version 4.31

Figure 1: Combined - Map



Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

Figure 2: 12/28/2011 [Combined] - Quality Factor Plot

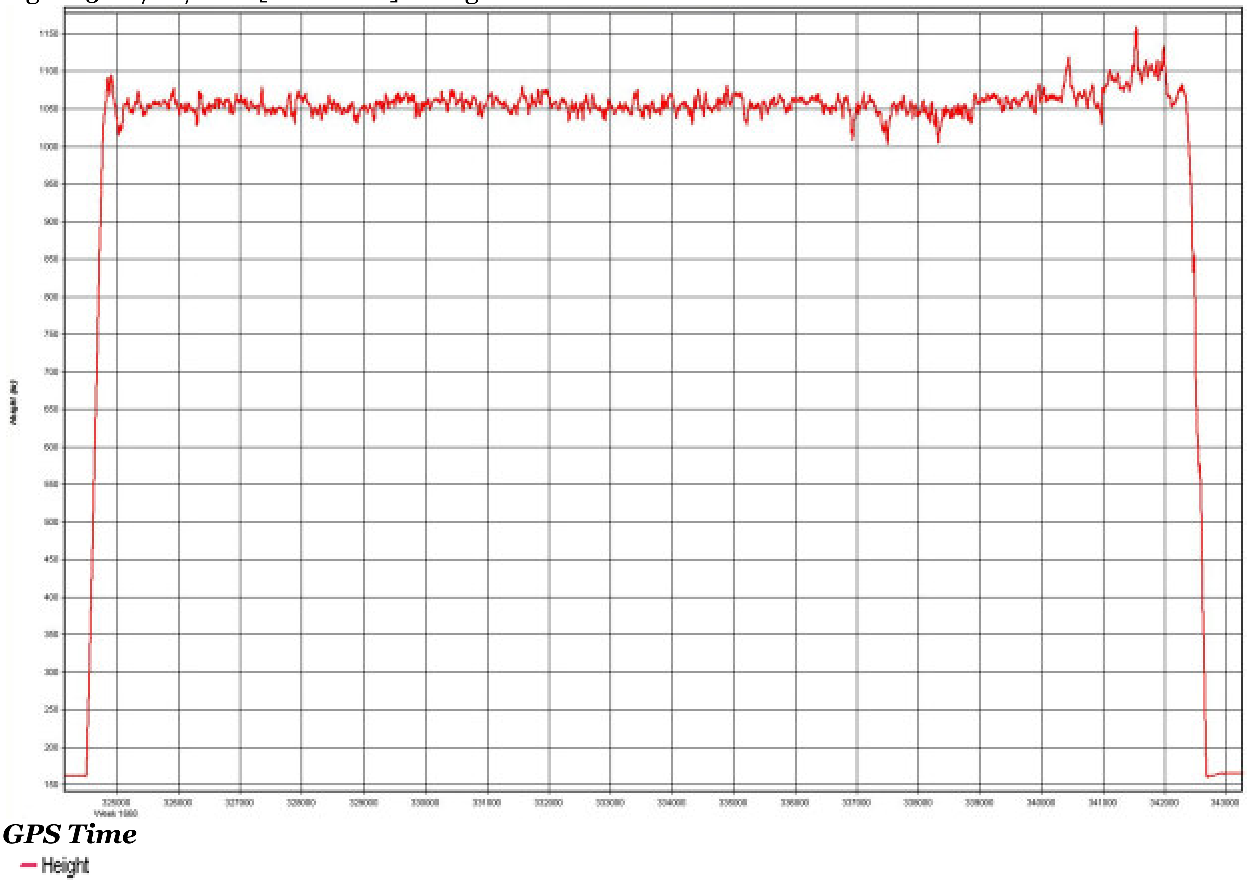


GPS Time

— Fixed Integer — Stable float — Converging float — DGPS or worse — Single Point — No solution

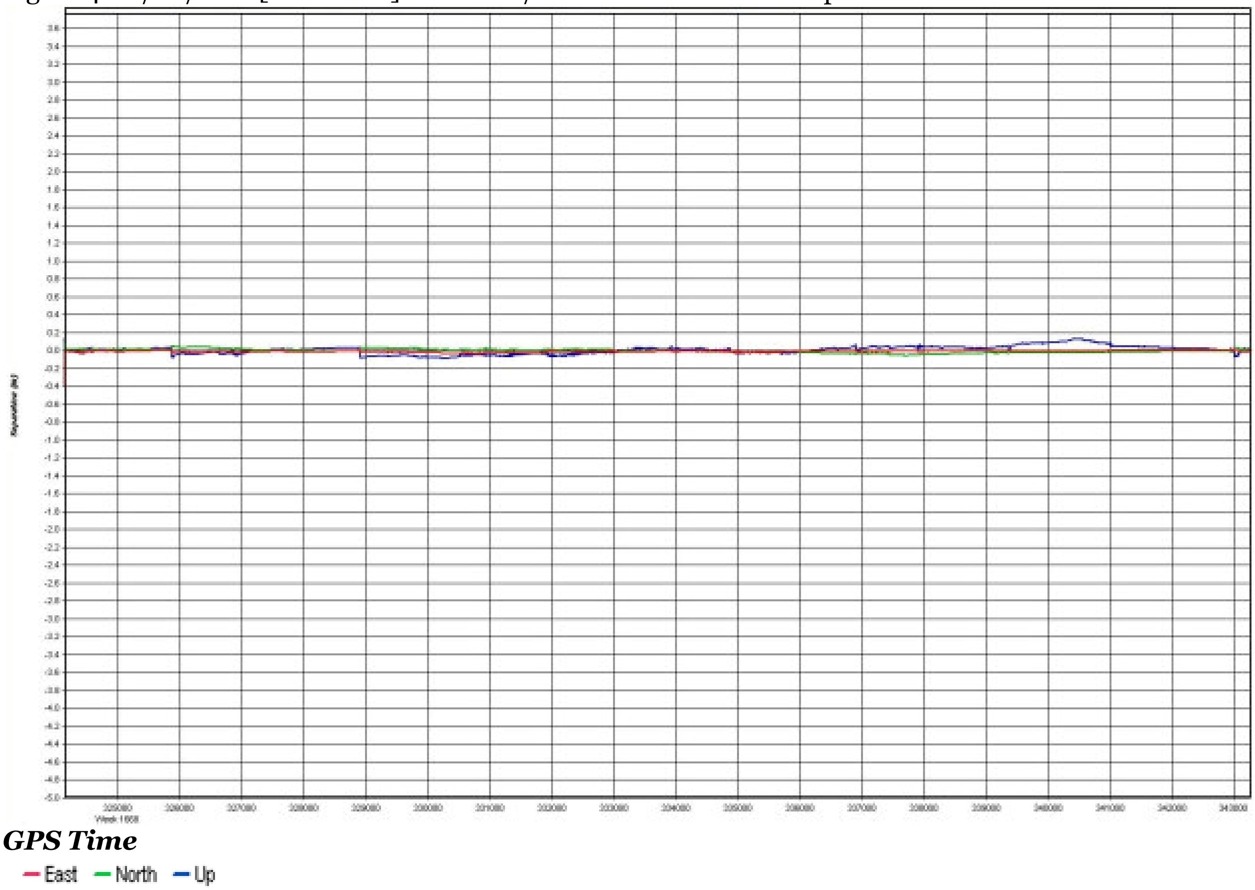
Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

Figure 3: 12/28/2011 [Combined] - Height Profile Plot



Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

Figure 4: 12/28/2011 [Combined] - Forward/Reverse or Combined Separation Plot

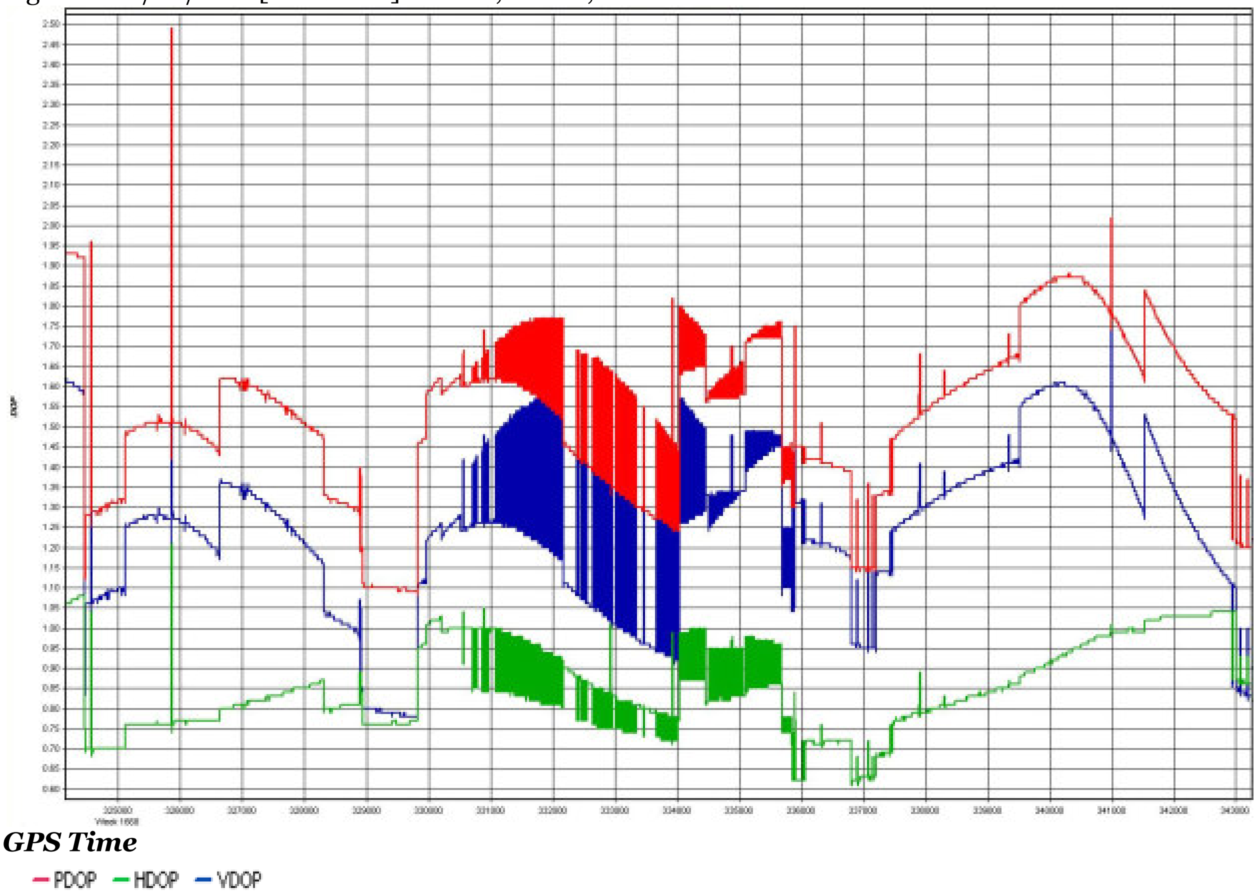


Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

Figure 5: 12/28/2011 [Combined] - Forward/Reverse or Combined Weighting Plot

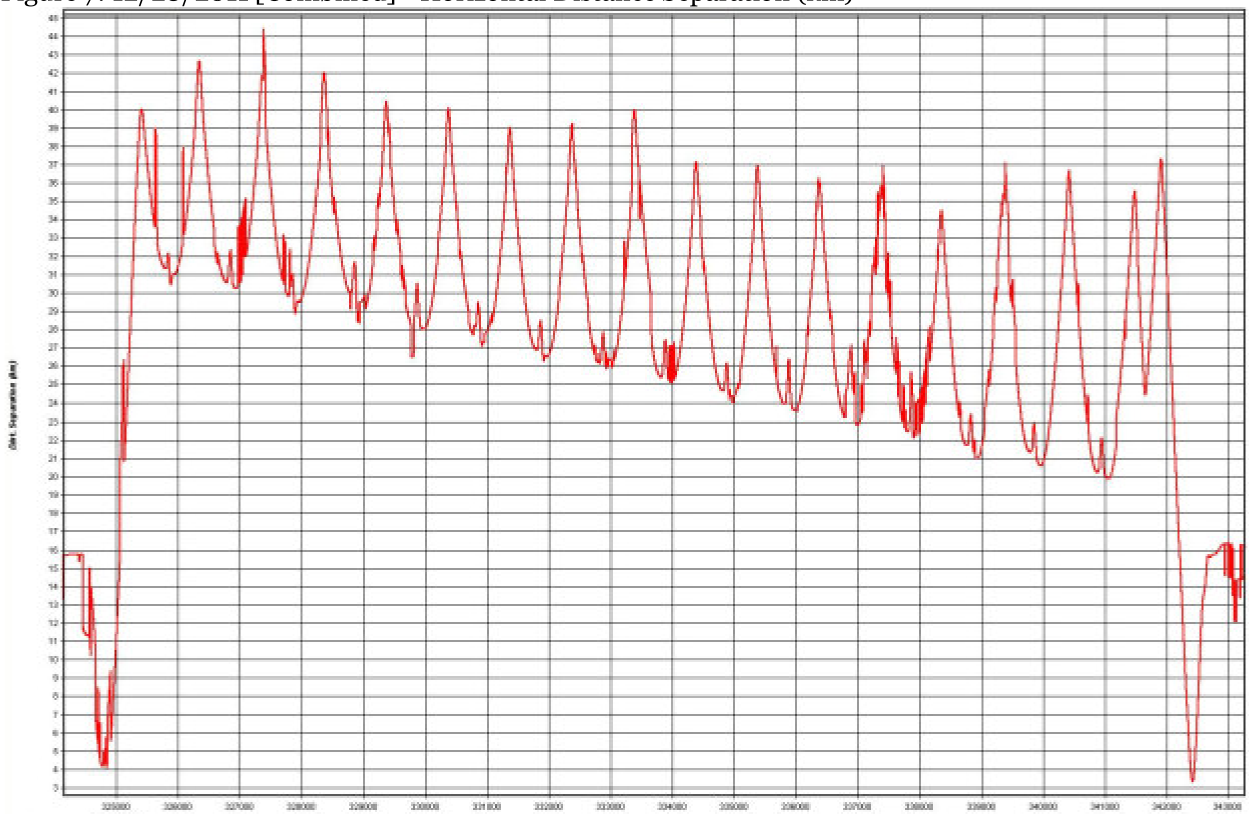
Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

Figure 6: 12/28/2011 [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

Figure 7: 12/28/2011 [Combined] - Horizontal Distance Separation (km)



GPS Time

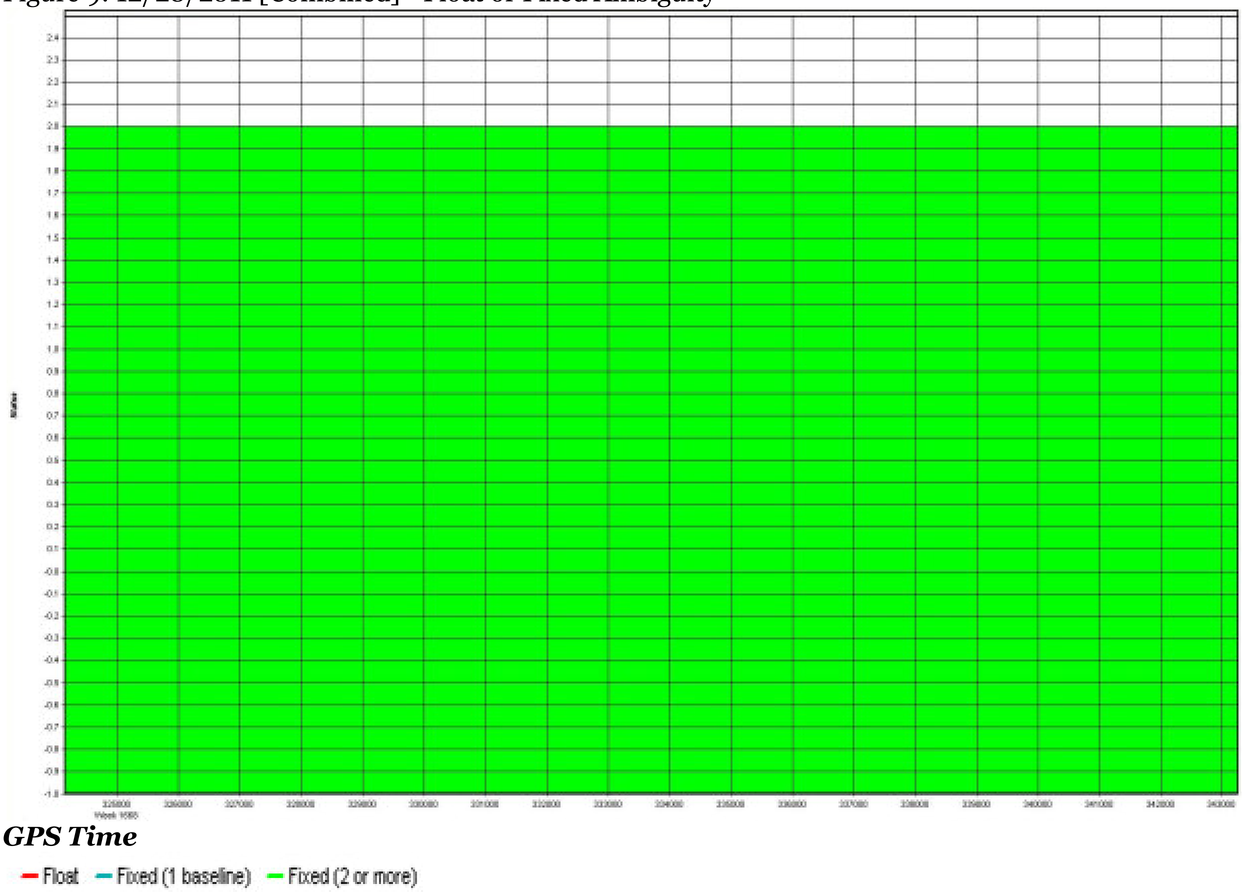
Distance

Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

Figure 8: 12/28/2011 [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

Figure 9: 12/28/2011 [Combined] - Float or Fixed Ambiguity



Process	Run (33)	by Unknown	on 12/28/2011	at 10:00

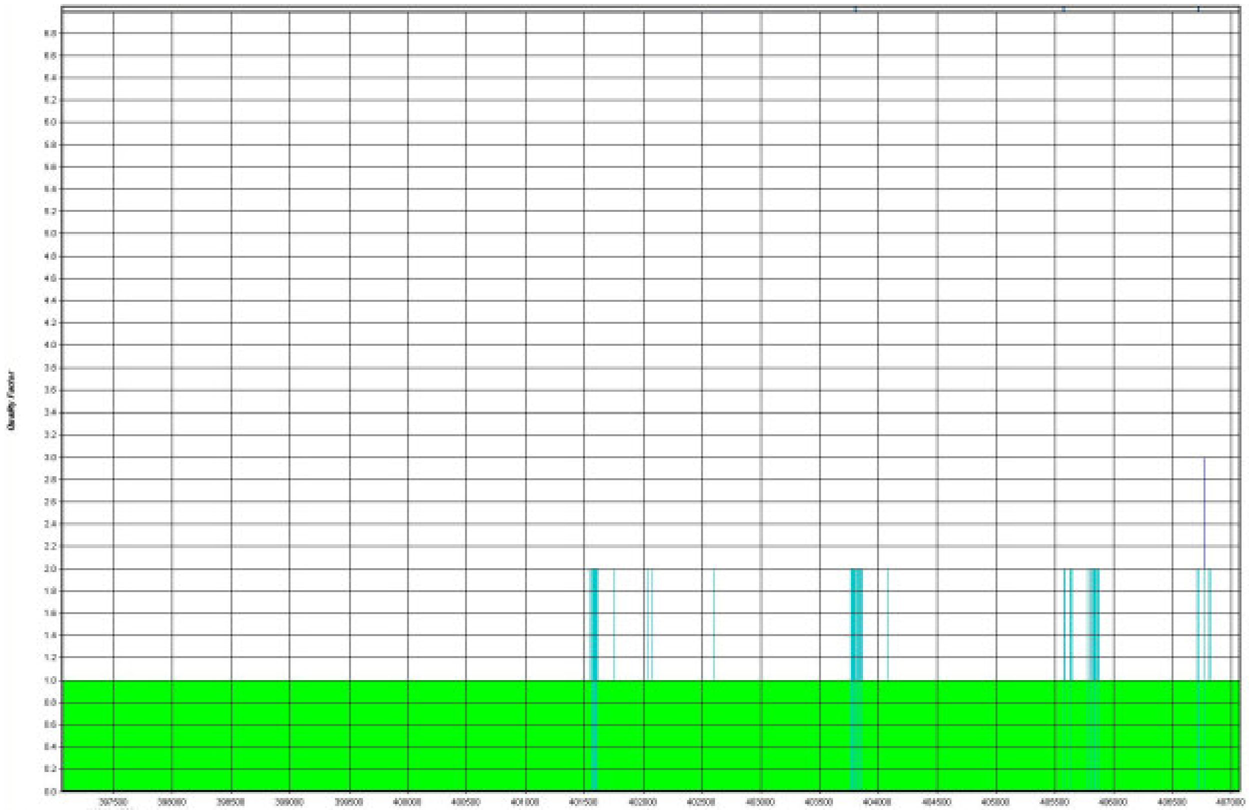
2.14 Output Results for 12/29/2011AM

POSPAC Version 4.31

Figure 1: Combined - Map

Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

Figure 2: 12/29/2011AM [Combined] - Quality Factor Plot

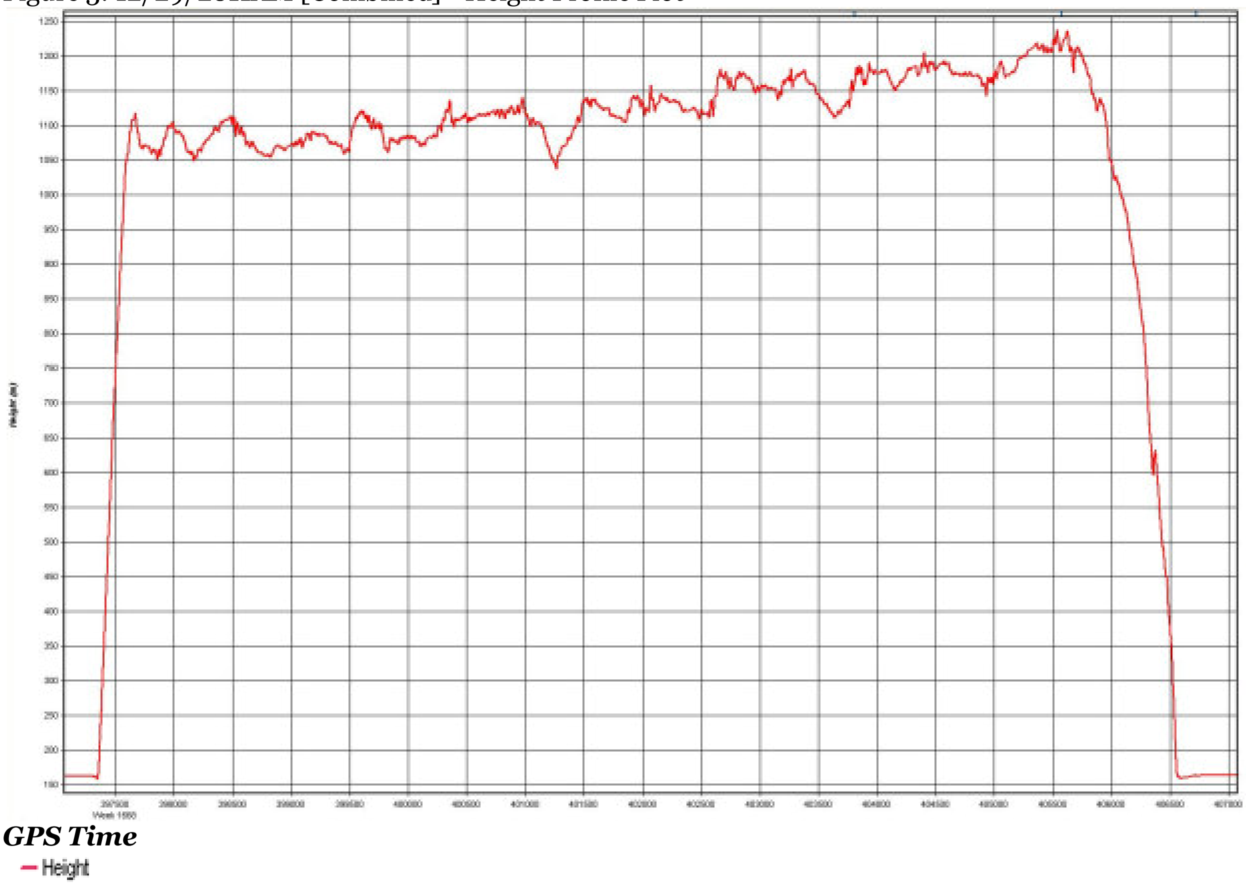


GPS Time

— Fixed Integer — Stable float — Converging float — DGPS or worse — Single Point — No solution

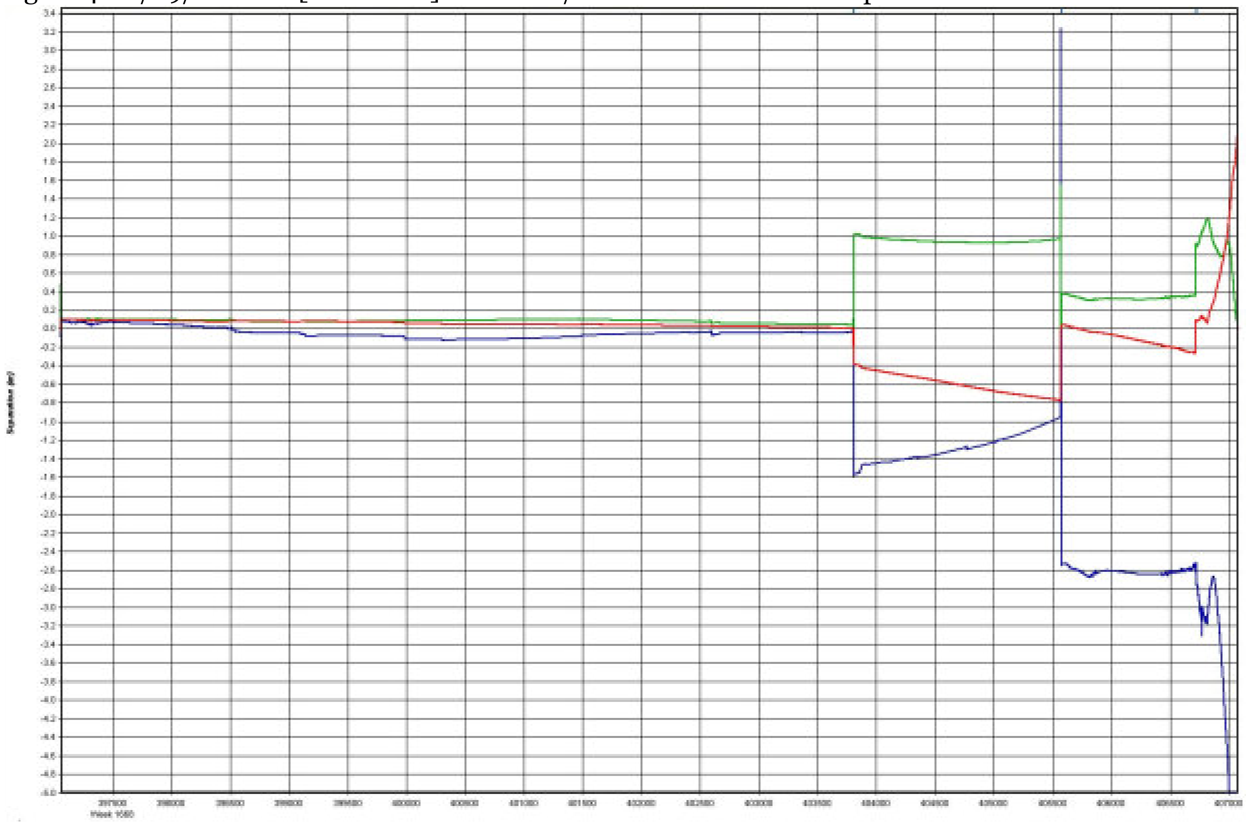
Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

Figure 3: 12/29/2011AM [Combined] - Height Profile Plot



Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

Figure 4: 12/29/2011AM [Combined] - Forward/Reverse or Combined Separation Plot

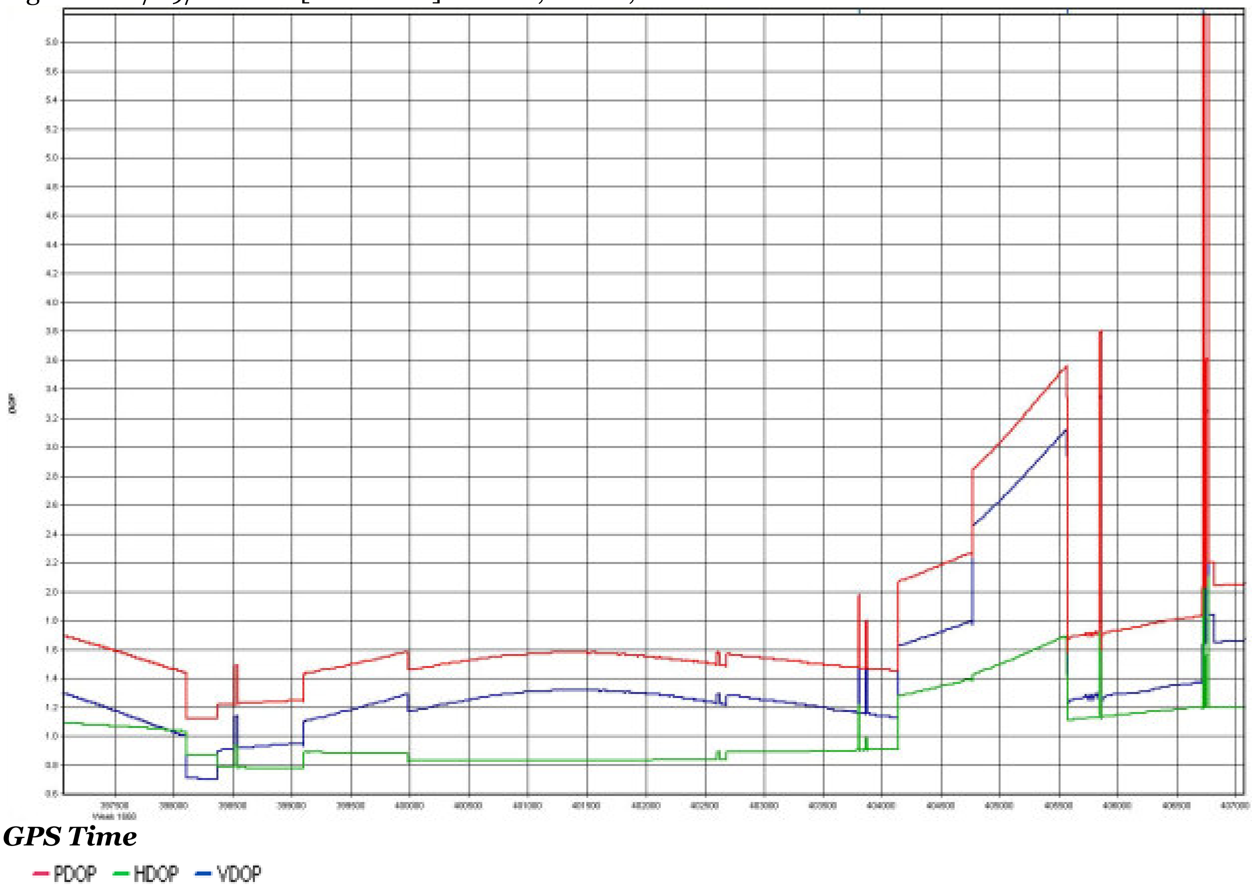


Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

Figure 5: 12/29/2011AM [Combined] - Forward/Reverse or Combined Weighting Plot

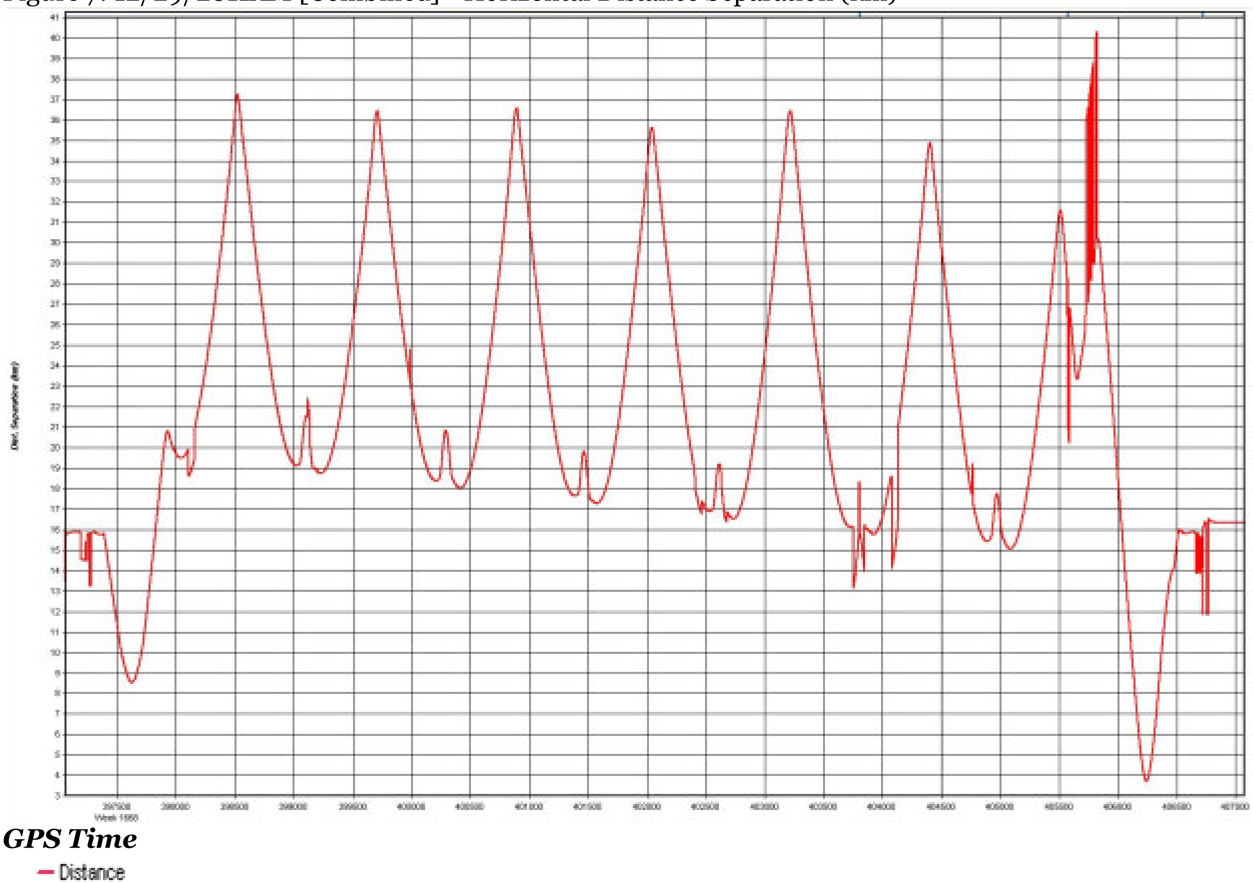
Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

Figure 6: 12/29/2011AM [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

Figure 7: 12/29/2011AM [Combined] - Horizontal Distance Separation (km)

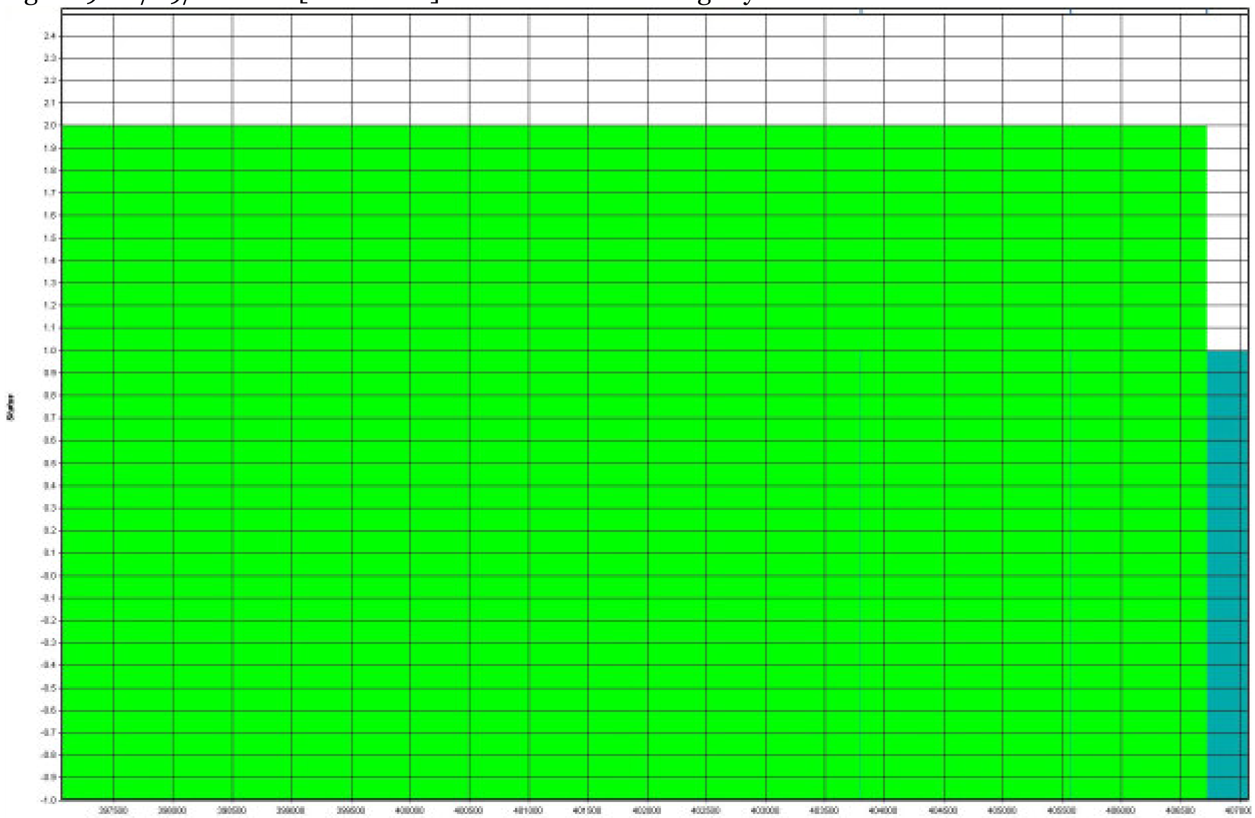


Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

Figure 8: 12/29/2011AM [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

Figure 9: 12/29/2011AM [Combined] - Float or Fixed Ambiguity

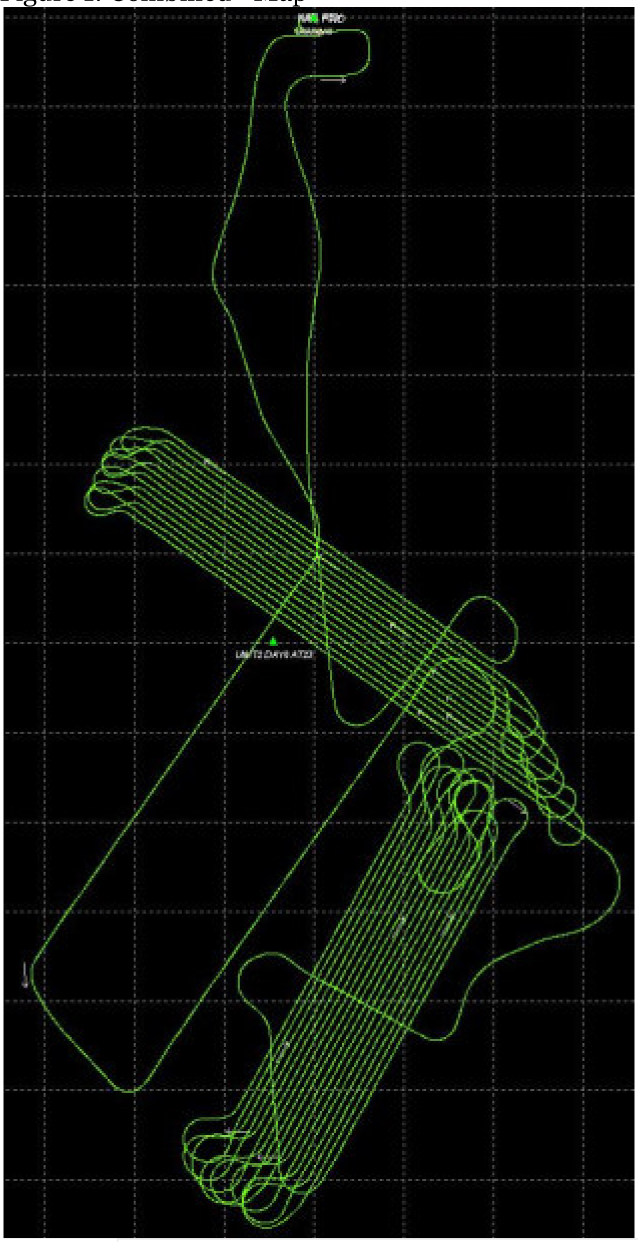


Process	Run (14)	by Unknown	on 12/29/2011	at 06:20

2.15 Output Results for 12/29/2011PM

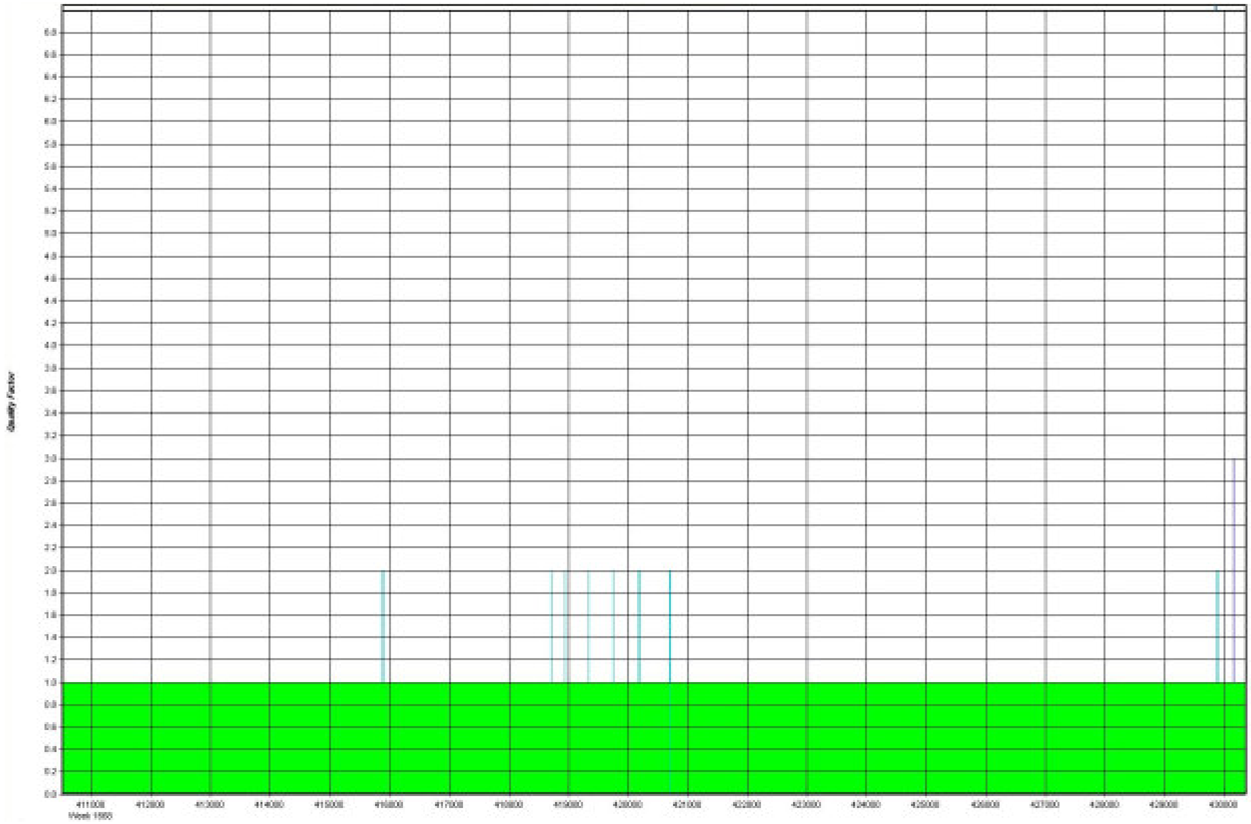
POSPAC Version 4.31

Figure 1: Combined - Map



Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

Figure 2: 12/29/2011PM [Combined] - Quality Factor Plot



GPS Time

— Fixed Integer — Stable float — Converging float — DGPS or worse — Single Point — No solution

Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

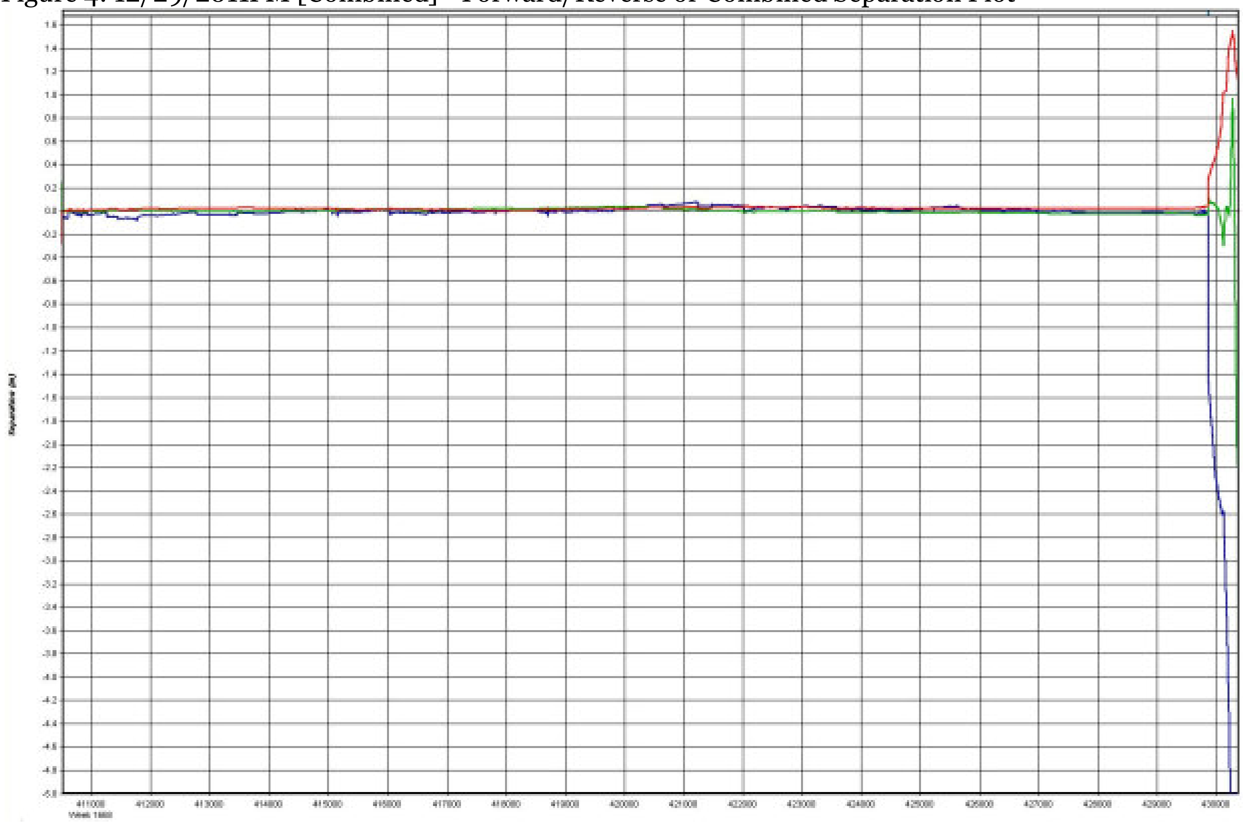
Figure 3: 12/29/2011PM [Combined] - Height Profile Plot

GPS Time

— Height

Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

Figure 4: 12/29/2011PM [Combined] - Forward/Reverse or Combined Separation Plot

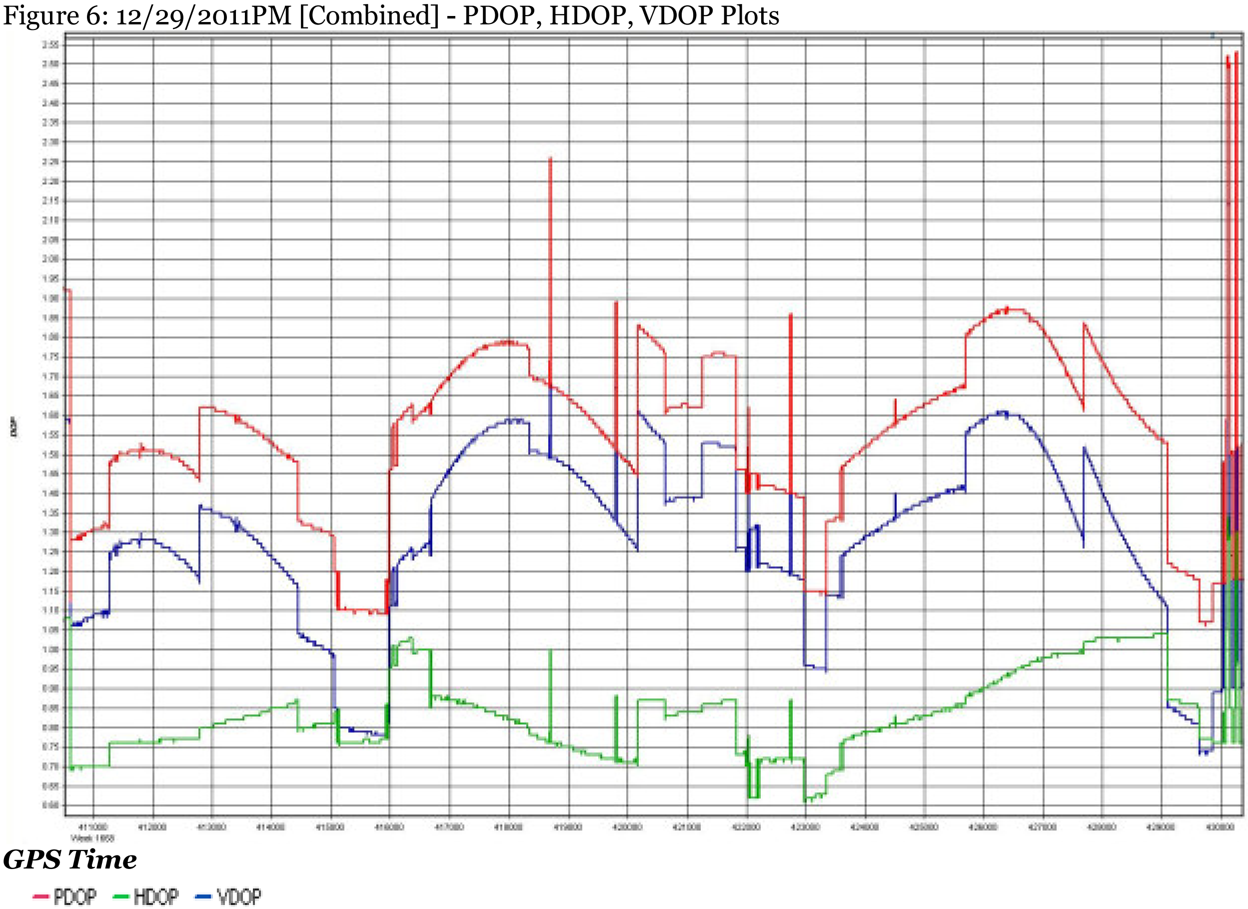


Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

Figure 5: 12/29/2011PM [Combined] - Forward/Reverse or Combined Weighting Plot

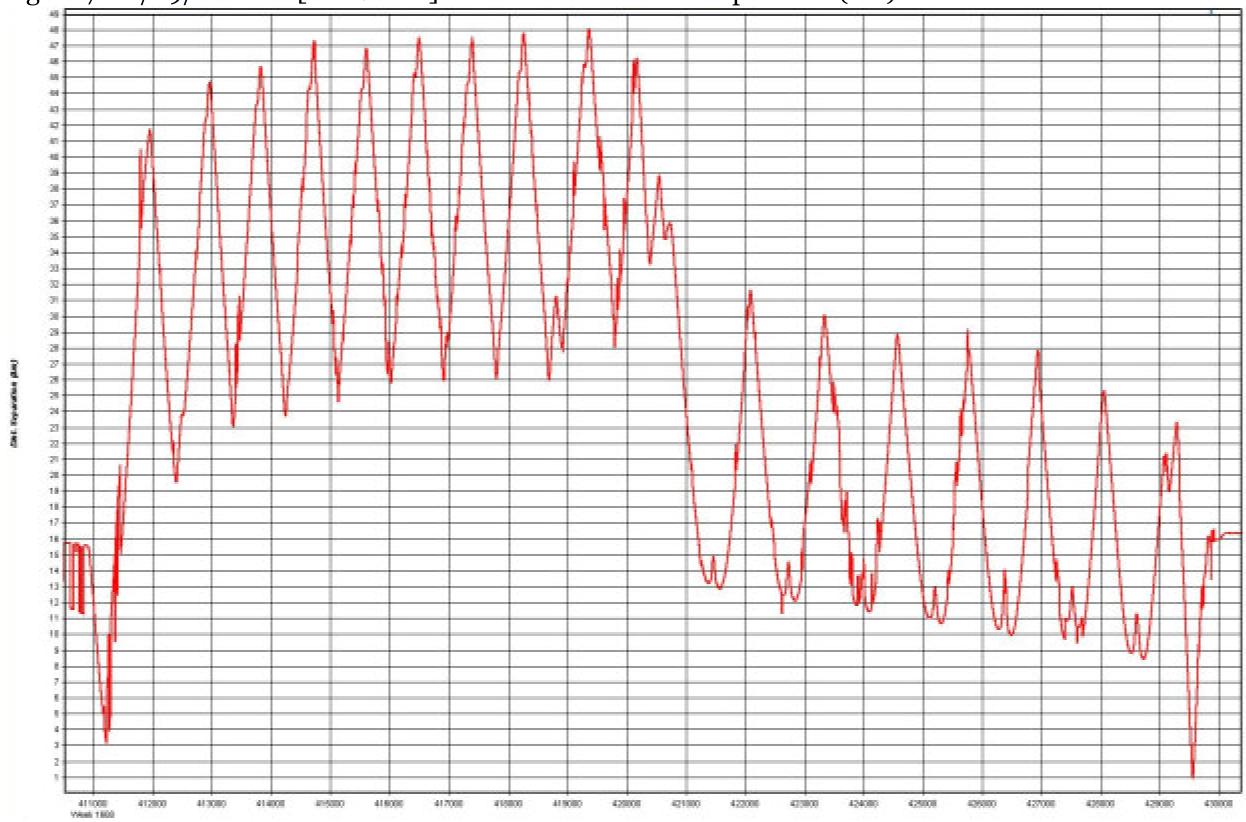
Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

Figure 6: 12/29/2011PM [Combined] - PDOP, HDOP, VDOP Plots



Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

Figure 7: 12/29/2011PM [Combined] - Horizontal Distance Separation (km)

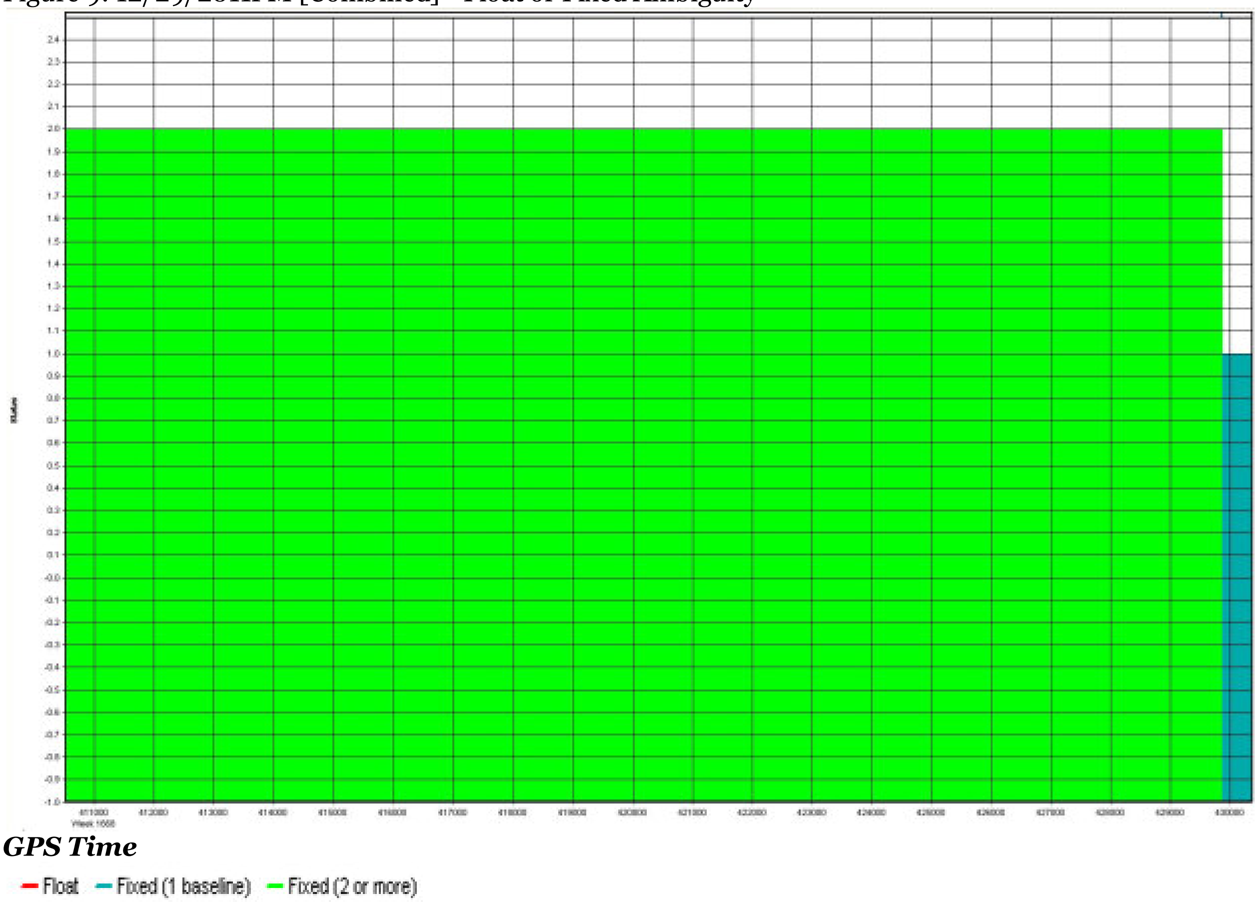


Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

Figure 8: 12/29/2011PM [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

Figure 9: 12/29/2011PM [Combined] - Float or Fixed Ambiguity

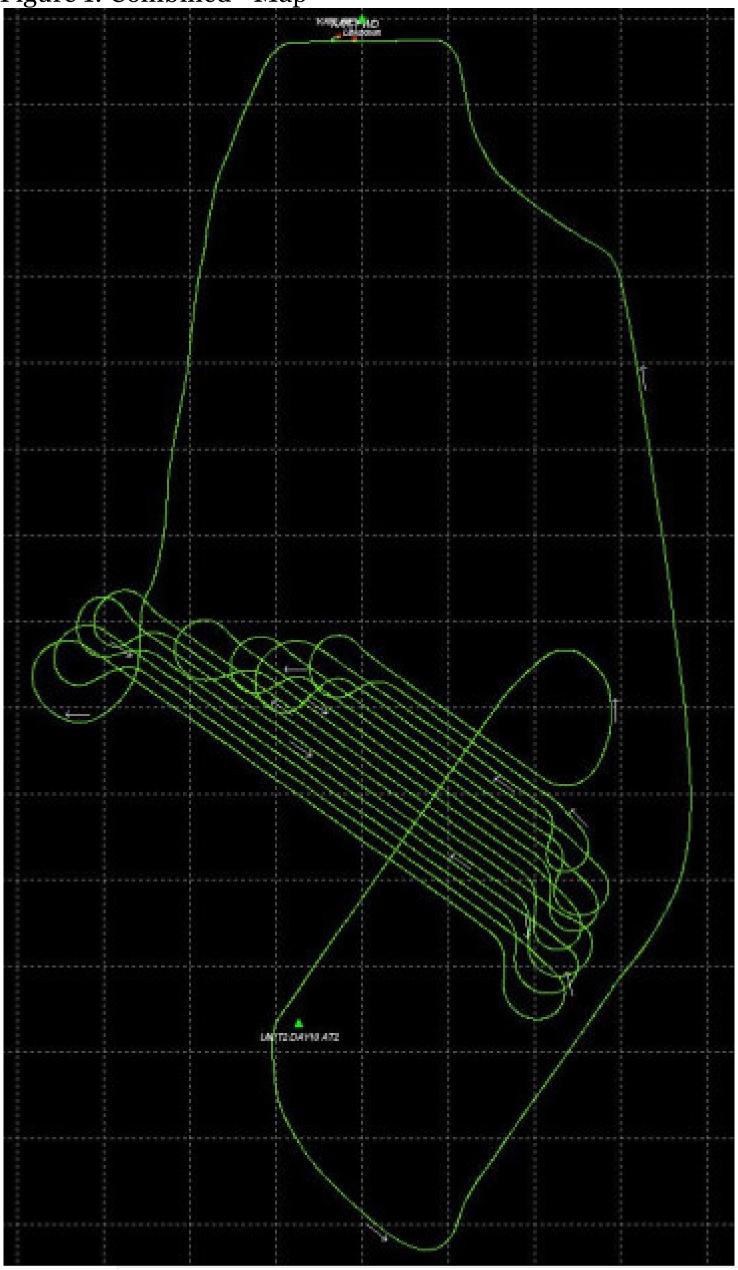


Process	Run (33)	by Unknown	on 12/29/2011	at 10:00

2.16 Output Results for 12/30/2011

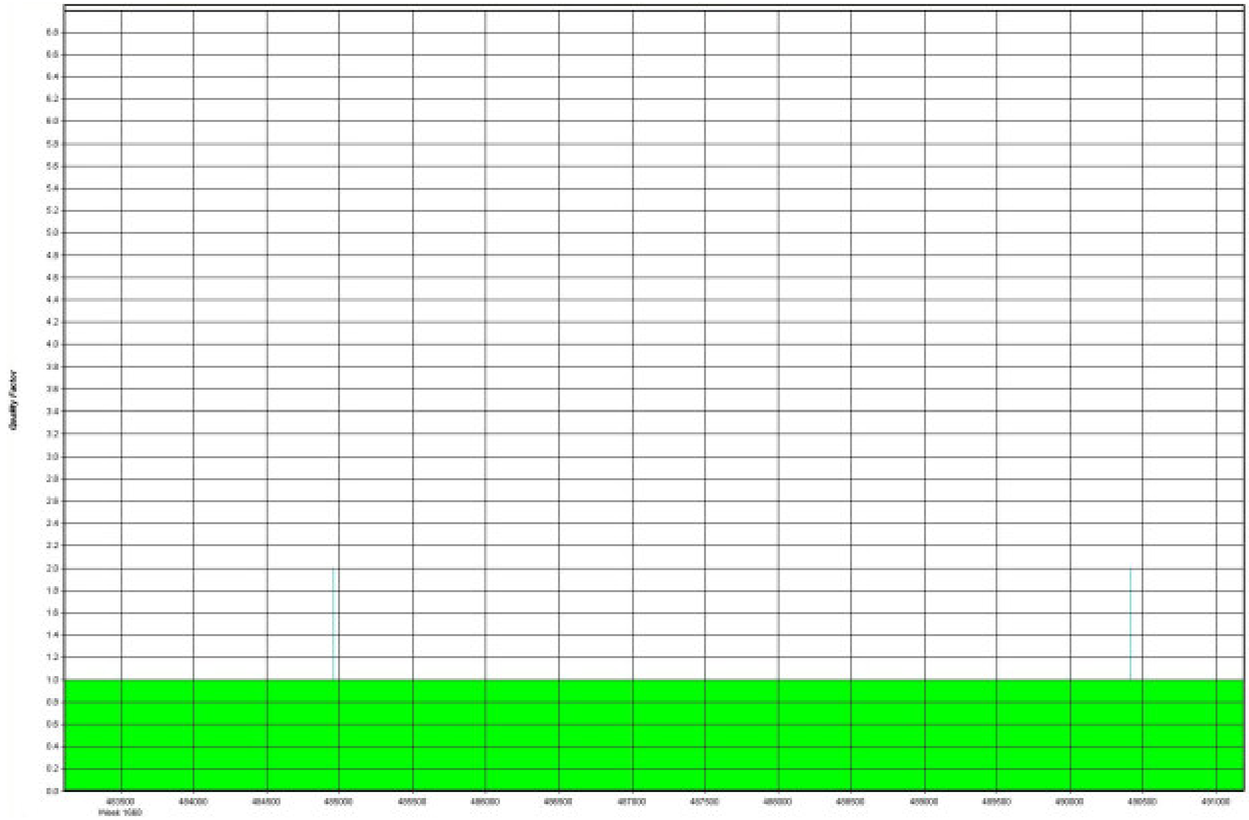
POSPAC Version 4.31

Figure 1: Combined - Map



Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

Figure 2: 12/30/2011 [Combined] - Quality Factor Plot

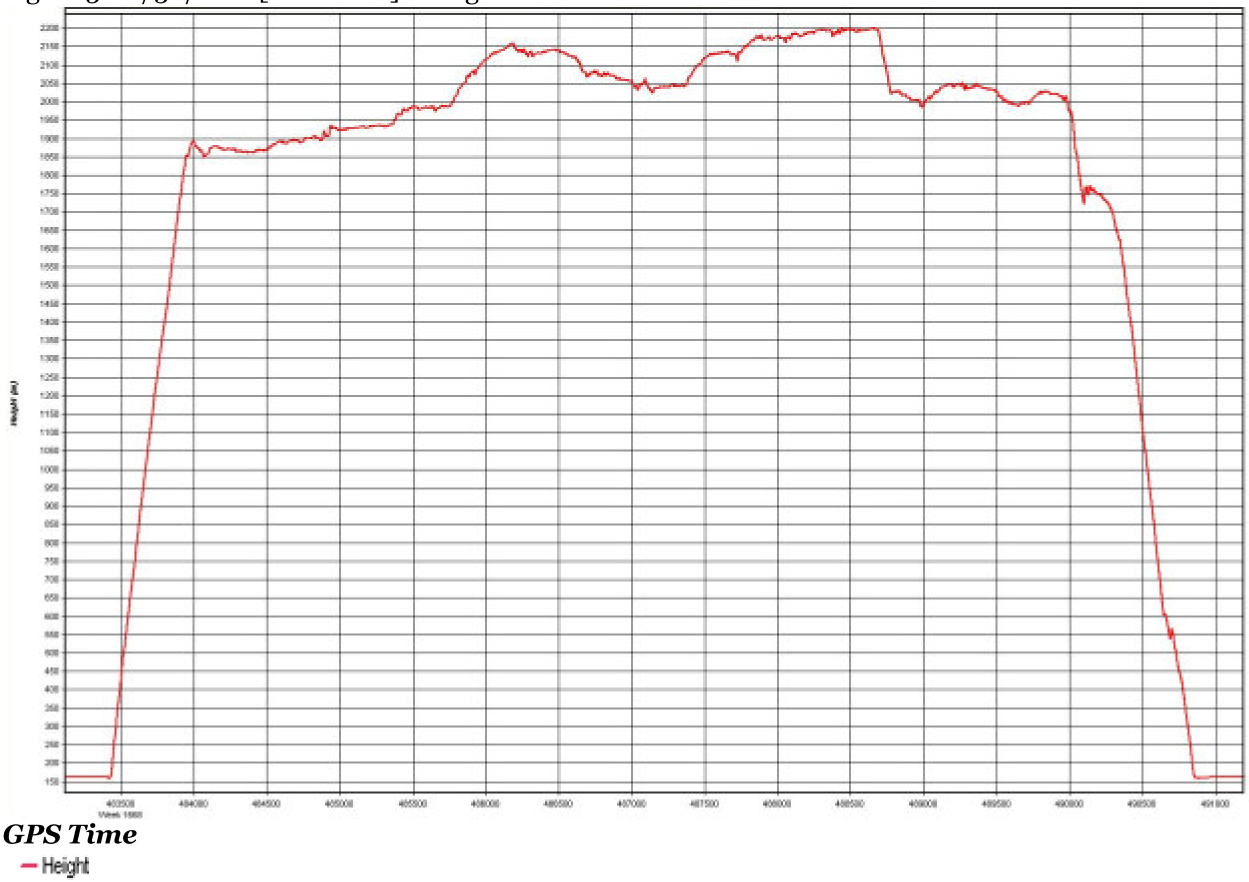


GPS Time

— Fixed Integer — Stable float — Converging float — DGPS or worse — Single Point — No solution

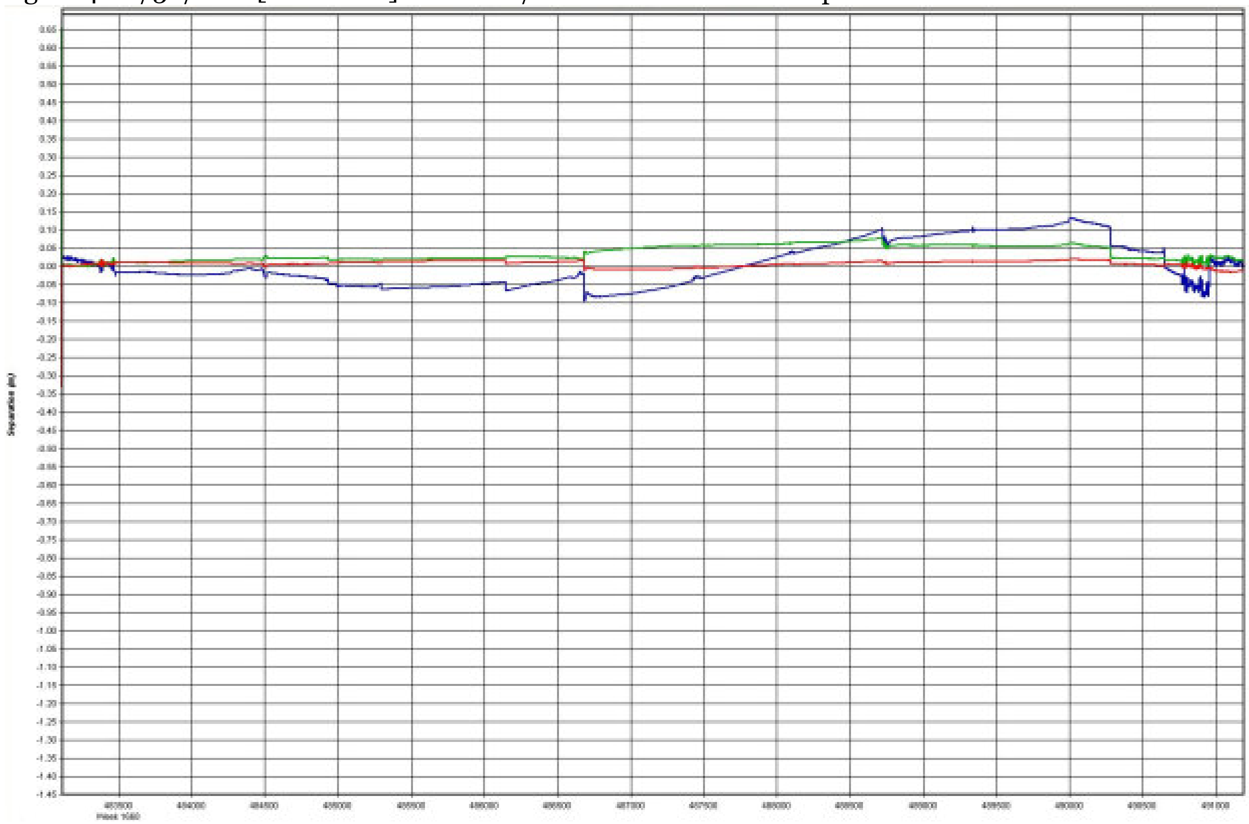
Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

Figure 3: 12/30/2011 [Combined] - Height Profile Plot



Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

Figure 4: 12/30/2011 [Combined] - Forward/Reverse or Combined Separation Plot



GPS Time

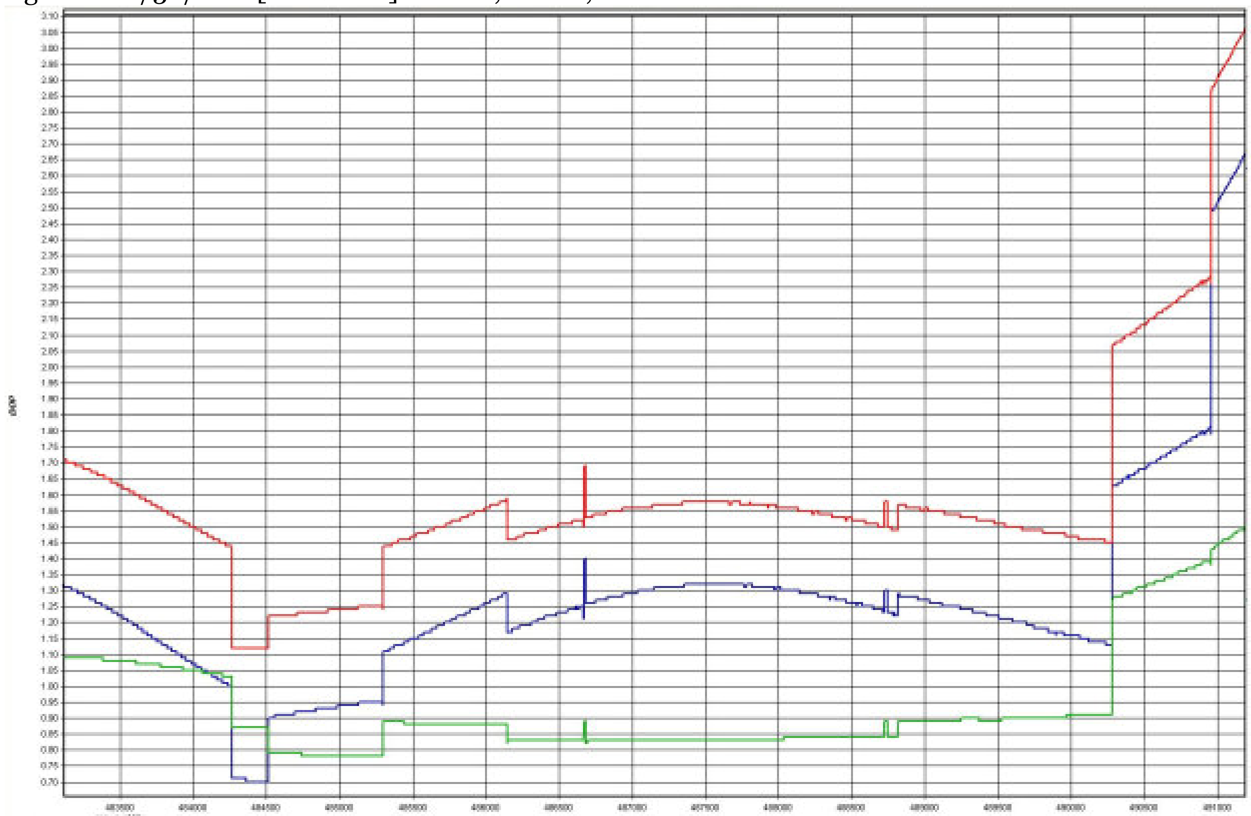
East North Up

Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

Figure 5: 12/30/2011 [Combined] - Forward/Reverse or Combined Weighting Plot

Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

Figure 6: 12/30/2011 [Combined] - PDOP, HDOP, VDOP Plots

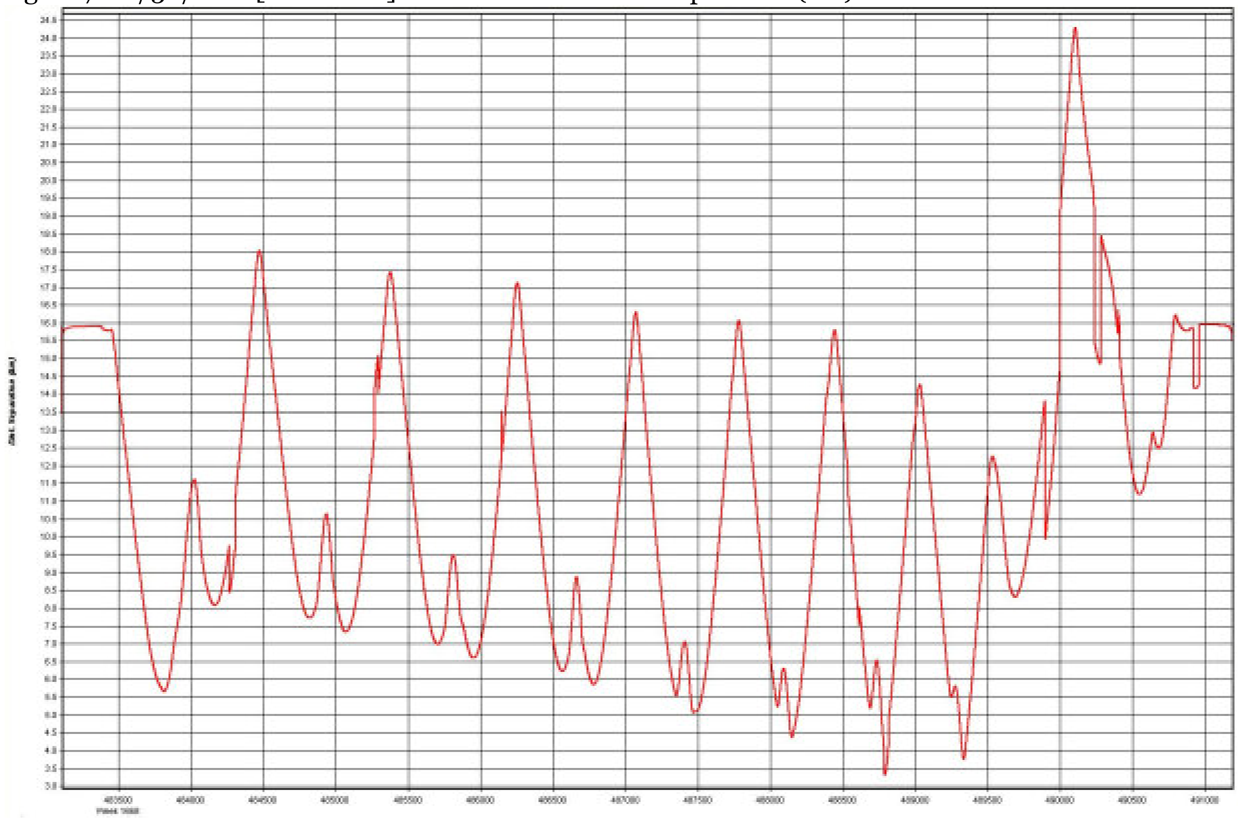


GPS Time

— PDOP — HDOP — VDOP

Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

Figure 7: 12/30/2011 [Combined] - Horizontal Distance Separation (km)

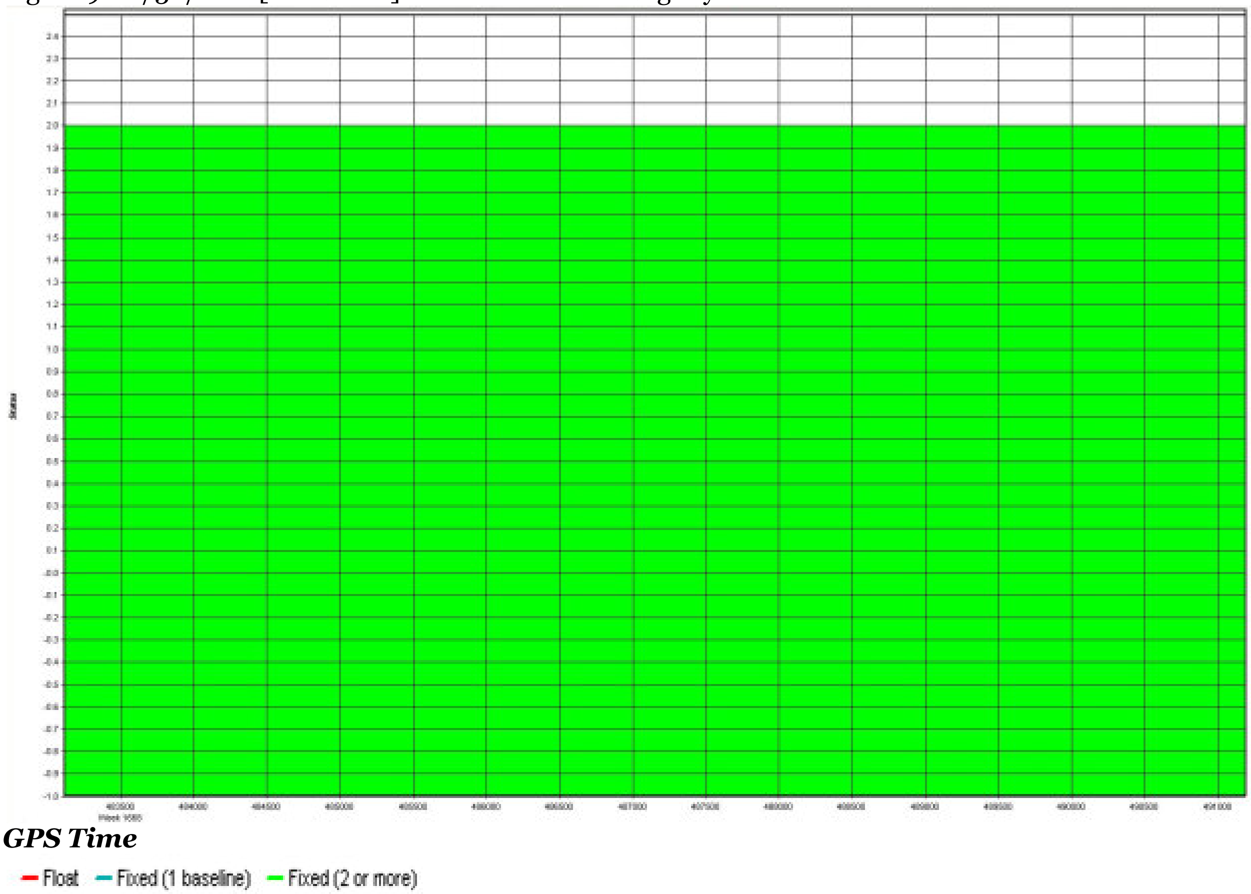


Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

Figure 8: 12/30/2011 [Combined] - Forward/Reverse or Combined RMS Plot

Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

Figure 9: 12/30/2011 [Combined] - Float or Fixed Ambiguity



Process	Run (17)	by Unknown	on 12/30/2011	at 06:15

LiDAR Quality Assessment Report

The USGS National Geospatial Technical Operations Center, Data Operations Branch is responsible for conducting reviews of all Light Detection and Ranging (LiDAR) point-cloud data and derived products delivered by a data supplier before it is approved for inclusion in the National Elevation Dataset and the Center for LiDAR Information Coordination and Knowledge. The USGS recognizes the complexity of LiDAR collection and processing performed by the data suppliers and has developed this Quality Assessment (QA) procedure to accommodate USGS collection and processing specifications with flexibility. The goal of this process is to assure LiDAR data are of sufficient quality for database population and scientific analysis. Concerns regarding the assessment of these data should be directed to the Chief, Data Operations Branch, 1400 Independence Road, Rolla, Missouri 65401 or NGTOCoperations@usgs.gov.

Materials Received: 8/7/2012

Project ID: CA_OrangeCo_2011

Project Alias(es): Orange County, CA

Project Type: GPSC

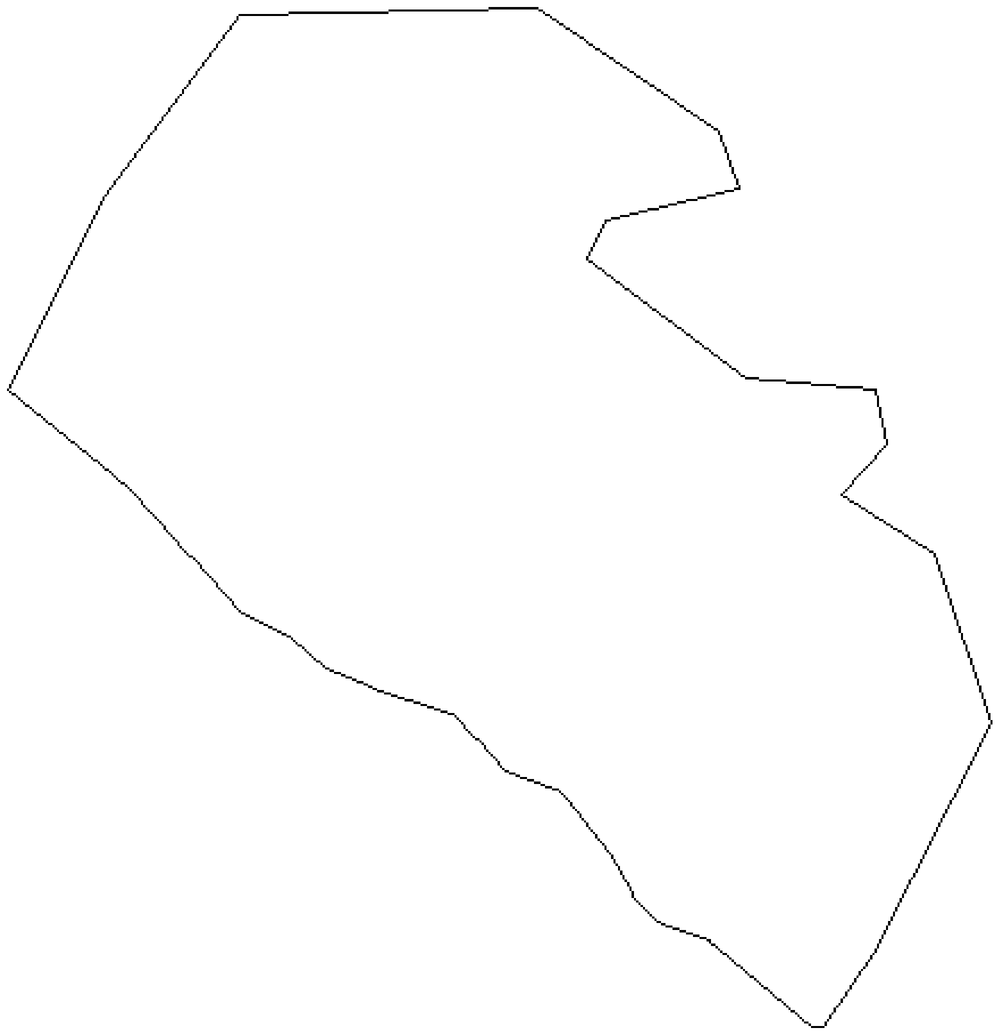
Project Description: The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (LiDAR) technology for the USGS FEMA IX Orange County, California Project Area.

Year of Collection: 2011

Lot 1 of 1 lots.

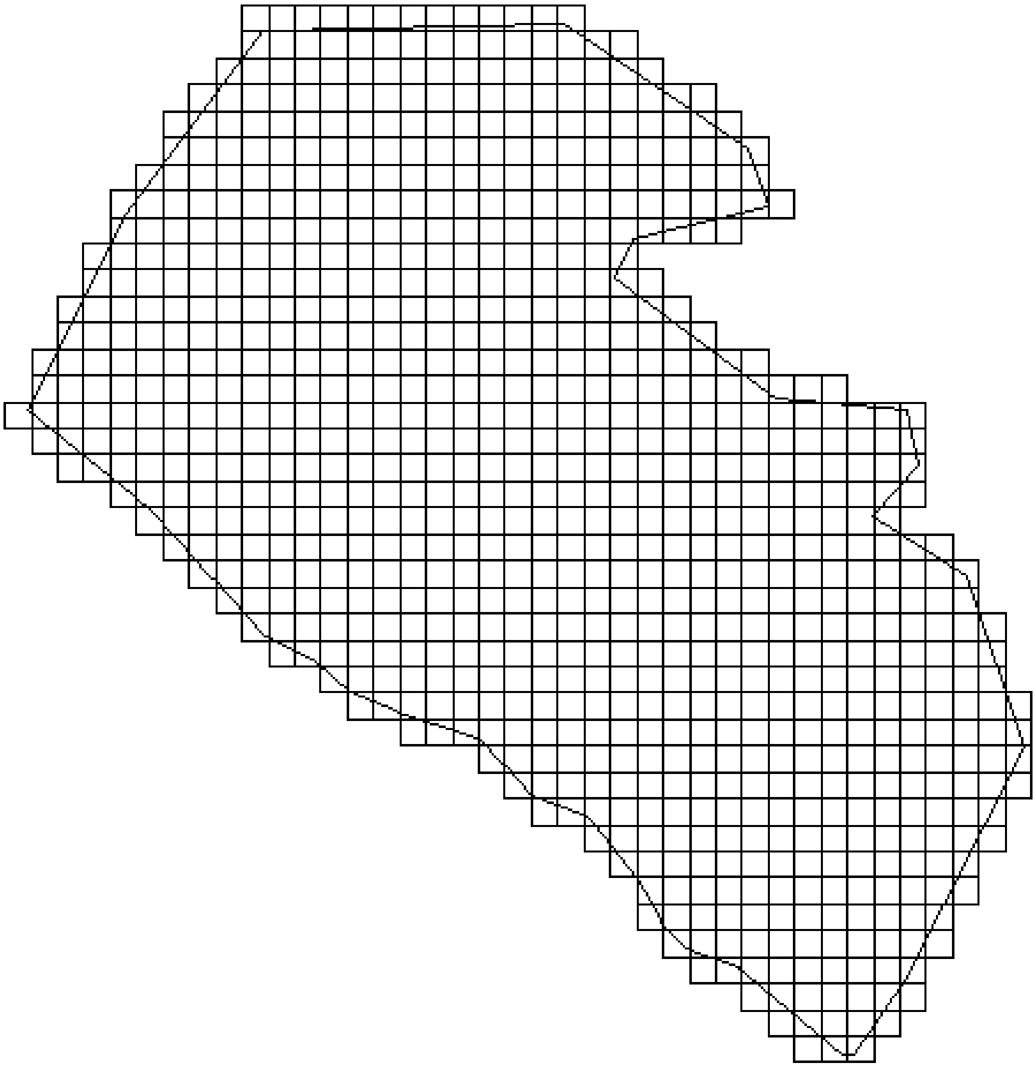
Project Extent:

☑ Project Extent image?



Project Tiling Scheme:

☑ Project Tiling Scheme image?



Contractor:

Dewberry

Applicable Specification:

V13

Licensing Restrictions:

None

☐ Third Party Performed QA?

Project Points of Contact:

POC Name	Type	Primary Phone	E-Mail
Gail Dunn	CPT	573-308-3756	gdunn@usgs.gov

Project Deliverables

All project deliverables must be supplied according to collection and processing specifications. The USGS will postpone the QA process when any of the required deliverables are missing. When deliverables are missing, the Contracting Officer Technical Representative (COTR) will be contacted by the Elevation/Orthoimagery Section supervisor and informed of the problem. Processing will resume after the COTR has coordinated the deposition of remaining deliverables.

- ☑ Collection Report
- ☑ Survey Report
- ☑ Processing Report
- ☑ QA/QC Report
- ☑ Control and Calibration Points
- ☑ Project Shapefile/Geodatabase
- ☑ Project Tiling Scheme Shapefile/Gdb
- ☑ Control Point Shapefile/Gdb
- ☑ Breakline Shapefile/Gdb
- ☑ Project XML Metadata

Multi-File Deliverables

File Type	Quantity
☑ Swath LAS Files ☑ Required? ☑ XML Metadata?	232
☑ Intensity Image Files ☑ Required?	868
☑ Tiled LAS Files ☑ Required? ☑ XML Metadata?	868
☑ Breakline Files ☑ Required? ☑ XML Metadata?	6
☑ Bare-Earth DEM Files ☑ Required? ☑ XML Metadata?	868

Additional Deliverables

	Item
☑	Orange County Photos, labeled in .jpg format; 415 total
☑	Dewberry_Response_To_USGS_Review_Orange_county_10012012.pdf
☑	REDELIVERY REPORT.docx
☑	Transmittal.docx
☑	USGS_Calls_With_Dewberry_Comments.shp

Errors, Anomalies, Other Issues to document? ◉ Yes ○ No

No XML metadata received for intensity image files with first delivery. XML metadata for intensity images delivered to reviewer via ftp transfer on 10/02/12 with the following comments: All metadata has been redelivered in addition to the intensity metadata due to the effect of the additional checkpoint.

Breakline files delivered in both shapefile (3) and geodatabase (3) format for a total of 6 breakline files.

No control points used to calibrate sensor received by reviewer at NGTOC. The "USGS FEMA Region IX Orange County, CA LiDAR" report lists control and accuracy checkpoint reports and points as deliverables on page 5. However, on page 15 of the report Dewberry describes their use of "DZ Orthos" to ensure the data was calibrated correctly. Control points in shapefile format delivered to reviewer via ftp on 10/02/12.

Project Geographic Information

Areal Extent:

696

Sq Mi

Grid Size:

1

meters

Tile Size:

1500x1500

meters

Nominal Pulse Spacing:

1

meters

Vertical Datum: NAVD88 meters

Horizontal Datum: NAD83 meters

Project Projection/Coordinate Reference System: UTM Zone 11 N meters.

This Projection Coordinate Reference System is consistent across the following deliverables:

- ☑ Project Shapefile/Geodatabase
- ☑ Project Tiling Scheme Shapefile/Gdb
- ☑ Checkpoints Shapefile/Geodatabase
- ☑ Project XML Metadata File
- ☑ Swath LAS XML Metadata File
- ☑ Classified LAS XML Metadata File
- ☑ Breaklines XML Metadata File
- ☑ Bare-Earth DEM XML Metadata File
- ☑ Swath LAS Files
- ☑ Classified LAS Files
- ☑ Breaklines Files
- ☑ Bare-Earth DEM Files

Review Cycle

This section documents who performed the QA Review on a project as well as when QA reviews were started, actions passed, received, and completed.

Reviewer: Hannah Boggs

Review Start Date: 8/7/2012

Action to Contractor Date	Issue Description	Return Date
8/30/2012	Corrections requested.	10/2/2012

Review Complete: 10/15/2012

Metadata Review

Provided metadata files have been parsed using 'mp' metadata parser. Any errors generated by the parser are documented below for reference and/or corrective action.

The Project XML Metadata file parsed withouterrors.

The Swath LAS XML Metadata file parsed withouterrors.

The Classified LAS XML Metadata file parsed withouterrors.

The Breakline XML Metadata file parsed withouterrors.

The Bare-Earth DEM XML Metadata file parsed withouterrors.

Project QA/QC Report Review

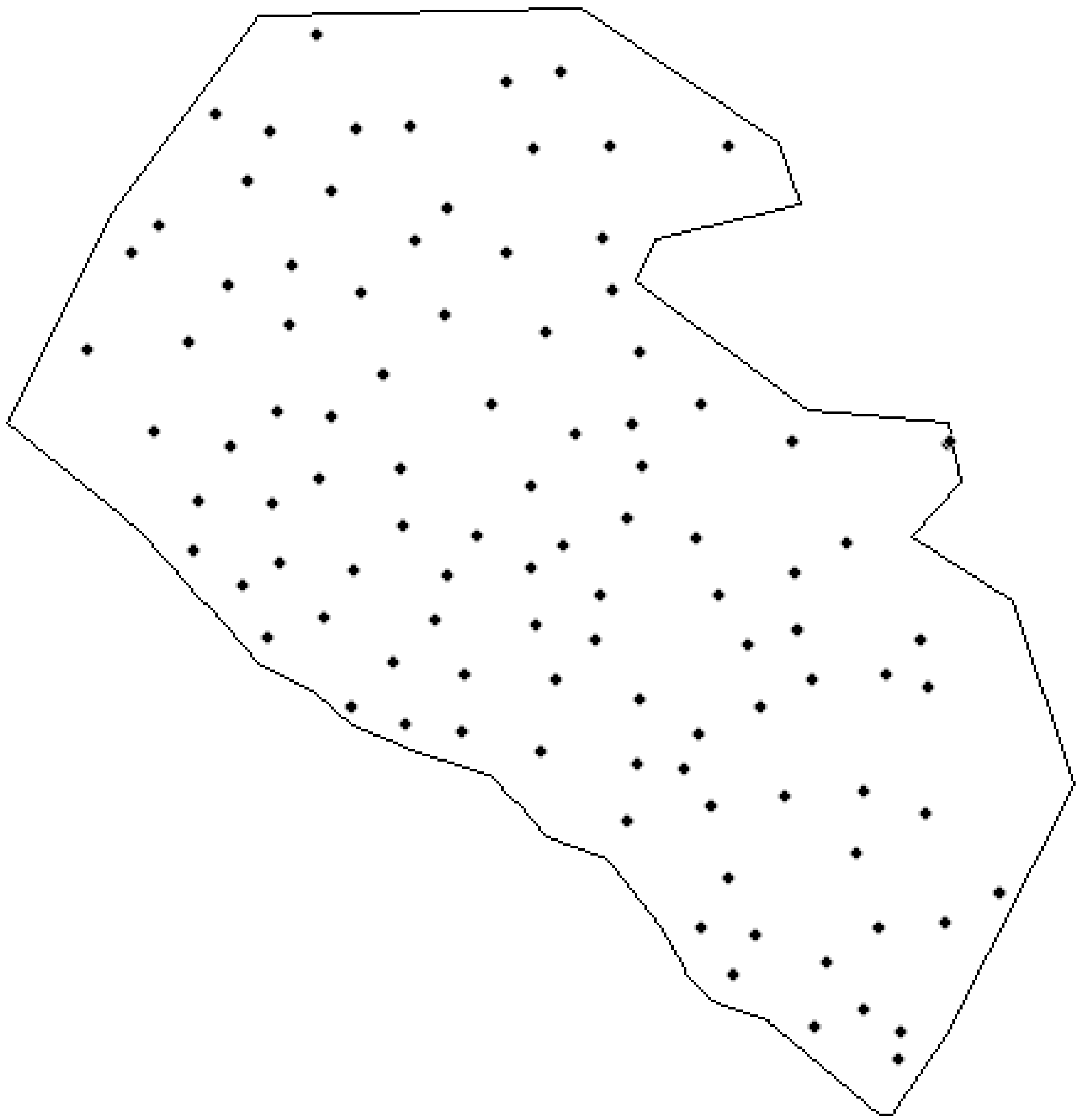
ASPRS recommends that checkpoint surveys be used to verify the vertical accuracy of LiDAR data sets. Checkpoints are to be collected by an independent survey firm licensed in the particular state(s) where the project is located. While subjective, checkpoints should be well distributed throughout the dataset. National Standards for Spatial Data Accuracy (NSSDA) guidance states that checkpoints may be distributed more densely in the vicinity of important features and more sparsely in areas that are of little or no interest. Checkpoints should be distributed so that points are spaced at intervals of at least ten percent of the diagonal distance across the dataset and at least twenty percent of the points are located in each quadrant of the dataset.

NSSDA and ASPRS require that a minimum of twenty checkpoints (thirty is preferred) are collected for each major land cover category represented in the LiDAR data. Checkpoints should be selected on flat terrain, or on uniformly sloping terrain in all directions from each checkpoint. They should not be selected near severe breaks in slope, such as bridge abutments, edges of roads, or near river bluffs. Checkpoints are an important component of the USGS QA process. There is the presumption that the checkpoint surveys are error free and the discrepancies are attributable to the LiDAR dataset supplied.

For this dataset, USGS checked the spatial distribution of checkpoints with an emphasis on the bare-earth (open terrain) points; the number of points per class; the methodology used to collect these points; and the relationship between the data supplier and checkpoint collector. When independent control data are available, USGS has incorporated this into the analysis.

Checkpoint Shapefile or Geodatabase:

☑ Checkpoint Distribution Image?



The following land cover classes are represented in this dataset (uncheck any that do not apply):

- [x] Bare Earth
- [x] Tall Weeds and Crops
- [x] Brush Lands and Low Trees
- [x] Forested Areas Fully Covered by Trees
- [x] Urban Areas with Dense Man-Made Structures

There are a minimum of 20 checkpoints for each land cover class represented. Points within each class are uniformly distributed throughout the dataset. USGS was able to locate independent checkpoints for this analysis. USGS accepts the quality of the checkpoint data for these LiDAR datasets.

Errors, Anomalies, Other Issues to document? (•) Yes ( ) No

☐ Image?

Only 19 points exist in the Forested and Fully Grown land cover class. Dewberry redelivered the checkpoint shapefile to the reviewer via ftp site on 10/02/12 with the following comments: "The missing checkpoint for the Forested and Fully Grown land cover class was located and added to the LiDAR and DEM dataset testing. This additional point changed the LiDAR dataset SVA for the Forested and Fully Grown land cover category by 0.01m. This additional point did not significantly impact the DEM dataset SVA. There was a slight change to the overall CVA for both the DEM and LiDAR datasets but it was less than 0.001m. The final report and metadata were updated to reflect these changes."

☐ Image?

The USGS/FEMA Region IX-Orange County, CA LiDAR report produced for the U.S. Geological Survey lists the vertical accuracy testing steps on page 29 of the report. Step 2 reads, "Next, Dewberry interpolated the bare-earth LiDAR DTM to provide the z-value for each of the 102 checkpoints." This FVA assessment should be performed against unclassified swath las files. Reviewer was unable to locate FVA assessment against unclassified swath las files. Delivered to the reviewer from Dewberry on 10/02/12 the pdf, "Dewberry Response to USGS Review Orange County 10012012" explains that the swath accuracy results were included in the initial delivery in the swath xml metadata, but a small section has been added to the project report to provide additional clarity.

Accuracy values are reported in terms of Fundamental Vertical Accuracy (FVA), Supplemental Vertical Accuracy(s) (SVA), and Consolidated Vertical Accuracy (CVA).

Accuracy values are reported in: meters

Required FVA Value is 0.245 meters or less.
Target SVA Value is 0.363 meters or less.
Required CVA Value is 0.363 meters or less.

The reported FVA of the LAS Swath data is 0.16 meters.

The reported FVA of the Bare-Earth DEM data is 0.19 meters.
SVA are required for each land cover type present in the data set with the exception of bare-earth. SVA is calculated and reported as a 95th Percentile Error.

Land Cover Type	SVA Value	Units
Tall Weeds and Crops	0.12	meters
Brush Lands and Low Trees	0.18	meters
Forested Areas Fully Covered by Trees	0.12	meters
Urban Areas with Dense Man-Made Structu...	0.16	meters

The reported CVA of this data set is: 0.17 meters.

LAS Swath File Review

LAS swath files or raw unclassified LiDAR data are reviewed to assess the quality control used by the data supplier during collection. Furthermore, LAS swath data are checked for positional accuracy. The data supplier should have calculated the Fundamental Vertical Accuracy using ground control checkpoints measured in clear open terrain. The following was determined for LAS swath data for this project:

LAS Version

- (●) LAS 1.2
- ( ) LAS1.3
- ( ) LAS 1.4

Swath File Characteristics

- [x] Separate folder for LAS swath files
- [x] Each swath files <= 2GB
- [ ] *If specified, *.wdp files for full waveform have been provided

The reported FVA of the LAS swath data is 0.16 meters.

Based on this review, the USGS accepts the LAS swath file data.

Errors, Anomalies, Other Issues to document? (●) Yes ( ) No

☐ Image?

Vertical Accuracy of las swath files was not reported. The USGS/FEMA Region IX-Orange County, CA LiDAR report produced for the U.S. Geological Survey lists the vertical accuracy testing steps on page 29 of the report. Step 2 reads, "Next, Dewberry interpolated the bare-earth LiDAR DTM to provide the z-value for each of the 102 checkpoints." This FVA assessment should be performed against unclassified swath las files. Reviewer was unable to locate documentation of FVA assessment against unclassified swath las files. In the pdf, "Dewberry Response to USGS Review Orange County 10012012" Dewberry explains that the swath accuracy results were included in the swath metadata, but a small section has been added to the project report to provide additional clarity.

LAS Tile File Review

Classified LAS tile files are used to build digital terrain models using the points classified as ground. Therefore, it is important that the classified LAS are of sufficient quality to ensure that the derivative product accurately represents the landscape that was measured. The following was determined for classified LAS files for this project:

Classified LAS Tile File Characteristics

- ☑ Separate folder for Classified LAS tile files
- ☑ Classified LAS tile files conform to Project Tiling Scheme
- ☑ Quantity of Classified LAS tile files conforms to Project Tiling Scheme
- ☑ Classified LAS tile files do not overlap
- ☑ Classified LAS tile files are uniform in size
- ☑ Classified LAS tile files have no points classified as '12'

☑ Point classifications are limited to the standard values listed below:

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
7	Noise (low or high, manually identified, if needed)

9	Water
10	Ignored ground (breakline proximity)
11	Withheld (if the "Withheld" bit is not implemented in processing software)

☐ Buy up?

Based on this review, the USGS accepts the classified LAS tile file data.

Errors, Anomalies, Other Issues to document? ◉ Yes ○ No

☐ Image?

Classified las tiles 11smt246195.las and 11smt306165.las are located within the project boundary and were not able to load into Arc Map. Once these two tiles are redelivered, the quantity of classified las tiles will conform to project tiling scheme. The las tiles were delivered to the reviewer via ftp site on 10/02/12 with the following comments: These two LAS tiles have been redelivered. USGS identified artifacts and missing water features in the delivered data. These calls resulted in the modification of twelve LAS tiles. The twelve modified LAS tiles have also been redelivered.

Breakline File Review

Breaklines are vector feature classes that are used to hydro-flatten the bare earth Digital Elevation Models.

Breakline File Characteristics

☑ Separate folder for breakline files
☑ All breaklines captured as PolylineZ or PolygonZ features
☑ No missing or misplaced breaklines

Based on this review, the USGS accepts the breakline files.

Errors, Anomalies, Other Issues to document? ○ Yes ◉ No

None.

Bare-Earth DEM Tile File Review

The derived bare-earth DEM file receives a review of the vertical accuracies provided by the data supplier, vertical accuracies calculated by USGS using supplied and independent checkpoints, and a manual check of the appearance of the DEM layer.

Bare-Earth DEM files provided in the following format: Erdas Imagine *.img

Bare-Earth DEM Tile File Characteristics

- [x] Separate folder for bare-earth DEM files
- [x] DEM files conform to Project Tiling Scheme
- [x] Quantity of DEM files conforms to Project Tiling Scheme
- [x] DEM files do not overlap
- [x] DEM files are uniform in size
- [x] DEM files properly edge match
- [x] Independent check points are well distributed

All accuracy values reported in meters.

Reported Accuracies

Land Cover Category	# of Points	Fundamental Vertical Accuracy @95% Confidence Interval ($Accuracy_z$) Required FVA = 0.245 or less.	Supplemental Vertical Accuracy @95th Percentile Error Target SVA = 0.363 or less.	Consolidated Vertical Accuracy @95th Percentile Error Required CVA = 0.363 or less.
Open Terrain	21	0.19		
Tall Weeds and Crops	20		0.12	
Brush Lands and Low Trees	22		0.18	
Forested Areas Fully Covered by Trees	20		0.12	
Urban Areas with Dense Man-Made Structures	20		0.16	

Consolidated	103			0.17

☑ QA performed Accuracy Calculations?

Calculated Accuracies

Land Cover Category	# of Points	Fundamental Vertical Accuracy @95% Confidence Interval ($Accuracy_z$) Required FVA = 0.245 or less.	Supplemental Vertical Accuracy @95th Percentile Error Target SVA = 0.363 or less.	Consolidated Vertical Accuracy @95th Percentile Error Required CVA = 0.363 or less.
Open Terrain	21	0.19		
Tall Weeds and Crops	20		0.12	
Brush Lands and Low Trees	22		0.20	
Forested Areas Fully Covered by Trees	20		0.13	
Urban Areas with Dense Man-Made Structures	20		0.17	
Consolidated	103			0.17

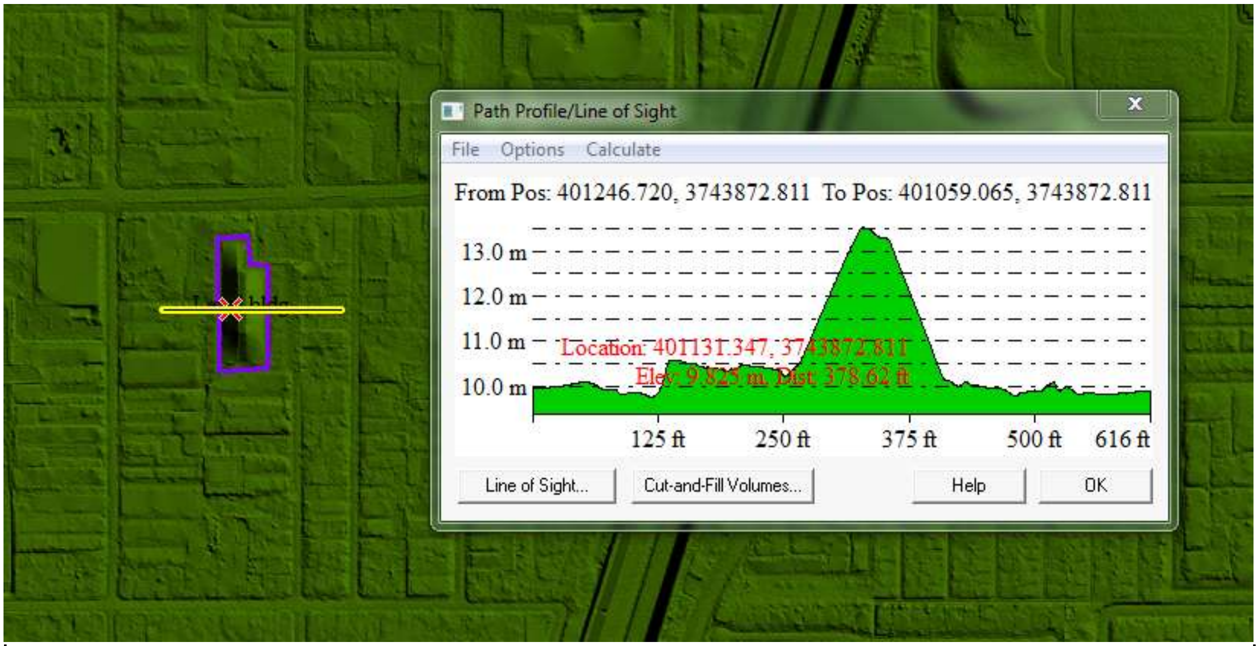
Based on this review, the USGS recommends the bare-earth DEM files for inclusion in the 1/3 Arc-Second National Elevation Dataset.

Based on this review, the USGS accepts the bare-earth DEM files.

Bare-Earth DEM Anomalies, Errors, Other Issues

Errors, Anomalies, Other Issues to document? ◉ Yes ○ No

☑ Image?

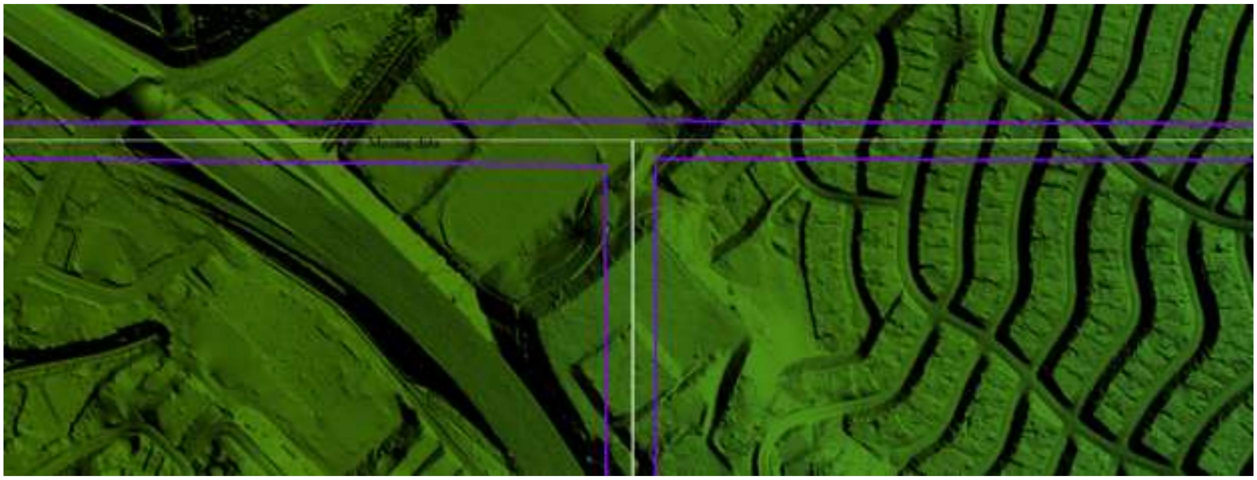


Reviewer identified buildings remaining in bare earth surface that need further removal. These errors are documented in a shapefile created by the reviewer at NGTOC named errors.shp. In the pdf, "Dewberry Response to USGS Review Orange County 10012012" Dewberry explains the common occurrence of homes built into hillsides, reviewer accepts this response.

☑ Image?

Reviewer identified a minimum of 3 waterbodies greater than 2 acres not hydroflattened. These errors are documented in a shapefile created by the reviewer at NGTOC named errors.shp. In the pdf, "Dewberry Response to USGS Review Orange County 10012012" Dewberry explains that one of four calls regarding breaklines/waterbodies was incorrect, from viewing the intensity images it can be determined that no water existed at the time of acquisition. The other three calls were addressed, corrected, and new DEM and LAS files were redelivered to the reviewer via ftp site on 10/02/12. Reviewer visually inspected the redelivered DEMs and found them acceptable.

☑ Image?

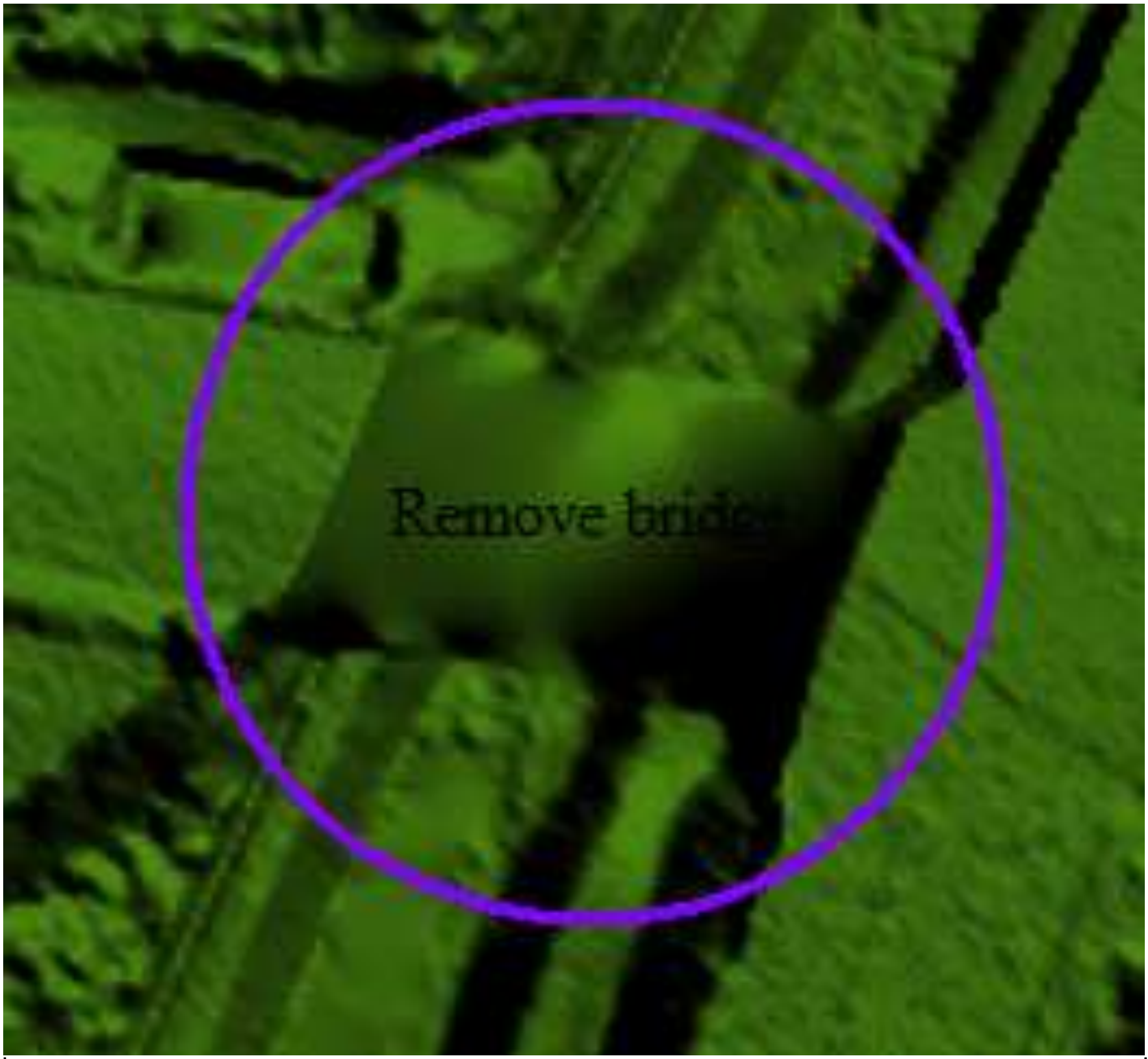


Reviewer identified 4 areas where data voids exist between tiles. The voids are located near the North, South, East and West extents of the project boundary. These errors are documented in a shapefile created by the reviewer at NGTOC named errors.shp. In the pdf, "Dewberry Response to USGS Review Orange County 10012012" Dewberry explains that these gaps were due to processing errors that occurred with the partial tiles along the project boundary. The 21 tiles where this error occurred have been reprocessed and redelivered. Reviewer visually inspected the redelivered DEMs and found them acceptable.

☑ Image?

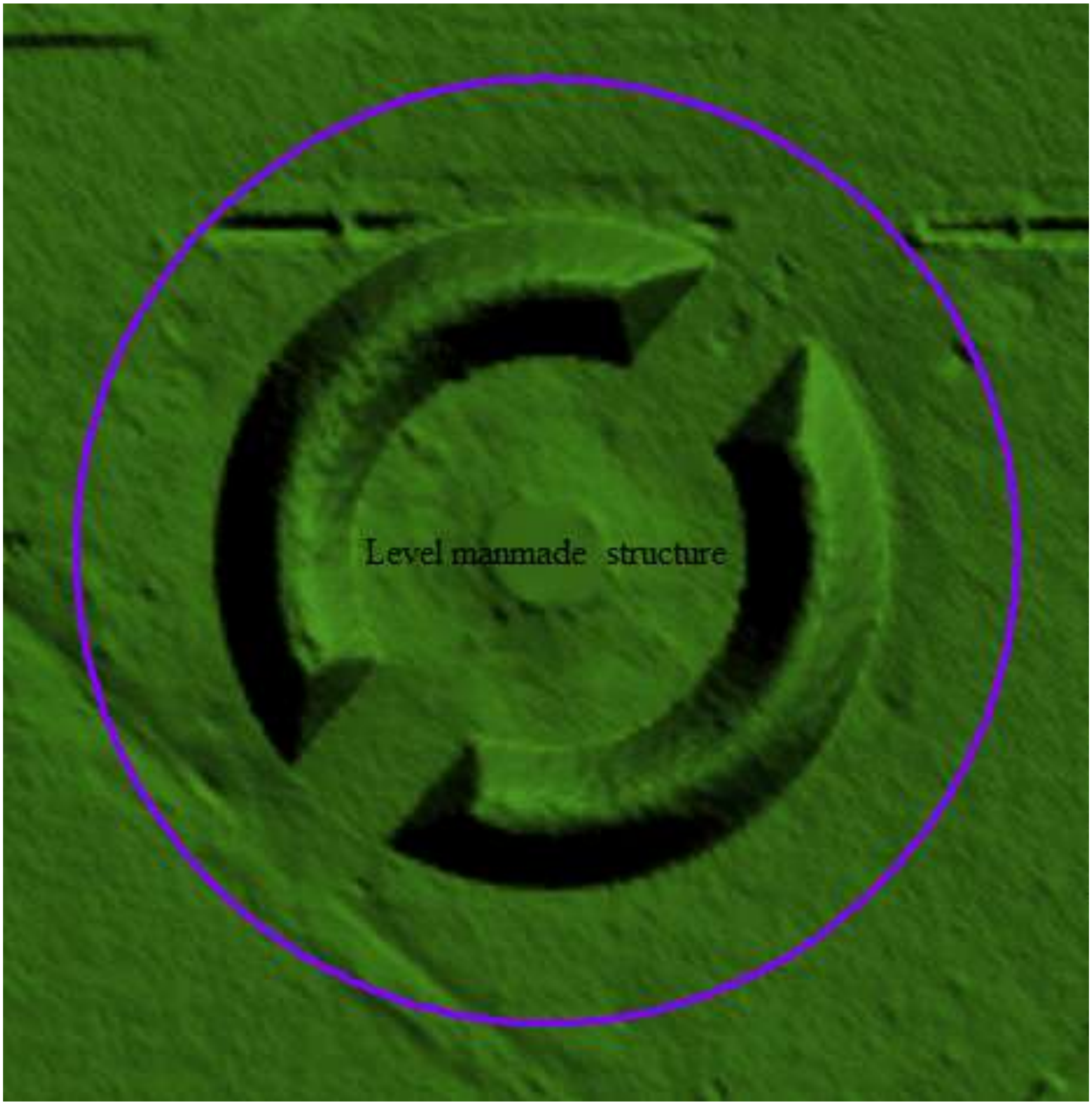
Reviewer identified bridges remaining in bare earth surface. These errors are documented in a shapefile created by the reviewer at NGTOC named errors.shp. See following image and comments for updated information.

☑ Image?



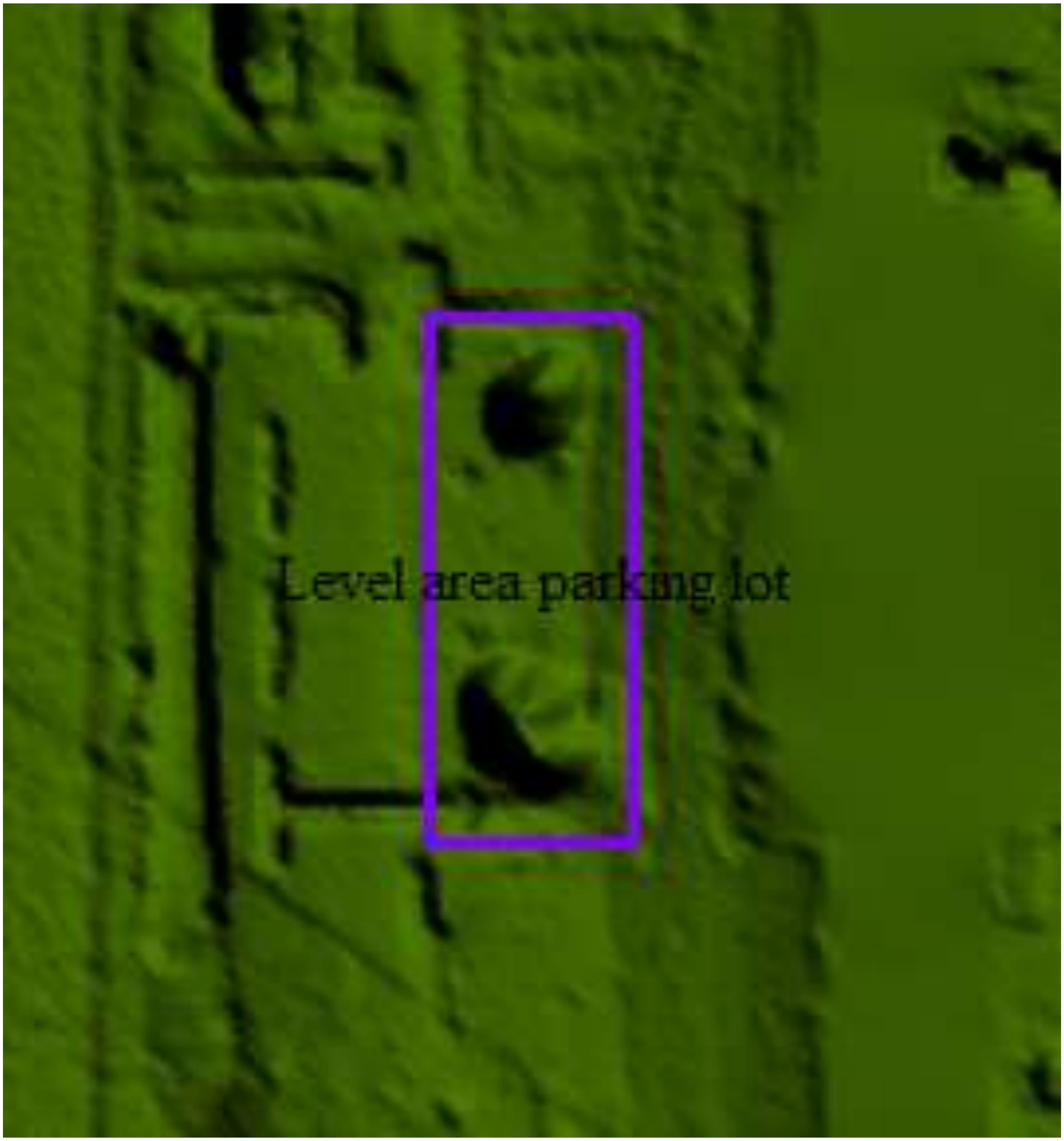
In the pdf, "Dewberry Response to USGS Review Orange County 10012012" Dewberry explains that these were originally believed to be culverts, but have been removed from the bare earth surface, DEMs were redelivered to reviewer via ftp site on 10/02/12. Reviewer visually inspected the redelivered DEMs and found them acceptable.

☑ Image?



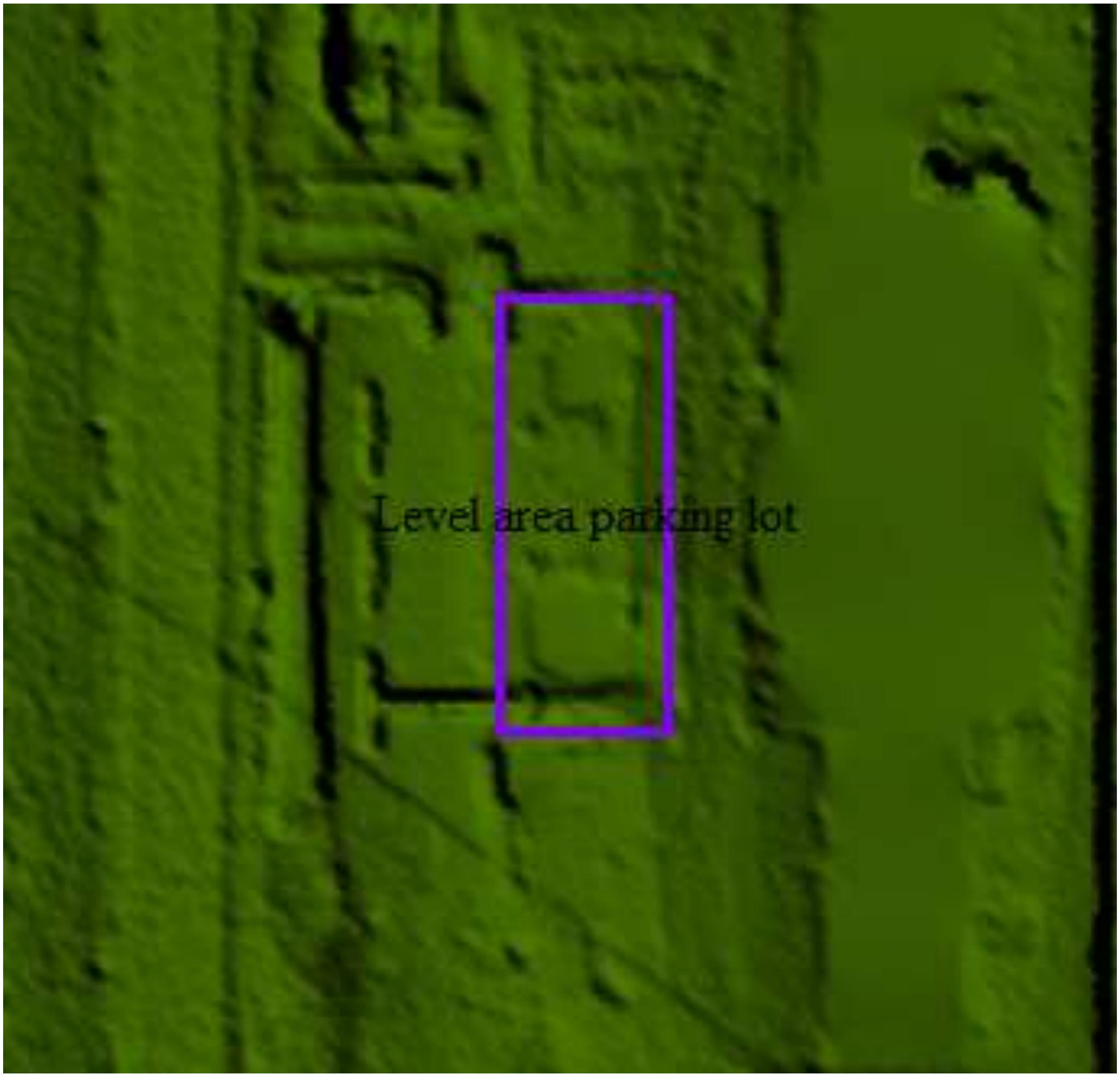
Reviewer identified a man-made structure in bare earth surface. This error is documented in a shapefile created by the reviewer at NGTOC named errors.shp. In the pdf, "Dewberry Response to USGS Review Orange County 10012012" Dewberry explains that in this instance earthen mounds have been formed around the feature and have been correctly included in the ground classification. Reviewer accepts this response.

☑ Image?



Reviewer identified areas of extreme elevation change within man-made parking lot that needs further removal. This error is documented in a shapefile created by the reviewer at NGTOC named errors.shp.

☑ Image?



In the pdf, "Dewberry Response to USGS Review Orange County 10012012" Dewberry notes that such artifacts have been removed, DEMs redelivered on 10/02/2012. Reviewer visually inspected redelivered DEMs and found them acceptable.

Based on this review, the deliverables provided meet the Task Order requirements.

Internal Note:

This is the end of the report.

QA Form V1.4 12OCT11.xsn

Dewberry & Davis LLC
1000 N. Ashley Drive, Suite 801
Tampa, FL 33602-3718
813.225.1325
813.225.1385 fax
www.dewberry.com

Dewberry Response to USGS Review of the FEMA IX - Orange County, CA LiDAR Processing Project

Produced for U.S. Geological Survey

USGS Contract: G10PC00013

Task Order:G12PD00039

Report Date: 10/01/2012

SUBMITTED BY:

Dewberry
1000 North Ashley Drive Suite 801
Tampa, FL 33602
813.225.1325

SUBMITTED TO:
U.S. Geological Survey
1400 Independence Road
Rolla, MO 6540
573.308.3810

Table of Contents

Executive Summary

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (LiDAR) technology for the USGS FEMA IX Orange County, California Project Area.

The LiDAR data were processed to a bare-earth digital terrain model (DTM). Detailed breaklines and bare-earth Digital Elevation Models (DEMs) were produced for the project area. .

Deliverables for this project included raw point cloud data, classified point cloud data, bare earth digital elevation models, intensity images, breaklines, control points, metadata, project report, and project extent shapefiles.

The USGS review of these deliverables resulted in one call to deliver intensity ortho metadata, one call regarding the location of the swath accuracy testing results, one call to include missing checkpoint from the forested and fully grown land cover class in the accuracy testing, two calls to redeliver unreadable LAS tiles, ten calls to remove buildings from ground, four calls to remove vegetation artifacts from ground, two bridge removal calls, four calls to modify breaklines, and four calls regarding data voids or missing data.

PROJECT AREA

Data was formatted according to tiles with each tile covering an area of 1500m by 1500m. A total of 868 tiles were produced for the project encompassing an area of approximately 681 sq. miles.

Figure 1: Project Map

Edit Calls

METADATA

All metadata has been redelivered in addition to the intensity metadata due to the effect of the additional checkpoint.

ACCURACY TESTING

The missing checkpoint for the Forested and Fully Grown land cover class was located and added to the LiDAR and DEM dataset testing. This additional point changed the LiDAR dataset SVA for the Forested and Fully Grown land cover category by 0.01m. This additional point did not significantly impact the DEM dataset SVA. There was a slight change to the overall CVA for both the DEM and LiDAR datasets but it was less than 0.001m. The final report and metadata were updated to reflect these changes.

LAS TILES

USGS was unable to load two LAS tiles. These two LAS tiles have been redelivered. USGS identified artifacts and missing water features in the delivered data. These calls resulted in the modification of twelve LAS tiles. The twelve modified LAS tiles have also been redelivered.

BUILDINGS AND STRUCTURES

There were eleven locations where comments were made to remove structure related artifacts. The DEM surface models are created from terrains. Terrain models create continuous surfaces from the inputs, in this instance LiDAR ground points. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This can cause visual artifacts in areas where the ground elevation is higher on one side of the building than the other. This is common throughout California where many homes are built into hillsides. As these “artifacts” are only visual and do not exist in the LiDAR points, no modifications were made to the LAS or DEMs in 10 of these areas. Modifications were made to 1 area where highpoints could be removed from the ground to create a cleaner surface model. Examples are shown below.

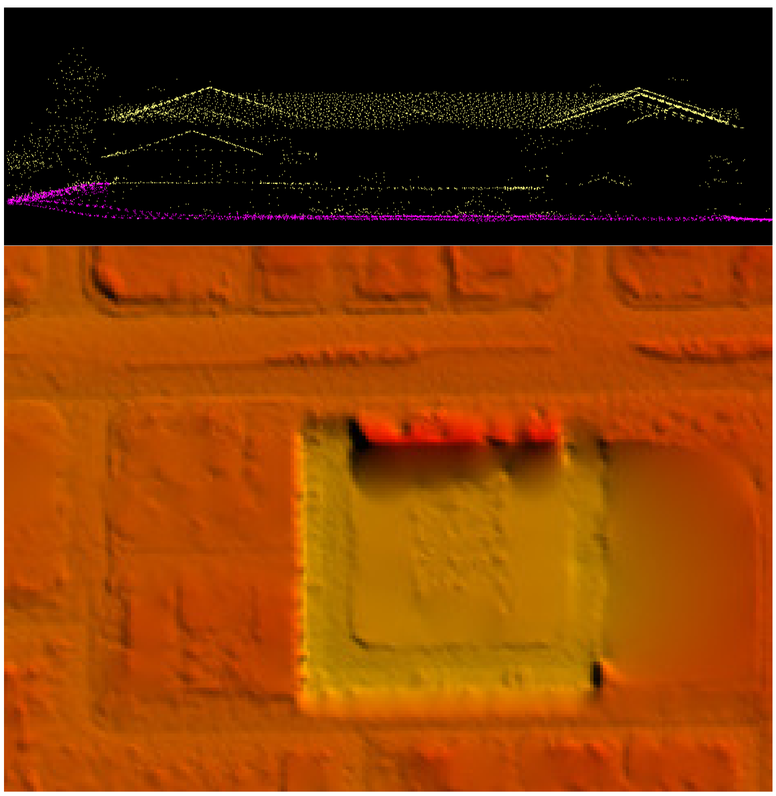


Figure 2 - Tile 11SMT096435. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of the building points that were removed. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

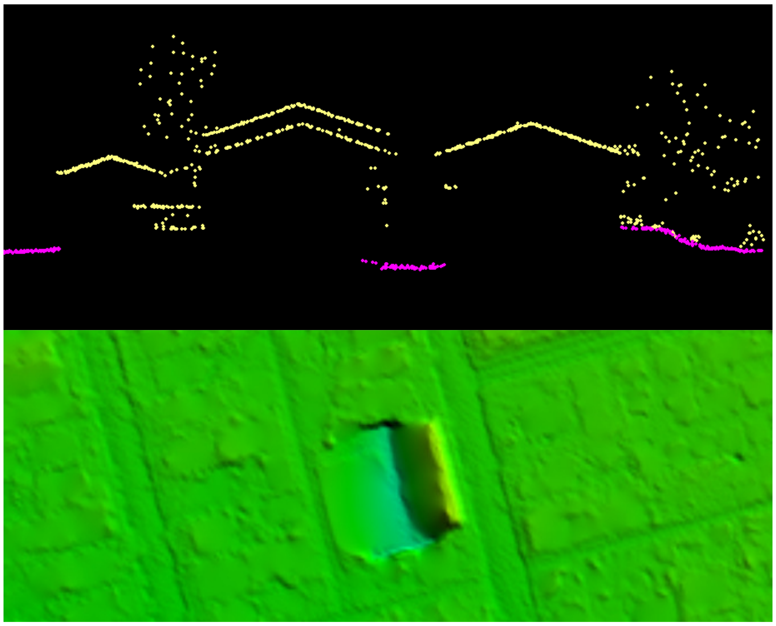


Figure 3 - Tile 11SMT141435. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of the building points that were removed. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

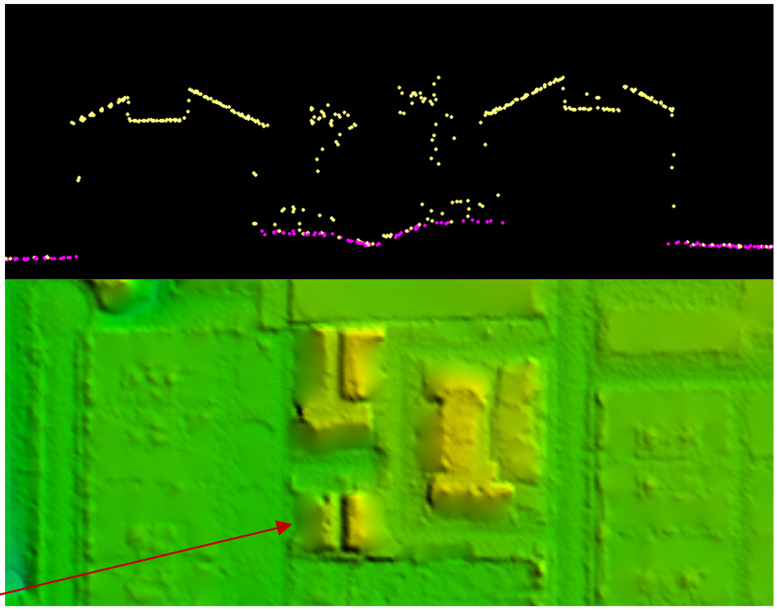


Figure 4 - Tile 11SMT066435. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of two apartment buildings separated by a courtyard. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

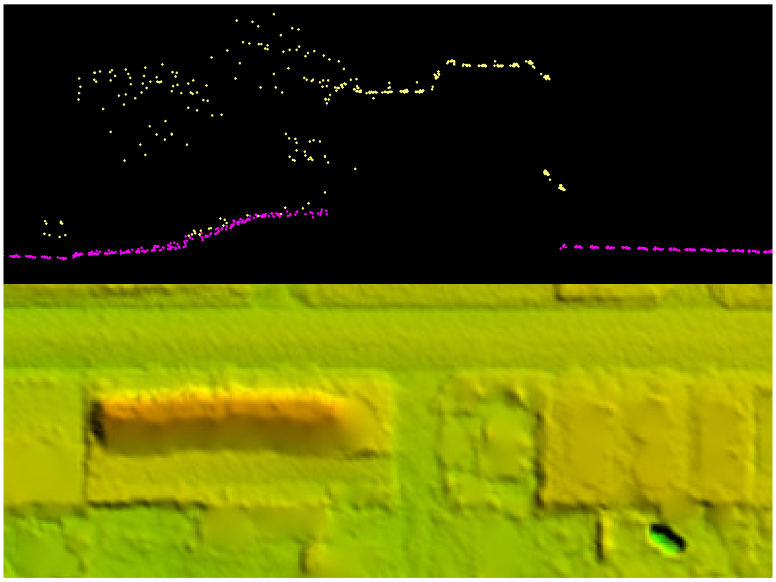


Figure 5 - Tile 11SMT081390. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of the building points that were removed. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

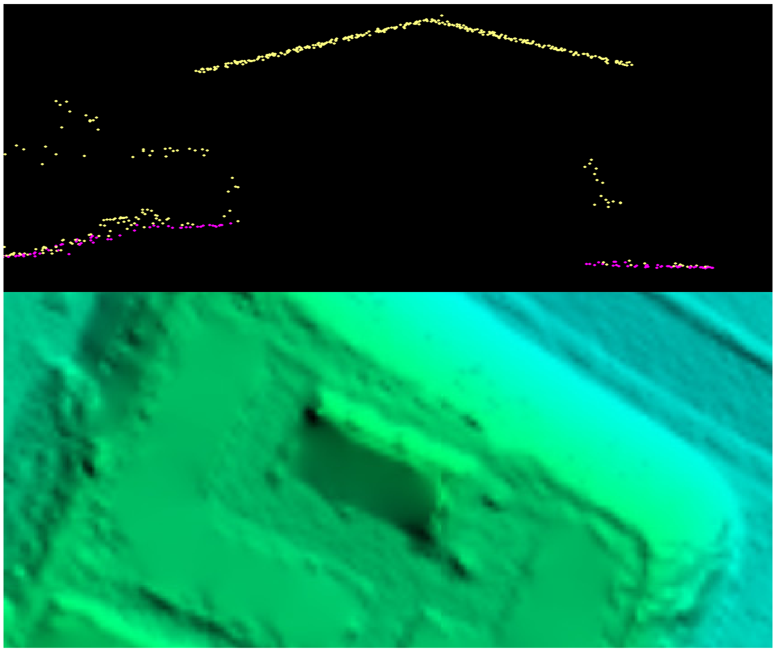


Figure 6 - Tiles 11SMT261225 and 11SMT276225. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of the building points that were removed. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

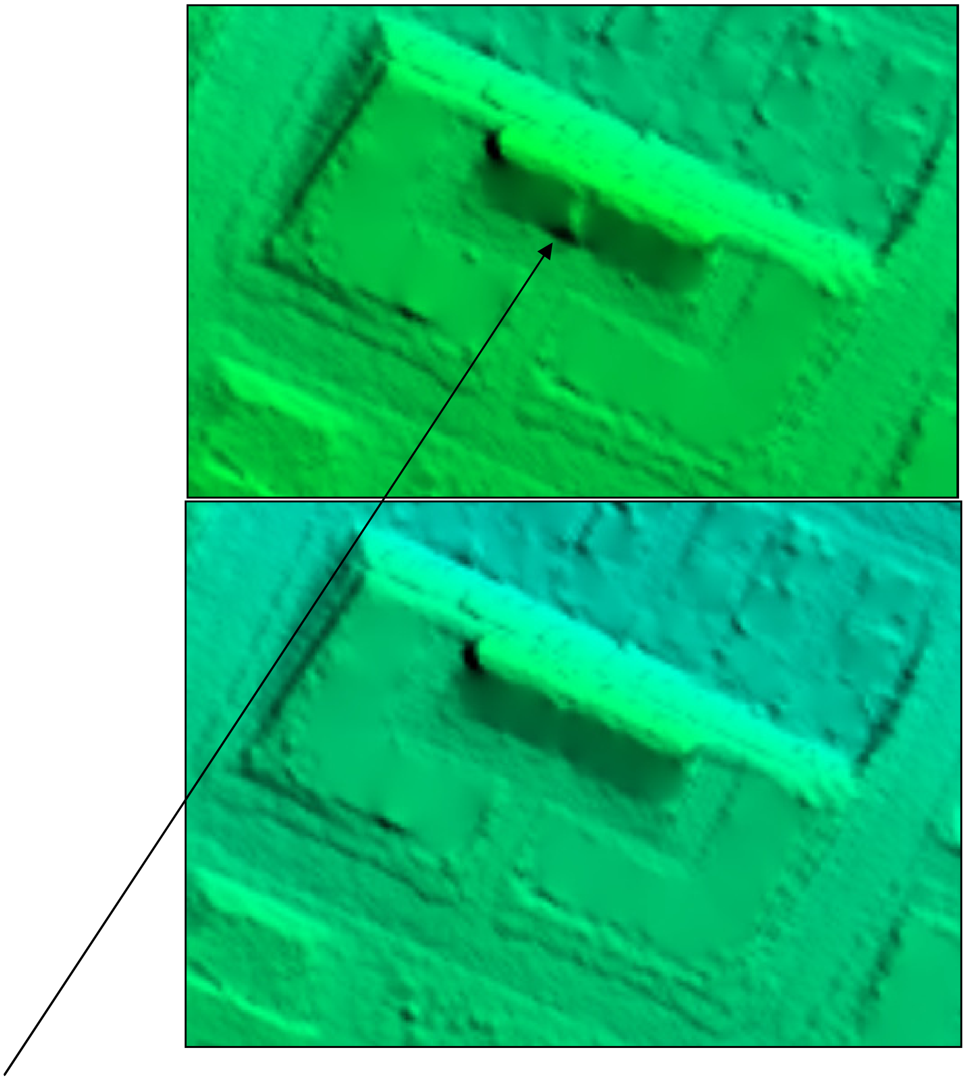


Figure 7 –Tile 11SMT276225. The DEM in the top view is similar to the previous calls but some high points are present that can be modified. These high points were removed from class 2 ground. The impact to the DEM is minor and a visual artifact is still present in the redelivered DEM shown in the bottom view because the surface model is interpolating between the available ground points on either side of the building points that were removed. All building points have been removed from ground.

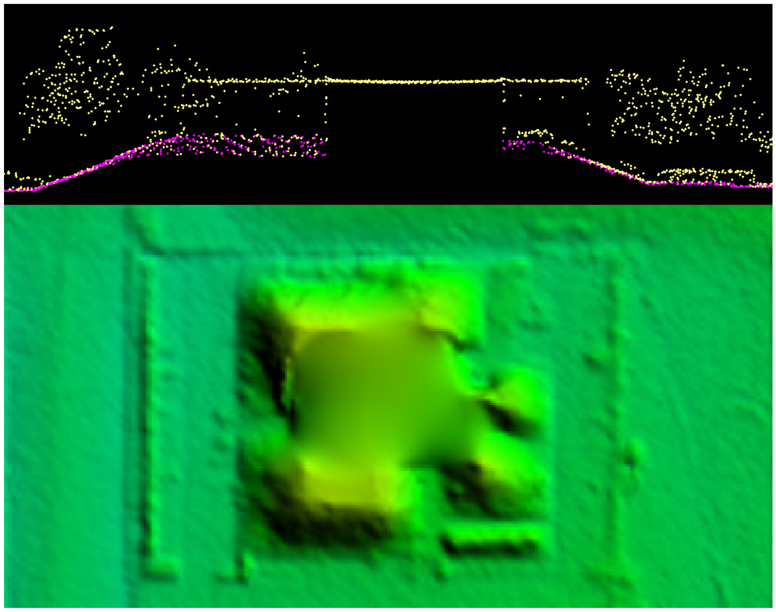


Figure 8 - Tile 11SMT096450. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of the medical center building points that were removed. This looks odd due to the hills included in the landscaping surrounding the building. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

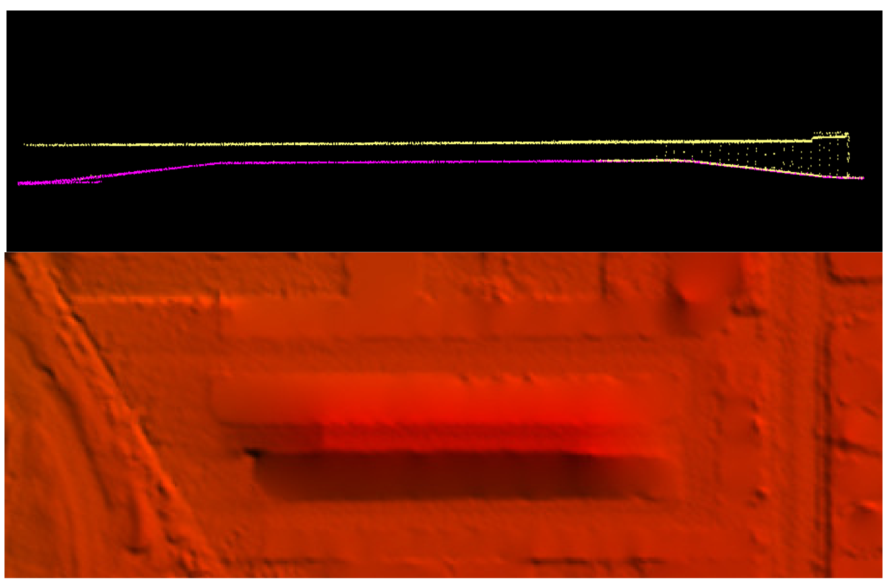


Figure 9 - Tiles 11SMT111210 and 11SMT126210. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of storage facility units that are separated by built up ground forming a raised ramp like feature. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

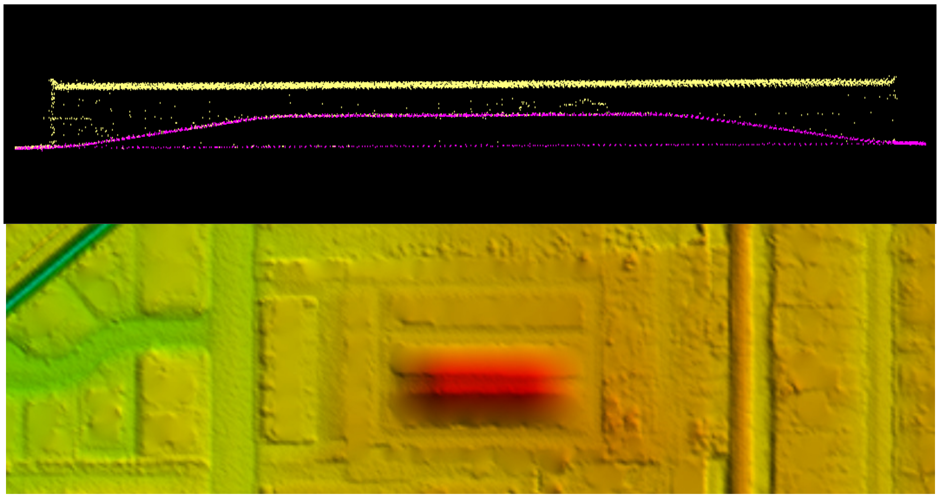


Figure 10 - Tile 11SMT066390. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of more storage facility units that are separated by built up ground forming a raised ramp like feature. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

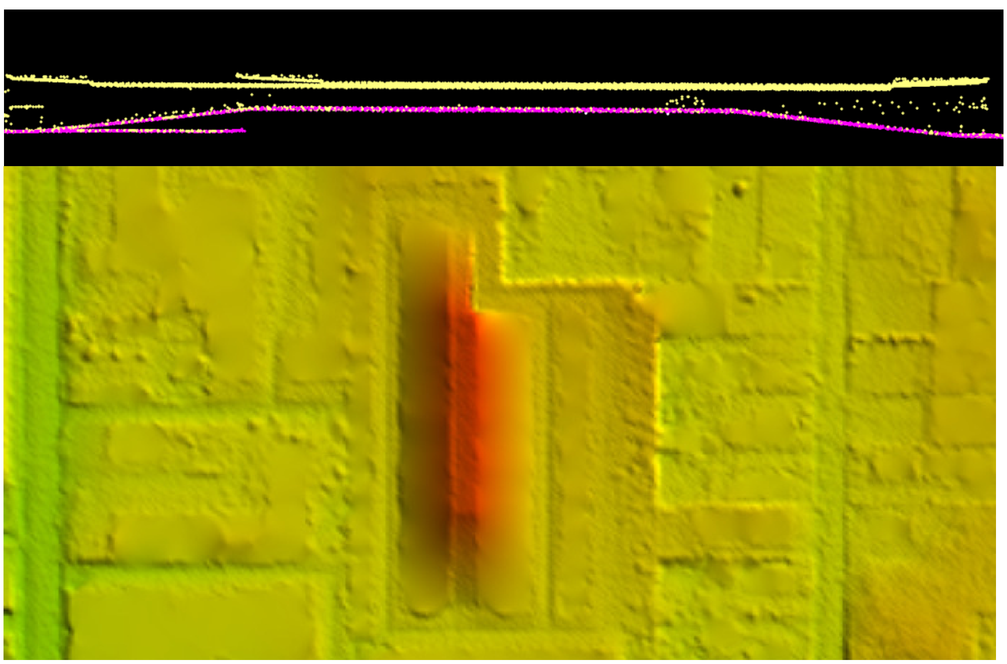


Figure 11 - Tile 11SMT006435. The DEM in the bottom view shows a visual artifact because the surface model is interpolating between the available ground points on either side of more storage facility units that are separated by built up ground forming a raised ramp like feature. The profile in the top view shows the LiDAR points of this particular feature colored by class. All building points have been removed from ground (pink) and are unclassified (yellow). There are no ground points that can be modified to correct this visual artifact.

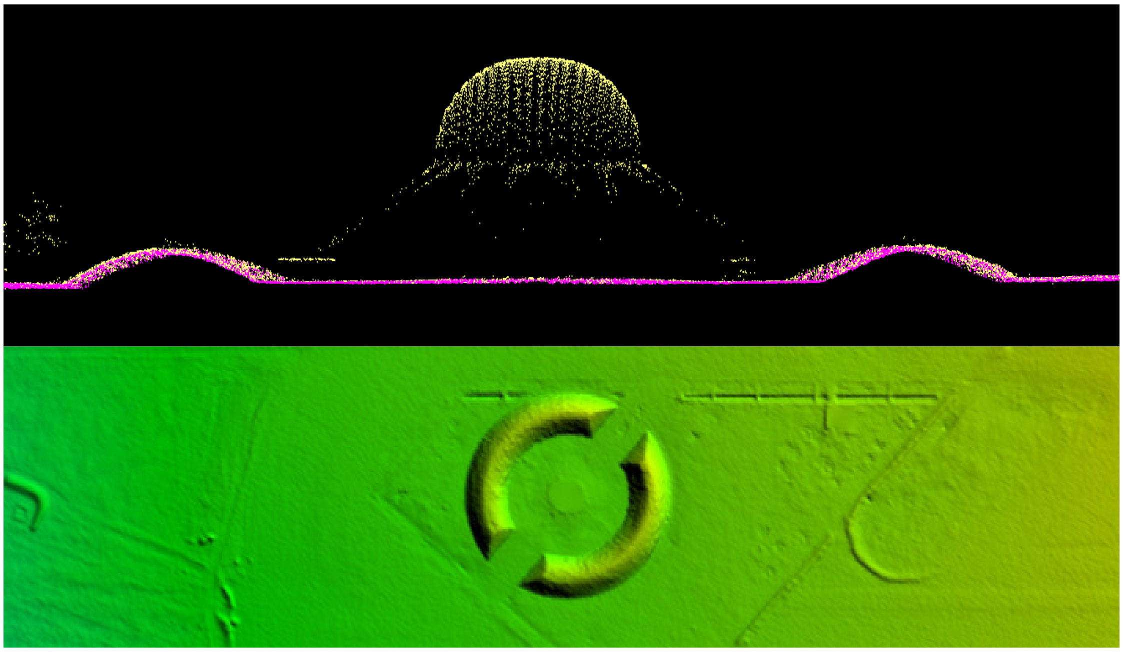


Figure 12 - Tile 11SMT306255. In ground structures exist within the project area. In the example above, earthen mounds have been formed around an area. These features are correctly included in the ground classification.

ARTIFACTS

There were three calls to remove features from the ground surface. Dewberry removed the identified features as requested by USGS. Examples are shown below.

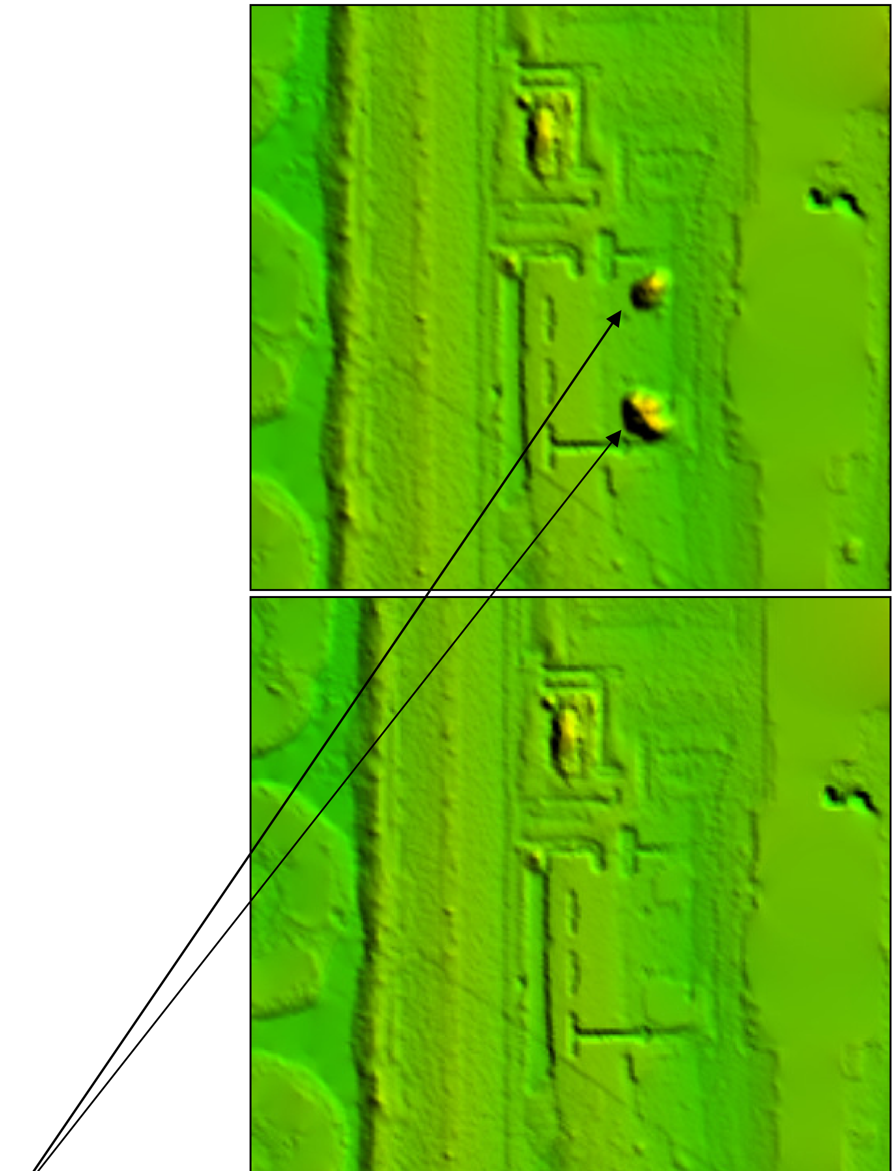


Figure 13 - Tile 11SMT081240. At the time of LiDAR acquisition, this area was under construction and dirt hills were present as shown in the top view. At the request of USGS, these hills have been removed from the ground as shown in the redelivered DEM in the bottom view.

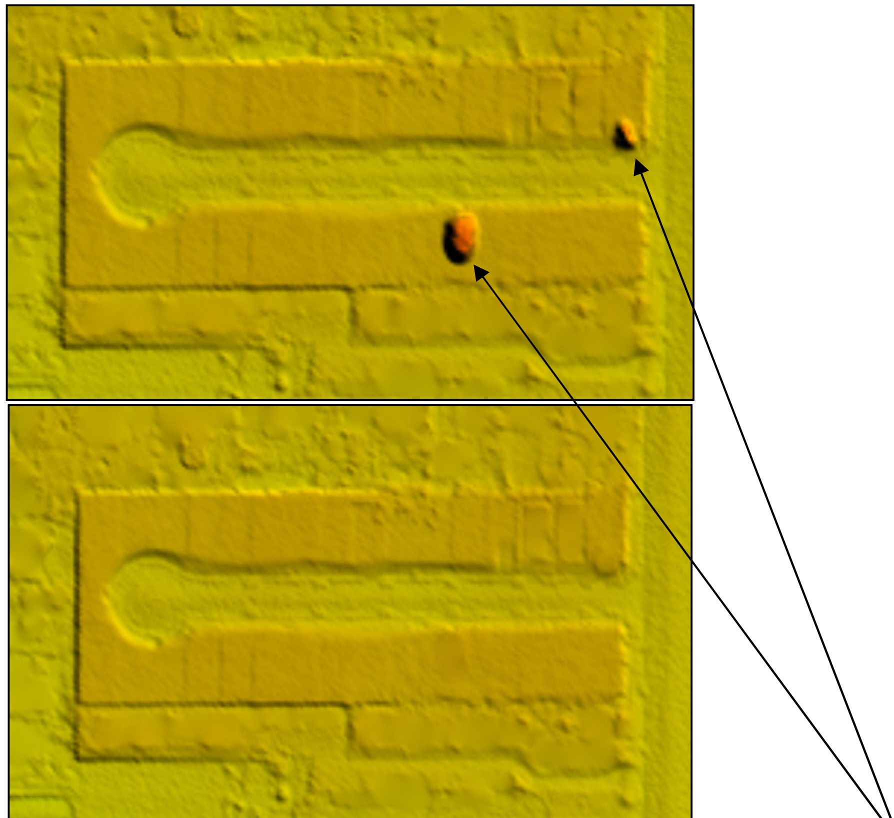


Figure 14 - Tile 11SMT066420. At the time of LiDAR acquisition, this area was under construction and dirt hills were present as shown in the top view. At the request of USGS, these hills have been removed from the ground as shown in the redelivered DEM in the bottom view.

BRIDGE REMOVAL

There were two locations where Dewberry interpreted a feature as a culvert and included it in the ground surface. USGS identified these features as bridges, not culverts. Dewberry has modified the points and removed these features from the ground surface. Examples are shown below.

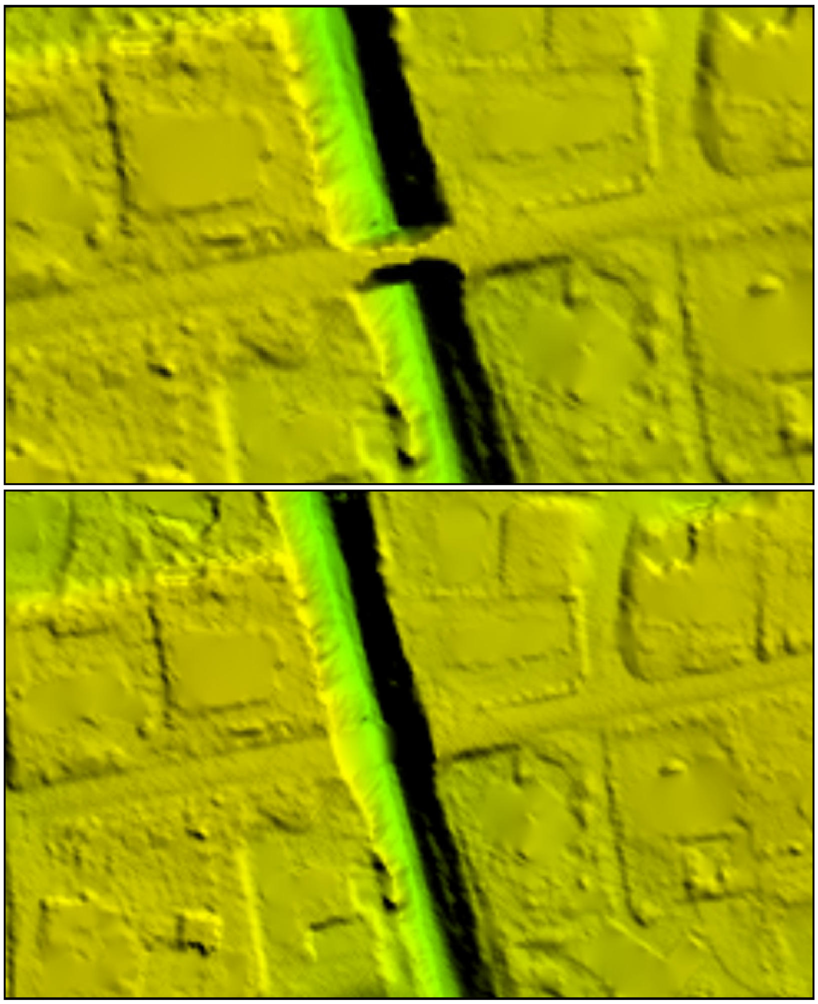


Figure 15 - Tile 11SMT126525. The feature identified was originally interpreted as a culvert and included in the ground surface as shown in the top view. USGS identified this feature as a bridge. The LAS and DEM have been corrected by removing this feature from the ground surface as shown in the bottom view.

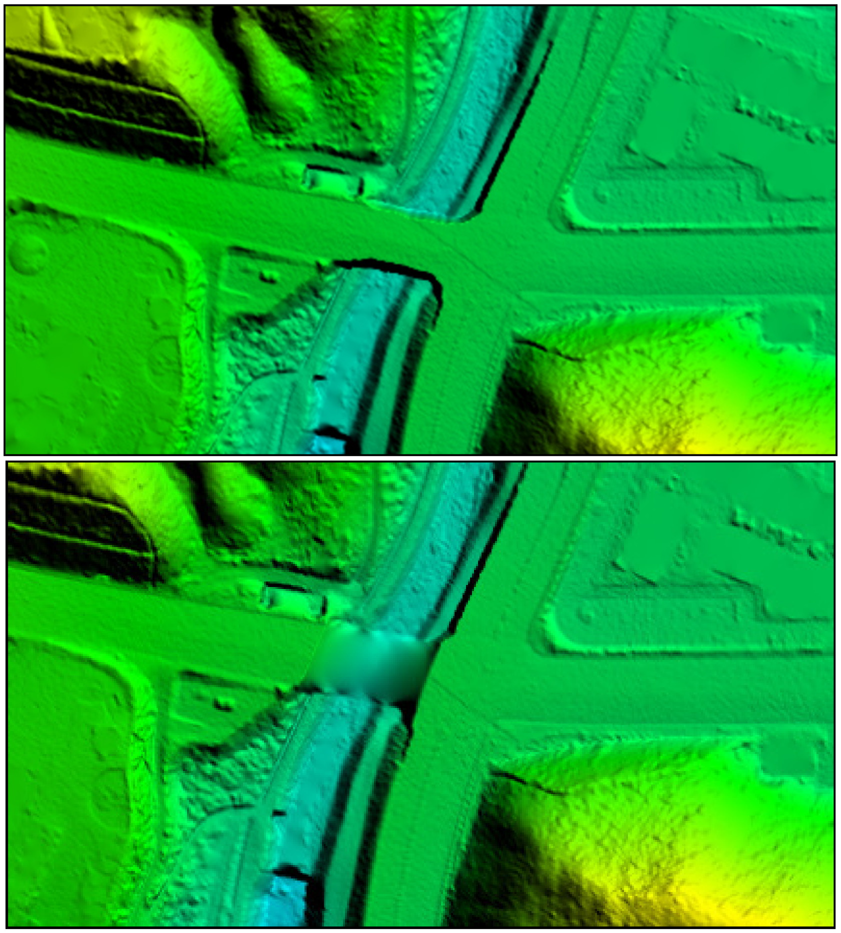


Figure 16 - Tile 11SMT321120. The feature identified was originally interpreted as a culvert and included in the ground surface as shown in the top view. USGS identified this feature as a bridge. The LAS and DEM have been corrected by removing this feature from the ground surface as shown in the bottom view.

BREAKLINE ADJUSTMENTS

There were four locations where USGS identified areas of water that were not included in the collected breaklines. While the interpretation of the feature may be questionable in the intensity imagery, Dewberry agrees with three of the calls after reviewing color imagery and the available LiDAR points. There is one location called out by USGS where, after reviewing the LiDAR, Dewberry confirmed that the breaklines accurately capture the existing water and no changes were necessary. Examples are shown below.

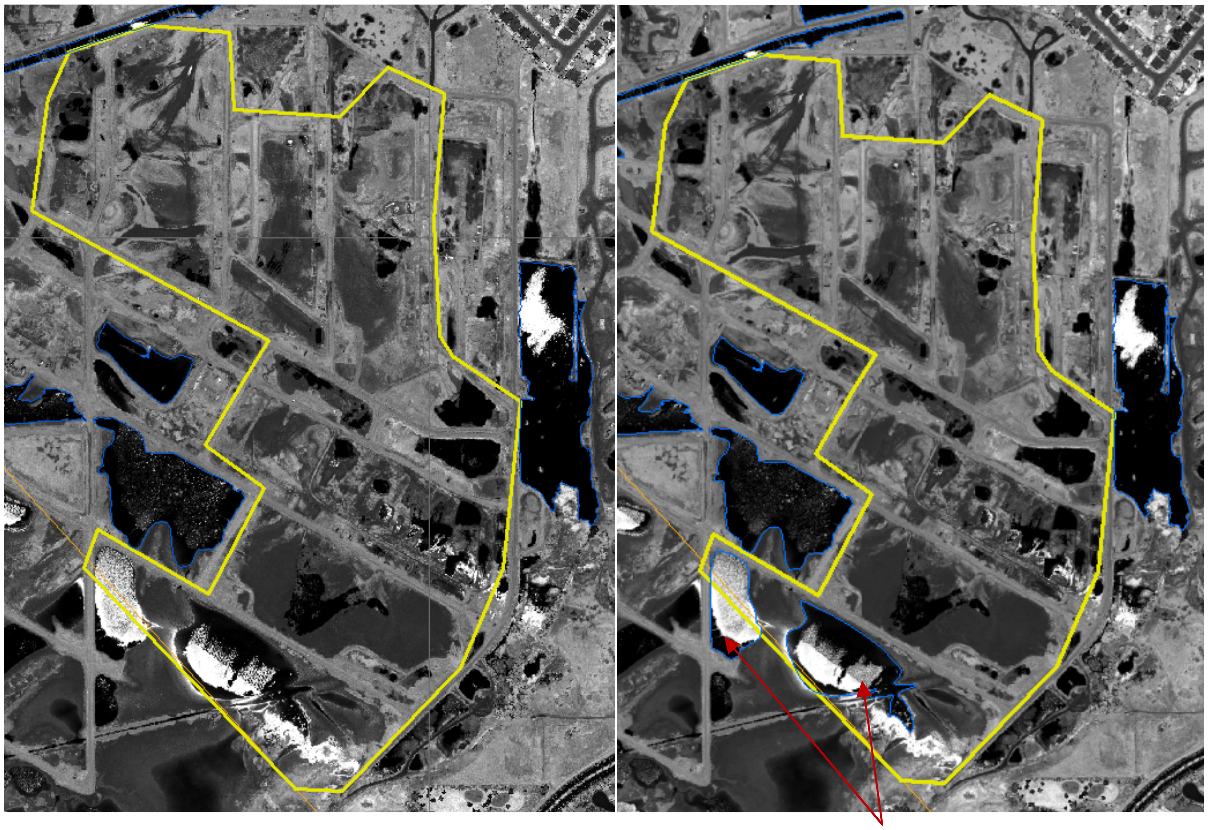


Figure 17 - Tiles 11SMT036270, 11SMT051270, 11SMT036285, and 11SMT051285: The intensity image showing the collected breaklines from the first delivery is on the left. The modified breaklines from this delivery are shown in the intensity image on the right. Dewberry added two ponds to the delivered breaklines. The LAS and DEMs have been corrected to reflect the addition of these features.

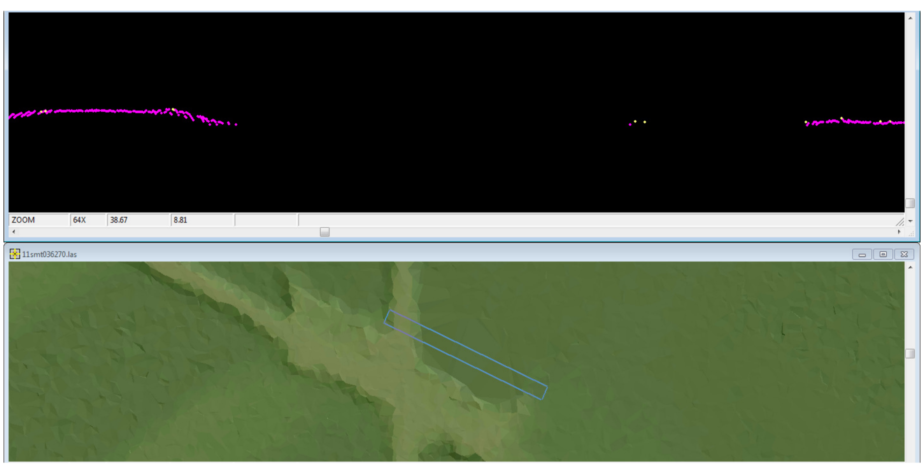


Figure 18 - Tiles 11SMT036270, 11SMT051270, 11SMT036285, and 11SMT051285: The LiDAR points shown above confirm that the breaklines delivered to USGS should be modified to include additional water bodies. The black areas are where no points were returned due to the presence of water. The black areas that are 2 acres or greater and have been confirmed to be water have been added to the breaklines and the LAS and DEMs have been modified to reflect these changes.

Figure 19 - Tile 11SMT201465. As the intensity imagery shows, the breaklines delivered to USGS correctly capture the water bodies in the area that are 2 acres or greater.

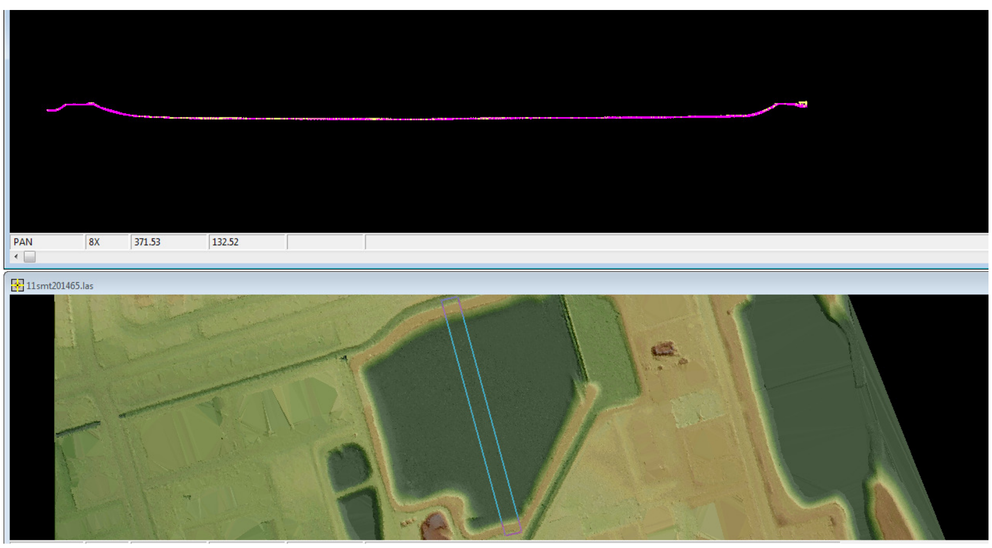


Figure 20 - Tile 11SMT201465. The LiDAR points shown above confirm that the breaklines delivered to USGS correctly capture the water bodies in the area that are greater than 2 acres. Within the identified area, several points were returned indicating the presence of ground. These points have been correctly classified as ground (shown in pink) and the area was not hydro flattened in the delivered DEM. Had there been water present, a black area would show where very few or no points were returned due to the presence of water. It is likely that this area was dry during the time of the mission.

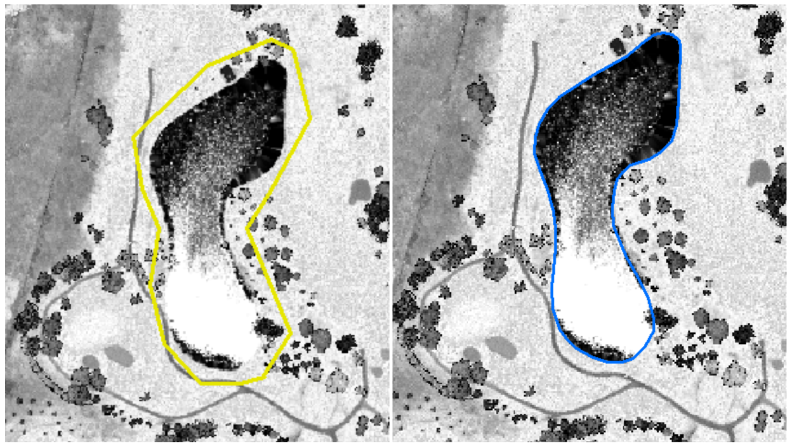


Figure 21 - Tile 11SMT021390. The intensity image showing the collected breaklines from the first delivery is on the left. The modified breaklines from this delivery are shown in the intensity image on the right. Dewberry added one pond to the delivered breaklines. The LAS and DEMs have been corrected to reflect the addition of these features.

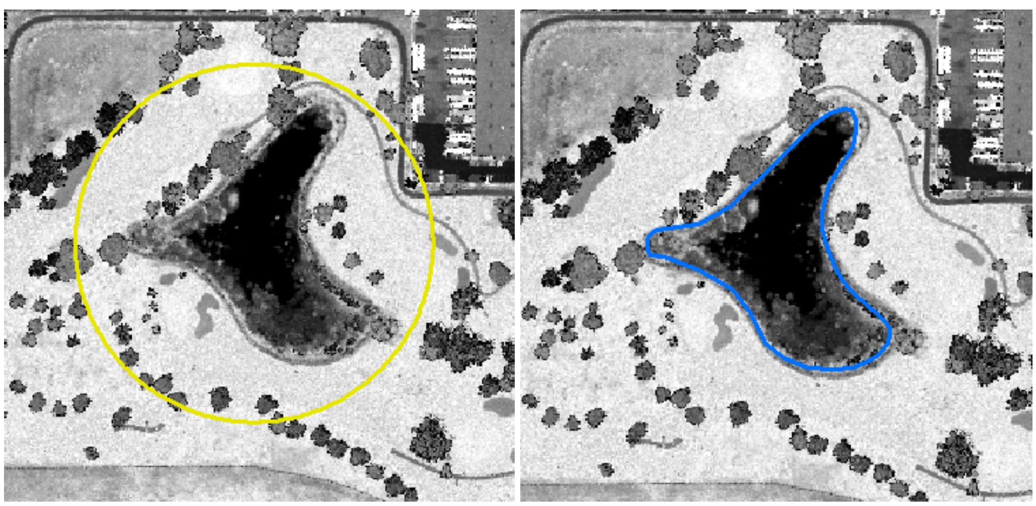


Figure 22 - Tile 11SMT036390. The intensity image showing the collected breaklines from the first delivery is on the left. The modified breaklines from this delivery are shown in the intensity image on the right. Dewberry added one pond to the delivered breaklines. The LAS and DEMs have been corrected to reflect the addition of these features.

MISSING DATA

There were four locations called out by USGS for data voids or missing data. Fortunately, there were no true data density, data voids. The gaps identified were due to processing errors that occurred with the partial tiles along the project boundary. The twenty-one tiles where this error occurred have been reprocessed and redelivered.

Summary of Edit Calls

- There was one call to deliver intensity ortho metadata.
  - Intensity ortho metadata has been creates and delivered.

- There was one call to deliver the swath calibration points.
  - The swath calibration points have been included in this delivery.

- There was one call regarding the location of the swath accuracy testing results.
  - The swath accuracy results were included in the swath metadata but a small section has been added to the project report to provide additional clarity.

- There was one call to include a missing checkpoint from the forested and fully grown land cover class in the accuracy testing.
  - This checkpoint has been included, in the accuracy testing of the swaths, classified LAS and DEMs and the new values have been updated in the report and corresponding metadata.

- There were two calls to redeliver unreadable LAS tiles.
  - These two tiles have been redelivered.

- There were eleven calls to remove buildings from ground.
  - Ten of these issues have been corrected.
  - There was one call where no changes were necessary.

- There were three calls to remove artifacts from ground.
  - All three of these issues have been corrected.

- There were two bridge removal calls.
  - Both of these issues have been corrected.

- There were four calls to modify breaklines.
  - Three of these issues have been corrected.
  - There was one call where no changes were necessary.

- There were four areas with calls regarding data voids or missing data.
  - The twenty-one affected DEM tiles were reprocessed and redelivered.