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SIX COUNTY SC LIDAR QUALITY ASSURANCE

ABBEVILLE COUNTY REVIEW

FOR

UNITED STATES GEOLOGIC SURVEY
AND
SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES

USGS CONTRACT: G10PC00025
TASK ORDER G12PD00482

Final review: February 6, 2013

aerometric Geospatial Solutions

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1) Executive Summary

USGS Contract Number	Production Contractor	Date Prepared	Delivery #	Aerometric, Inc. Recommendation
G10PC00025	Dewberry	February 6, 2013	Final	PASS

Table 1: Executive Summary Table

Aerometric, Inc. has reviewed the Abbeville County portion of the Six County SC LiDAR Quality Assurance as outlined in the SC Acceptance Criteria. Abbeville County consists of 526 square miles provided in 664 LAS files (5,000 i. ft x 5,000 i. ft.) as prepared by Dewberry in ASPRS LAS cloud data classification. Breaklines were also provided supplemental to the LAS in preparation of the overall county Digital Elevation Model (DEM). The location of Abbeville County is as follows:

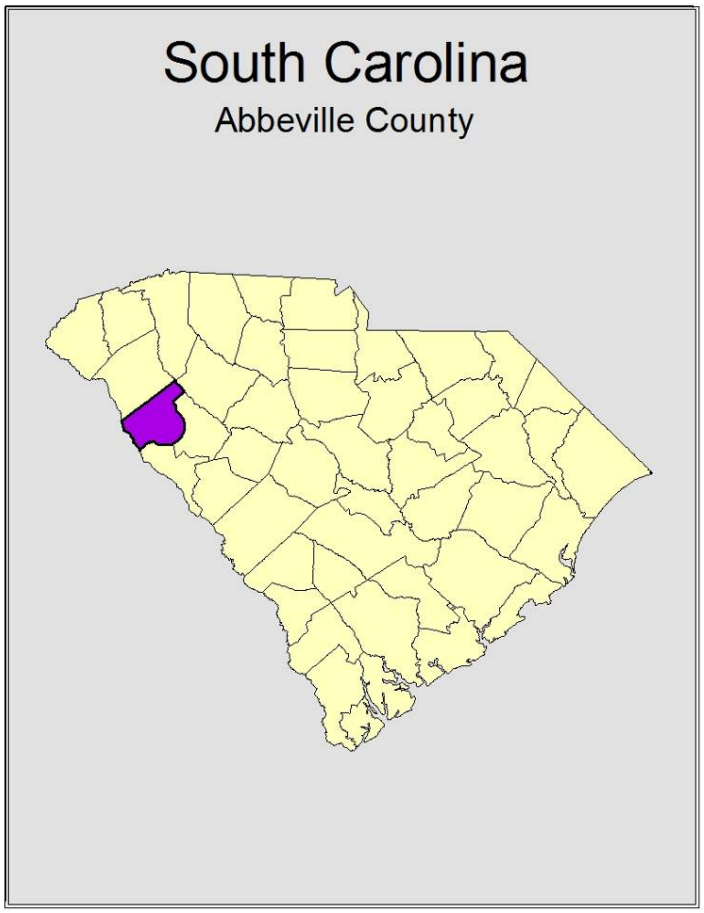

Figure 1: Vicinity map

The order of the Completeness/Usability Acceptance Criteria was modified for readability, but the status of each acceptance criteria is as follows:

CRITERIA	TESTED CHARACTERISTIC	STATUS
COMPLETENESS/USABILITY ACCEPTANCE CRITERIA		
1	Flight lines	PASS
2	Acquisition Parameters	PASS
3	GPS Trajectories	PASS
4	Metadata	PASS
5	USB external hard drives	PASS
6	File organization	PASS
7	File name	PASS
8	Format of LiDAR Mass Points	PASS
9	Format of DEM	PASS
10	Format of LiDAR Processing Report	PASS
11	Format of Accuracy Report	PASS
12	Georeferencing	PASS
13	Horizontal Units	PASS
14	Vertical Units	PASS
15	Horizontal Datum	PASS
16	Vertical Datum	PASS
17	Coordinate System	PASS
18	Mass points	PASS
19	Elevation	PASS
20	Conformance of tiles to index grid	PASS

CRITERIA	TESTED CHARACTERISTIC	STATUS
VERTICAL AND HORIZONTAL ACCURACY ACCEPTANCE CRITERIA		
21	FEMA Ground Cover Category Accuracy Validation	PASS
22	ASPRS/NDEP Vertical Accuracy Validation	PASS
23	NSSDA Horizontal Accuracy	PASS
LiDAR Acceptance Criteria		
24	Ground	PASS
25	Continuity	PASS
26	Inconsistent Post-Processing/Editing	PASS
27	Over-smoothing	PASS
28	Artifacts	PASS
29	Content	PASS
BREAKLINE ACCEPTANCE CRITERIA		
30	Completeness	PASS
31	Monotonicity	PASS
32	Vertical Consistency	PASS
33	Topology	PASS
INTENSITY ACCEPTANCE CRITERIA		
34	Intensity	PASS

Table 2: Acceptance status summary table

2) Overview

Aerometric, Inc. has reviewed the Abbeville County portion of the Six County SC LiDAR Quality Assurance as outlined in the SC Acceptance Criteria (Criteria). Automated checks and functionality of data has been evaluated for the entire project area, and manual/visual reviews were performed for 10% of the project area. This report was prepared to follow the Criteria's outline, which covers four categories – Completeness/Usability Acceptance Criteria, Vertical and Horizontal Accuracy Acceptance Criteria, LiDAR Acceptance Criteria, and Breakline Acceptance Criteria. These four criteria areas and their associated sub-categories are described in the following narrative.

3) Completeness/Usability Acceptance Criteria

This portion of the SC Acceptance Criteria focuses on the fundamental elements of the project deliverables provided by Dewberry. The order of the Criteria outline was modified for readability, and divided into three categories: data format, project location, and project data. These categories and their compliance are described as follows:

DATA FORMAT

The first check of the submittal was checking that the media was readable, all files were accessible, and no files were corrupted.

As required, project metadata should be an overview of the entire A-to-Z project in terms of a single XML metadata. The deliverable file level metadata is in XML format as required. The metadata for bare-earth and breaklines is in a FGDC-compliant tile level. All the deliverable files pass the requirement validation of the Metadata Parser software from the USGS website. Also, it was noted that the XML metadata combined Stream Centerlines and Stream Connectors.

The file naming convention appears to adhere to the South Carolina Geodetic Survey 1:200-scale index. The LAS files and intensity images were written one per 5000' x 5000' (Item 6).

The DEM was provided for the full county in International Feet, Arc Grid Format, 3 decimal places in elevation, and with a format 10-foot grid spacing as required.

The Criteria required the LiDAR Processing Report and Accuracy Report to be provided as a PDF or Microsoft Office Word 2007 document is met.

PROJECT LOCATION

As required, the project files open in the correct location and conform to the tile index grid. No gaps were found between the tiles at a 1:1 view. Tiles were calculated for the minimum and maximum X and Y coordinates to equal a full 5000 ft tile. Those tiles that didn't equal the 5000 ft of the height or width were reviewed and confirmed that they were part of the project boundary or contained no data because of water restricting the sensor return.

The horizontal and vertical units are two decimal places. The horizontal units are in international feet and the vertical units are in US survey feet as required. Additionally, the horizontal datum is in NAD 83 NSRS, and project files are projected on the 3900 South Carolina State Plane Coordinate System to meet the Criteria. The vertical datum is in NAVD 88 processed with Geoid09 as required.

The content of deliverable products is completed to the full boundary extent provided by the SC DNR for the county.

PROJECT DATA

The first item outlined in the Criteria states that flight lines are directed to be flown as planned with 45% minimum overlap between flight lines and a maximum flying height of ≈8,300 ft AMT. According to the metadata, the flight lines were flown with a sidelap of 50% with a target altitude of 1,500 meters (4920') and based on the stated flight parameters meet the criteria. Additionally, the Positional Dilution of Precision (PDOP) needed to be less than 4, and the collected data could not have holidays. The flightlines were visually checked for gaps and assured that they contained enough sidelap. Also, the flight collection was required to have periodic and local calibration checks. The figures below show the extents of overlap:

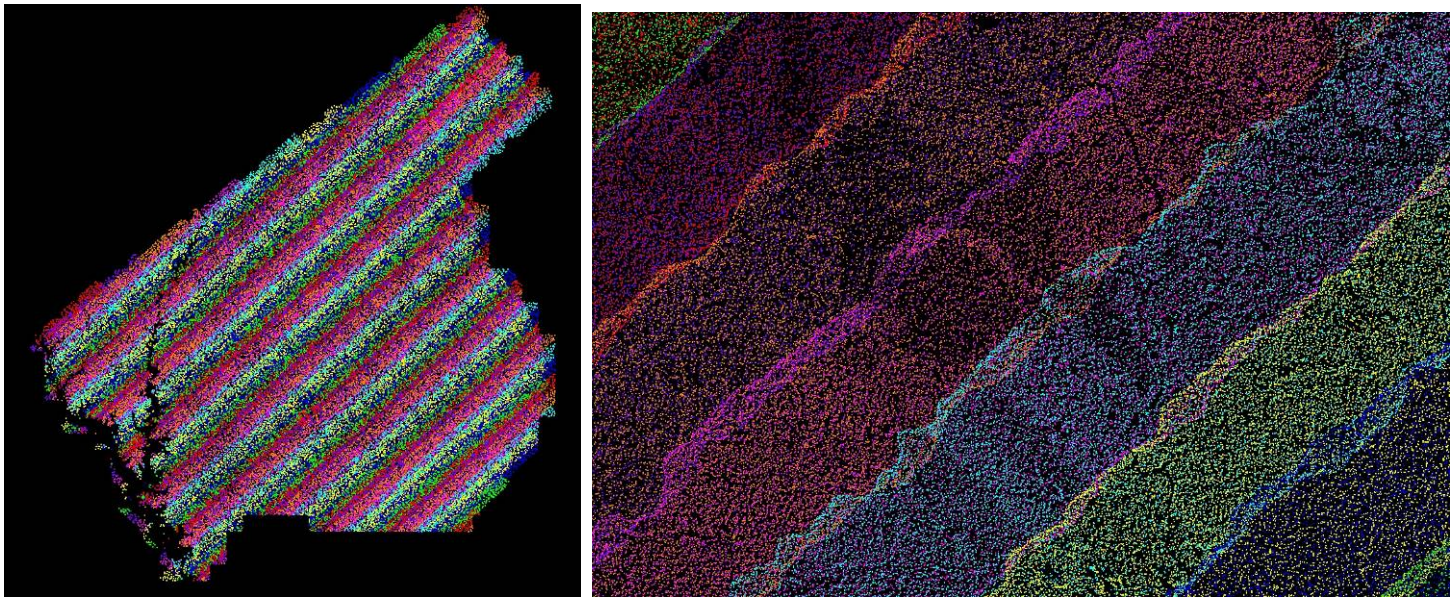

Figure 2: Overall project flight line exhibit (left) and enlarged view (right)

The acquisition parameters require GPS baseline lengths to be less than 25 miles. The field of view Criteria is 40 degrees, the captured field of view is absent from the metadata. Given ±20 degrees scan angle from nadir, the field of view would be 40 degrees, therefore it met the criteria. For further information on the flight acquisition, see the *"LiDAR Acquisition and Control Survey Report",* provided by Towill, which is located on the FTP site. The extensive report consists of: equipment, procedures, graphs, plots, processing, maps, etc.

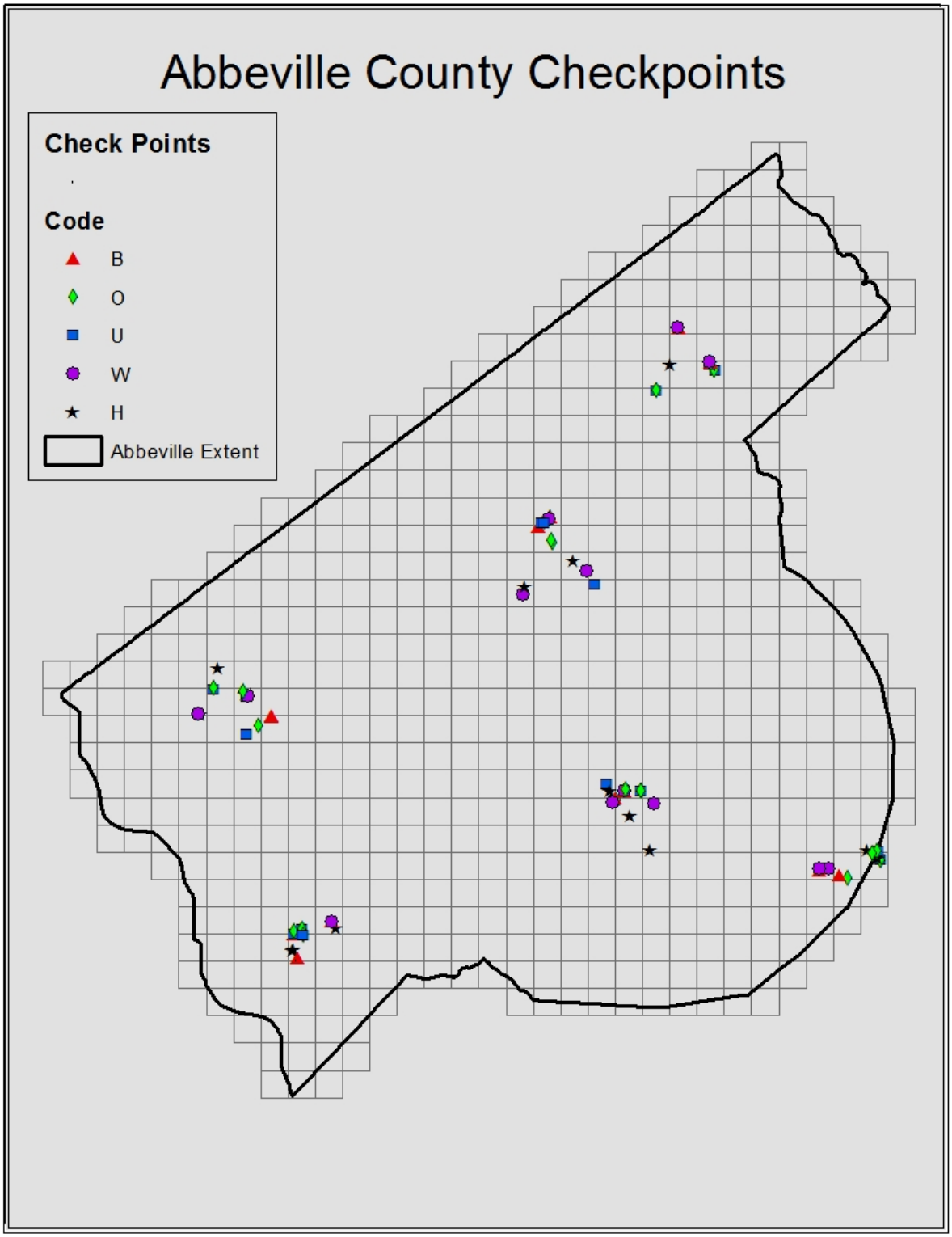

Figure 3: Abbeville county survey checkpoints

Additionally, the Criteria require the GPS trajectories to be evaluated with forward and reverse comparisons within 10-20 cm. The GPS solution charts are provided in the Appendix of this report and conform to the Criteria. The GPS solution charts below represent the Combining of the forward GPS solution and the reverse solution. The forward solution is the processing of the GPS data from the start of a mission to the end of a mission. The reverse solution is the processing of the GPS data from the end of the mission to the start of a mission. The red line represents the combined solution in relationship of the east component of the data. The green line represents the combined solution in relationship to the north component of the data. The blue line represents the combined solution of the vertical component of the data. In *figure 11*, it should be noted that the vertical component (blue line) appears to be very noisy and jagged, this is a result of a less dynamic solution of the vertical agreement between the forward and reverse GPS solution of the data. In simple terms the vertical component of the data did not agree as well as in the other *figures (4-11)* but is well within the required tolerances. This is not an indication of an error in the data but representing a difference in the two solutions. Providing, the GPS Combined solution is within tolerance as required this will not affect the overall LiDAR Data.

The format of LiDAR Mass Points has a nominal post spacing of 1.4 meters. The mass points were provided as Point Data Format 1 with the LAS 1.2 classification codes:

- Class 1 = Unclassified (non-ground)
- Class 2 = Ground (bare-earth)
- Class 7 = Noise
- Class 8 = Model Key Points
- Class 9 = Water/Hydro
- Class 10 = Ignored Ground
- Class 11 = Withheld Points
- Class 13 = Points removed from bridges

The Class 1 points are more specifically defined as unclassified, and used for all other features that do not fit into the Classes 2, 7, 8, 9, 10, 11, or 13 including vegetation, buildings, etc. by the Dewberry Report. An automated routine was performed to confirm only the classes noted above were used for point classification throughout the project.

According to the Criteria, the DEM must to have no null values and valid min/max stats. The breaklines must also match the elevations. The automated review of the DEM confirms that it has no null values and the breaklines match the elevations. The minimum and maximum DEM elevations are 320.7 ft and 830.909 ft respectively, and the minimum and maximum LAS are 321.03 ft and 831.16 ft respectively. Also, the Terrain Model fits in closely with the minimum and maximum values of 321 ft and 831.16 ft. These values are reasonably close to each other.

4) Vertical and Horizontal Accuracy Acceptance Criteria

As stated in the Criteria, the ground cover category accuracy validation is required, per Section A.8.6.2, Appendix A, to FEMA's "Guidelines and Specifications for Flood Hazard Mapping Partners," to acquire 20 check points for each of the following five categories: Bare Earth, High Grass/Crops, Scrub/Brush, Forested, and Urban areas. According to the Abbeville LiDAR Description document, only 13 check points were recorded for category of Brush areas. High Grass fell just short of 20 with 15 check points. Urban terrain recorded 17 check points. Open Terrain hit the goal of 20 check points. Woodland areas recorded 13 check points. Within the Woodland classification, survey point **1-4-9** was omitted from the statistical calculation because of it was considered an erroneous point.

As stated in the Criteria, the NSSDA/FEMA vertical accuracy validation must be tested in accordance with NSSDA and FEMA Vertical Accuracy Testing Guidelines, which states that, for two ft contour accuracy:

Accuracy requirement = 1.19 ft or 36.3 cm at 95% confidence level
$RMSE_z$ target = 0.61 ft or 18.5 cm

Ground Classification	# of Points	$RMSE_z$ (ft) Open Terrain Max* = 0.61 ft	$Accuracy_z$ at 95% Confidence Level Max* = 1.19 ft	Mean	Standard Deviation	Min	Max
OPEN TERRAIN	20	0.224	±0.439	0.139	0.180	-0.279	0.388
HIGH GRASS	15	0.397	±0.636	0.319	0.244	-0.310	0.728
BRUSH	13	0.416	±0.684	0.360	0.216	0.083	0.833
FORESTED	13	0.384	±0.605	0.213	0.333	-0.555	0.630
URBAN	17	0.125	±0.235	0.003	0.129	-0.341	0.209
ALL POINTS	79	0.405	±0.600	0.162	0.373	-2.267	0.833

Table 3: Confidence level for vertical accuracy in feet

Ground Classification	# of Points	FVA - Fundamental Vertical Accuracy (RMSEz * 1.96) Max = 1.19 ft	SVA - Supplemental Vertical Accuracy 95th Percentile Max = 1.19 ft	CVA - Consolidated Vertical Accuracy 95th Percentile Max = 1.19 ft
OPEN TERRAIN	20	±0.439	-	-
HIGH GRASS	15	-	±0.636	-
BRUSH	13	-	±0.684	-
FORESTED	14	-	±0.605	-
URBAN	17	-	±0.235	-
ALL	79	-	-	±0.589

Table 4: Fundamental, Supplemental, and Consolidated Vertical Accuracy at the 95th Percentile

The fundamental and consolidated vertical accuracy testing in the required terrains passed the USGS LiDAR specification. The vertical accuracy testing was completed in a software program called TopoAnalyst, which generated a PDF document *(TopoAnalyst_Abbeville.pdf)*. This document breaks down each category of land cover survey control points for further analysis.

The Criteria also states that the NSSDA horizontal accuracy requires breaklines to be compiled to meet RSMEz of 1 meter. The visual inspection of vertices in 10% of the project area found that water bodies, single stream, connector, and stream banks were generally collected accordingly. These breaklines are recommended to "Pass."

5) LiDAR Acceptance Criteria

As stated in the Criteria, the Ground Points (Bare Earth) surface must be post-processed to remove 98% of structure points and 95% of vegetation points. The visual inspection of 10% of the project area confirms that 95% of vegetation and 98% of structure points have been removed. Although, it was observed that some points around structures were left in as ground, the data is acceptable. A few points consisted of possible landscape items, bushes, steps or points that ride up the side walls of the building. Overall, the Criteria is met of 95% of vegetation and 98% of structure points being removed.

The Criteria also states that there can be no data voids greater than two times post spacing (2.8 meters) and no vertical offsets greater than 20 cm between adjoining strips and/or tiles. USGS Standards require that 90% of all points meet two times post spacing, which was confirmed in Item 8 of the Acceptance Criteria. An automated routine was used to confirm that more than 90% of points have another point within 2.8 meters per USGS Standards. Those LAS_files that didn't confirm a ≥ 90% of points having a point within 2.8 meters were visually reviewed. These reviewed LAS_files were part of the project boundary and/or had hydrology of some degree; therefore it passed the USGS Standard. No vertical offsets greater than 20 cm were observed during the 10% visual check.

There are to be no visible variations in TIN/DTM caused by differing processing techniques. As a result of the visual check, this item is recommended to pass this phase of the review.

The Criteria requires that smoothing techniques shall not remove topographic features necessary to define drainage features, and 90% of artifacts must be removed with no spikes, holes, or blunders, and no cornrows or seamline mismatches greater than 20 cm. The visual inspection of 10% of the project area confirms that the smoothing techniques did not remove topographic features necessary to define features, and artifacts were removed accordingly.

6) Breakline Acceptance Criteria

The Criteria requires that breaklines must be collected for all streams larger than 40 feet in width and for waterbodies 1 acre in size or greater. Single Drain breaklines must be created for streams with features less than 40 ft in width. Stream Connectors should be used to show flow between hydrology features at culverts and similar feature type locations. The visual inspection of 10% of the project area found that Stream Connector/Centerlines meet the Criteria. Streams greater than forty feet in width and waterbodies greater than one acre in size were collected during the visual check.

The Criteria also requires hydro-collection for downhill direction of stream flow. The visual inspection of hydro breaklines in 10% of the project area found that the river breaklines match this Criteria, and as a result, this item is recommended to “Pass.” An automated check was performed to locate monotocity errors on the Single Line Drains, which proved downhill flow consistently.

As stated in the Criteria, vertical consistency of the breaklines shall meet the following criteria:

- Vertices should not have a 0 elevation
- Vertices should not have excessive min or max z-values when compared to adjacent vertices
- Vertical variance between breaklines & LiDAR DTM < 1 ft

The visual inspection of hydro breaklines in 10% of the county meet the Criteria of vertices not having a 0 elevation and vertices shouldn't have an excessive min or max z-values when compared to adjacent vertices. Stream Connectors match elevations to Stream Centerlines and Single Line Drains vertexes as required.

As stated in the Criteria, breaklines should not intersect unless set at the same elevation, with an exception made for bridges and overpasses that intersect hydrographic features. The visual inspection of 10% of the project area confirms that the breaklines were collected as noted.

7) Intensity Acceptance Criteria

The intensity imagery was successfully brought into ArcMap and fit perfectly with the tile index. All 664 intensity images are accounted for. Additionally, several of the tiles were viewed to confirm the imagery appeared to adequately reflect the imagery as anticipated.

Approval Statement

All of the corrections and modifications recommended by Aerometric on behalf of the South Carolina Department of Natural Resources and US Geological Survey have been made to the LiDAR data for Abbeville County. We recommend that the LiDAR data for Abbeville County be accepted as final. Please note that the assessment of the LiDAR data and its derivative products is based on a combination on automated validation tools applied to 100% of the data and a manual analysis of approximately 10% of the land surface area for that county, which Aerometric believes is sufficient in detecting the vast majority of significant errors. Minor errors may still remain. Any significant anomalies discovered by subsequent use of the data should be brought to the attention of SCDNR."

8) Appendix

Criteria	Tested Characteristic	Measure of Acceptability
Completeness/Usability Acceptance Criteria		
1.	Flight lines	Flight lines flown as planned with 45% minimum sidelap between flight lines, flying height (≈8,300' AMT), PDOP ≤ 4; no holidays; periodic, local, calibration checks.
2.	Acquisition Parameters	GPS baseline lengths <25 miles; scan angles of ±20° from nadir; FOV 30°.
3.	GPS Trajectories	Forward and reverse comparisons within 10-20 cm.
4.	Metadata	-Project metadata should be an overview of the entire A-to-Z project in terms of a single XML metadata file. -A single XML metadata is also required for each deliverable data layer, i.e. for LAS, geodatabase file, Bare-earth DEM, Hillshade, Intensity images, Hydro breaklines, and all feature data layers. -XML files must pass validation using Metadata Parser (mp) software.
5.	USB external hard drives (Firewire) make/model coordinated with DEM	Media is readable, all files accessible, no files corrupted.
6.	File organization	Files written one per 5000' x 5000' for LAS and intensity images. DEMs, breaklines and terrains will be full county (International Foot).
7.	File name	Files named will follow the SC Geodetic Survey 1:200-scale index provided by the SC DNR.
8.	Format of LiDAR Mass Points	LAS, nominal post spacing 1.4 meters.
9.	Format of bare-earth DEM	ARC GRID Format, 10-foot grid spacing.
10.	Format of LiDAR Processing Report	PDF or MS Word 2007 document.
11.	Format of Accuracy Report	PDF or MS Word 2007 document.
12.	Georeferencing	Opens in correct location and conforms to the master index grid.
13.	Horizontal Units	3 decimal places, in International Feet for all products.
14.	Vertical Units	3 decimal places, in US Survey Feet for LAS and terrain products; Floating Point units to 6 decimal places, in US Survey Feet for DEM.
15.	Horizontal Datum	NAD83 (NSRS 2007).
16.	Vertical Datum	NAVD 88, processed with Geoid09.
17.	Coordinate System	3900 羊 South Carolina State Plane Coordinate System.
18.	Mass points	Point cloud with nominal post spacing of 1.4 m. LAS 1.2 classification codes: Class 1 = Unclassified (non-ground) Class 2 = Ground (bare-earth) Class 7 = Noise Class 8 = Model Key Points Class 9 = Water/hydro Class 10 = Ignored Ground Class 11 = Withheld Points Class 13 = Points removed from bridges
19.	Elevation	For DEM: no null values, valid min/max stats, elevation matches breaklines. Grid to be built using Natural Neighbor algorithm in ArcGIS.
20.	Conformance of tiles to index grid	Tiles match index grid, no gaps between tiles at 1:1 view. Tiles must be complete except for boundary tiles.
Vertical and Horizontal Accuracy Acceptance Criteria		

21.	FEMA Ground Cover Category Accuracy Validation	Tested in accordance with Section A.8.6.2, Appendix A, to FEMA's "Guidelines and Specifications for Flood Hazard Mapping Partners" for 5 categories: (1) bare-earth, low grass; (2) high grass & crops; (3) scrub/brush; (4) forested; (5) urban areas.
22.	Vertical Accuracy Validation	The SC DNR requires that all LiDAR products generated through this project must meet the USGS LiDAR Version 13 specifications: Fundamental Vertical Accuracy (FVA) in open terrain = 15.0 cm $RMSE_z$ = 29.4 cm vertical accuracy; Consolidated Vertical Accuracy (CVA) = 36.3 cm or 1.19 ft and Supplemental Vertical Accuracy (SVA) for vegetated categories = 36.3 cm or 1.19 ft each based on the 95th percentile errors.
23.	NSSDA Horizontal Accuracy	Compiled to meet $RMSE_r$ of 1 meter.
LiDAR Acceptance Criteria		
24.	Ground Points (Bare Earth)	Post-processed to remove 98% of structures and 95% of vegetation.
25.	Continuity	No data voids >2X post spacing. No vertical offsets > 20 cm between adjoining strips and/or tiles.
26.	Inconsistent Post Processing/Editing	No visible variations in TIN/DTM caused by differing processing techniques.
27.	Over-smoothing	Smoothing techniques shall not remove topographic features necessary to define drainage features.
28.	Artifacts	90% of artifacts removed; no spikes, holes, or blunders; no cornrows or seamline mismatches > 20 cm.
29	Content	All deliverable products must be completed to the full boundary extent provided by the SC DNR for each county.
Breakline Acceptance Criteria		
30.	Completeness	Hydrofeatures must be collected for drainage areas of ½ square mile or greater. Breaklines collected for all streams larger than 40 feet in width and for water bodies 1 acre in size or greater. Single line streams for features less than 40 ft. Stream connector/centerlines should be used to show flow between interconnecting rivers and streams at culverts and similar feature type locations. See Work Plan for more collection information. The drainage pattern for collected hydro features should exceed the density of the 1:24,000-scale National Hydrography Dataset (NHD) in most instances.
31.	Monotonicity	Hydro correction for downhill direction of stream flow is required.
32.	Vertical Consistency	• Vertices should not have a 0 elevation • Vertices should not have excessive min or max z-values when compared to adjacent vertices • Vertical variance between breaklines & LiDAR DTM < 1 ft
33.	Topology	Breaklines should not intersect unless the same elevation; but bridges and overpasses may intersect hydrographic features. Polygon Z are required for all stream banks and water bodies.
Intensity Acceptance Criteria		
34.	Intensity	Intensity Images to be reviewed and evaluated.

Table 5: Acceptance Status Summary Table

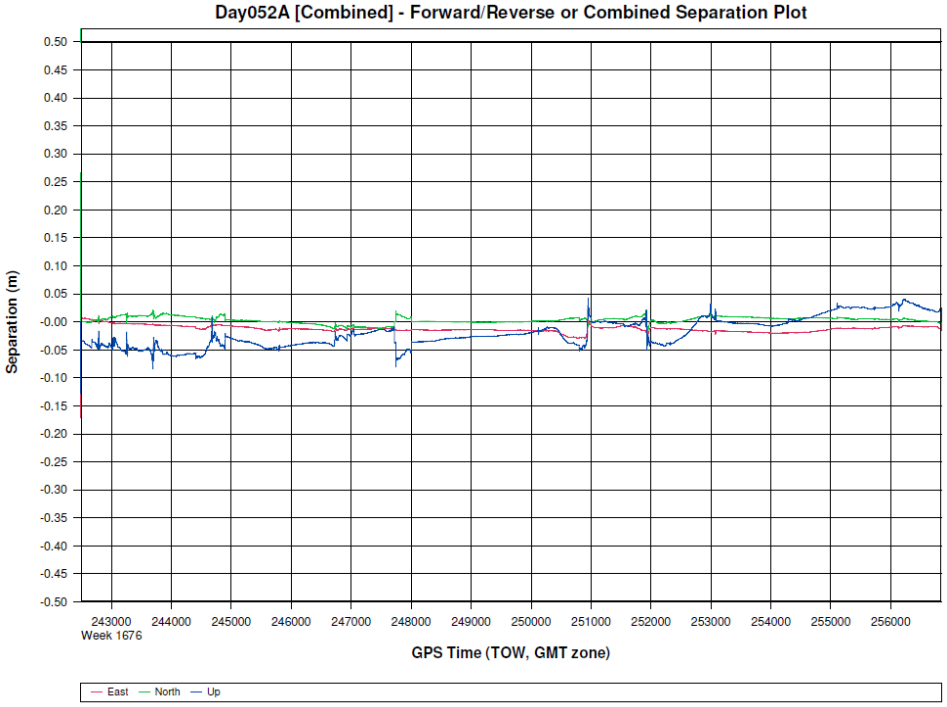

Figure 4: GPS Forward/Reverse Processing Chart – Day 052A

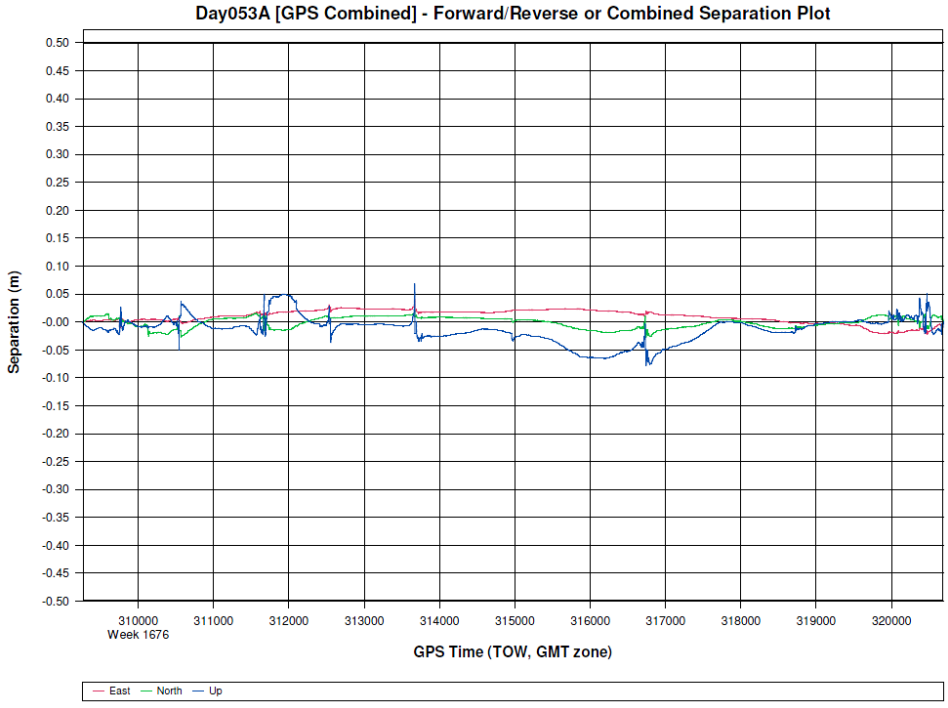

Figure 5: GPS Forward/Reverse Processing Chart – Day 053A

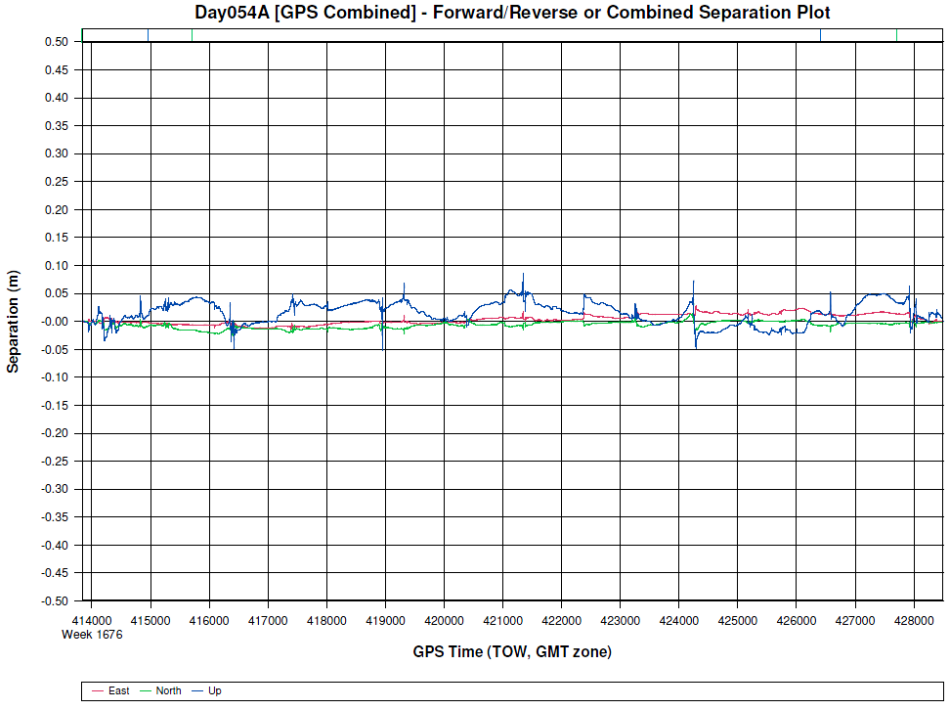

Figure 6: GPS Forward/Reverse Processing Chart – Day 054A

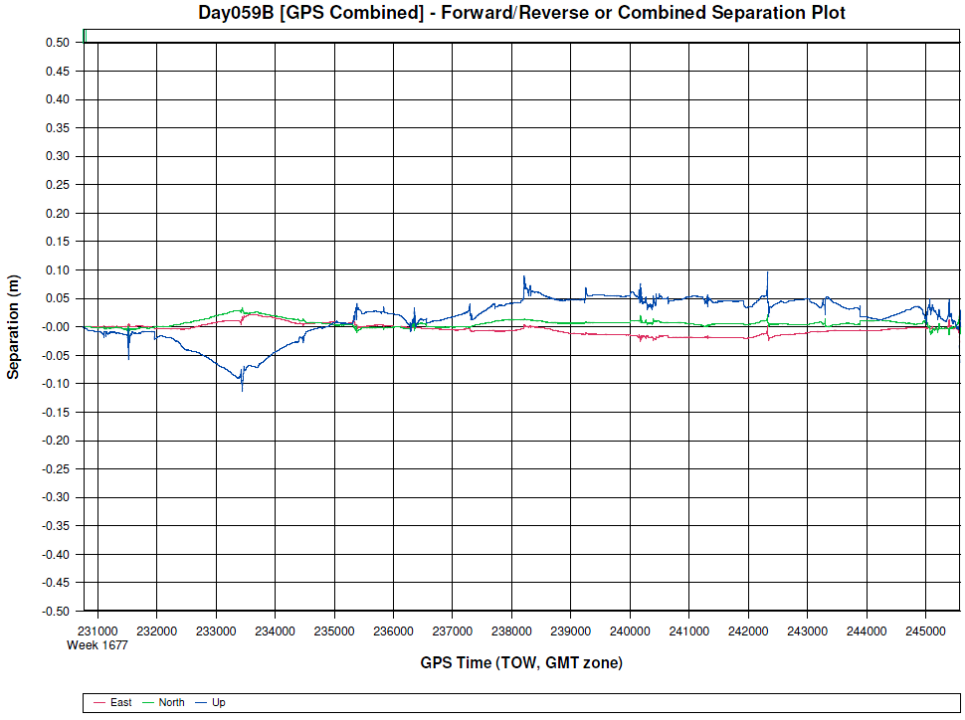

Figure 7: GPS Forward/Reverse Processing Chart – Day 059B

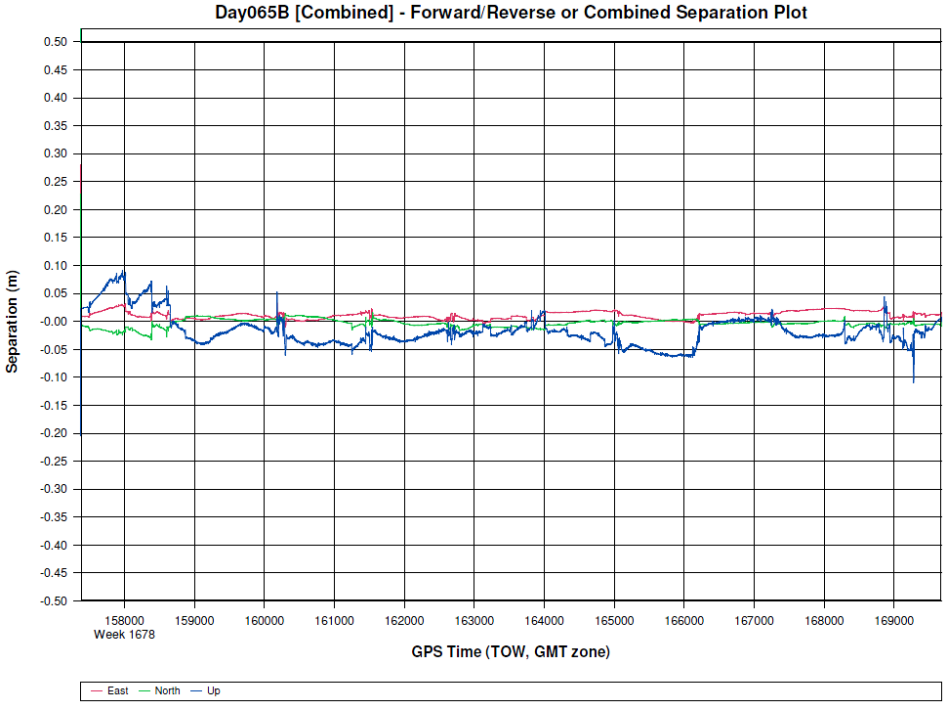

Figure 8: GPS Forward/Reverse Processing Chart – Day 065B

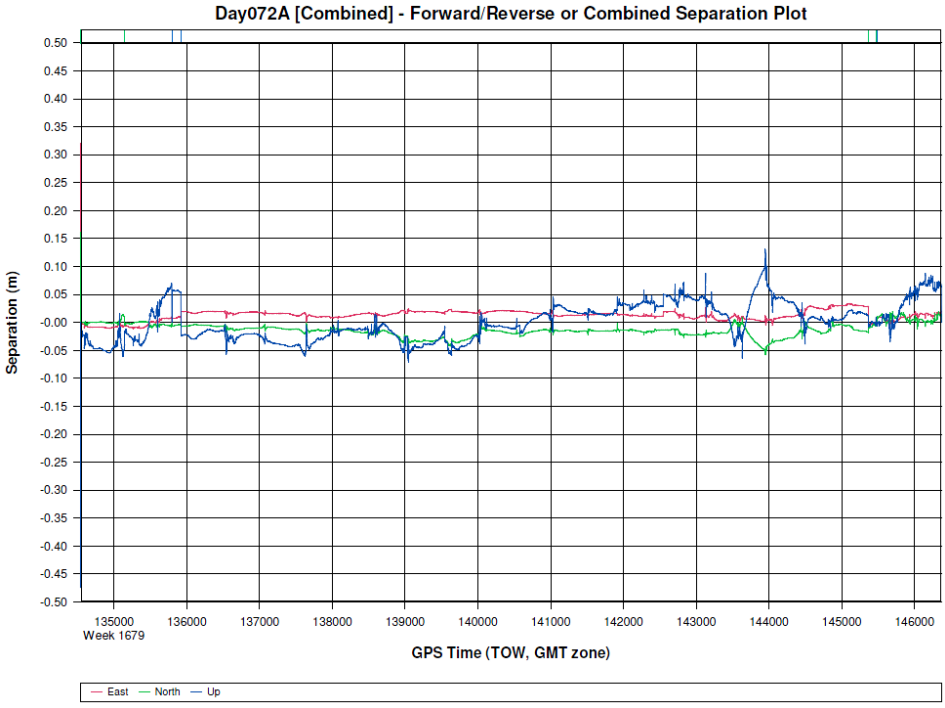

Figure 9: GPS Forward/Reverse Processing Chart – Day 072A

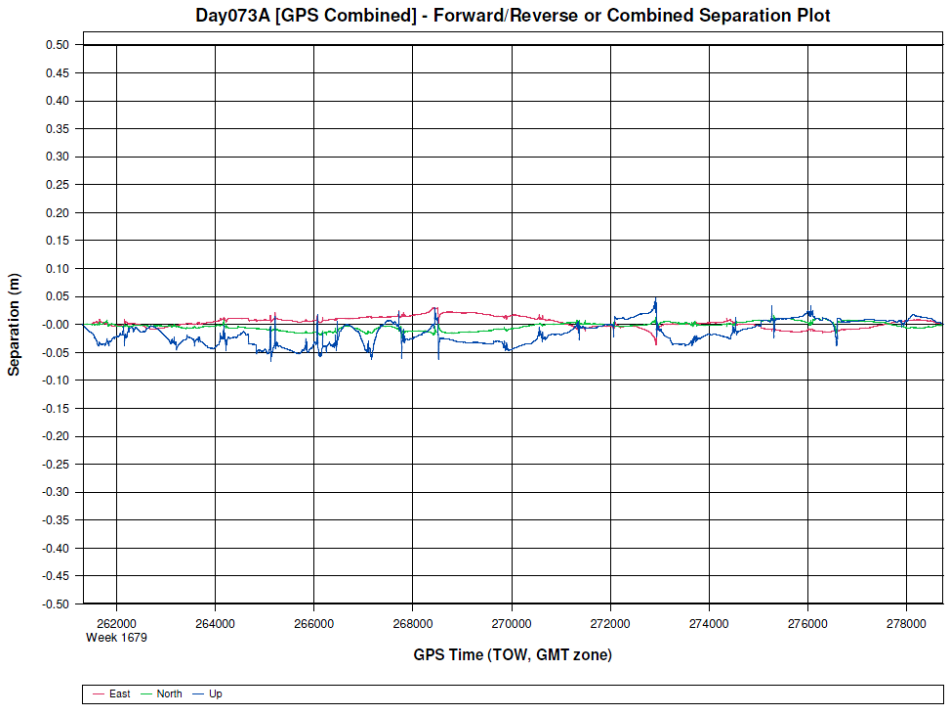

Figure 10:GPS Forward/Reverse Processing Chart – Day 073A

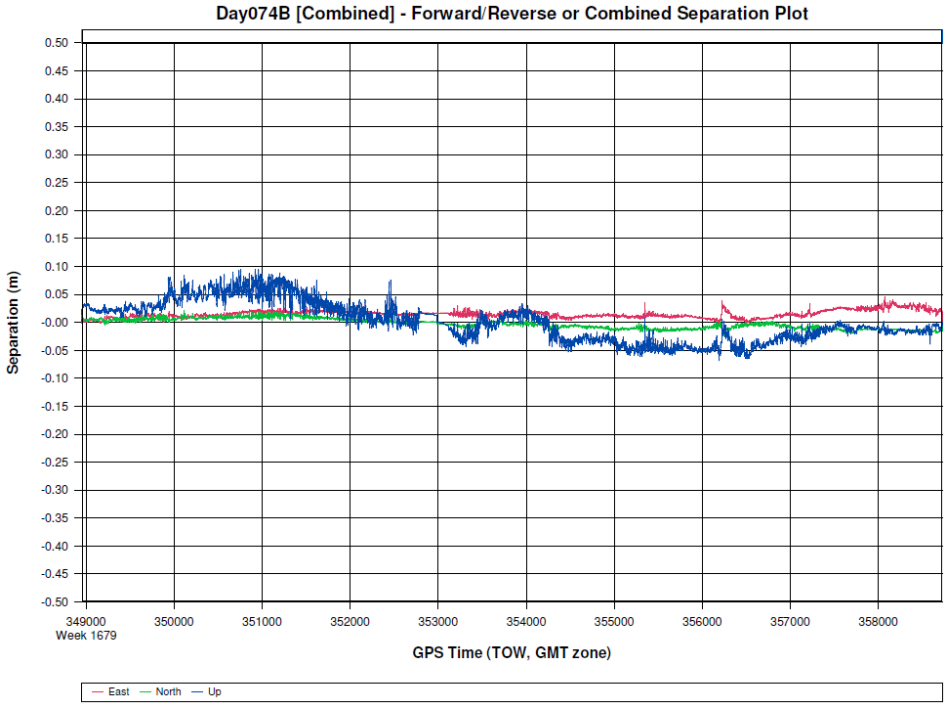

Figure 11: GPS Forward/Reverse Processing Chart – Day 074B