# FINAL REPORT OF SPECIFIC PURPOSE LIDAR SURVEY

## LiDAR, Breaklines and Contours for

## City of Live Oak, Florida

**Add-On Agreement to**

**State of Florida**

**Division of Emergency Management**

**Contract 07-HS-34-14-00-22-469**

**January 19, 2009**

**Prepared by:**


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**Final Report of Specific Purpose LiDAR Survey, including**

**LiDAR-Generated Breaklines and Contours for City of Live Oak, Florida**

**City of Live Oak Add-On Agreement to**

**FDEM Contract 07-HS-34-14-00-22-469**

For:
**City of Live Oak, Florida**
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# Report of Specific Purpose LiDAR Survey, LiDAR-Generated Breaklines and Contours City of Live Oak, Florida

## Type of Survey: Specific Purpose Survey

This report pertains to a Specific Purpose LiDAR Survey of the city of Live Oak, Florida, located within Suwannee County. The LiDAR aerial acquisition was conducted by Terrapoint USA on January 22, 2008, and the breaklines and contours were subsequently generated by Dewberry. The PDS team is under contract 07-HS-34-14-00-22-469 with the Florida Division of Emergency Management (FDEM) and offered LiDAR and derived products to add-on clients, including the City of Live Oak, at the same rates as negotiated for the FDEM contract and utilizing the same Baseline Specifications from FDEM.

The LiDAR dataset of Live Oak was acquired by Terrapoint USA and processed to a bare-earth digital terrain model (DTM) in accordance with FDEM Baseline Specifications. Detailed breaklines and contours were produced by the PDS team for a 16-tile area to be mapped. Each tile covers an area of 5000 ft by 5000 ft. The map at Appendix A displays the 16 tiles of Live Oak for which LiDAR DTMs and LiDAR-derived breaklines and contours were produced by the PDS team.

The FDEM Baseline Specifications require a maximum LiDAR post spacing of 4 feet, i.e., an average point density of less than 1 point per square meter. However, the PDS team required a much higher point density of its subcontractors in order to increase the probability of penetrating dense foliage; with nominal post spacing of 0.7 meters per flight line and 50% sidelap between flight lines, the average point density is 4 points per square meter. With higher point density there is a greater probability of penetrating dense vegetation and minimizing areas defined as "low confidence areas."

## The PDS Team

PDS is a Joint Venture consisting of PBS&J, Dewberry, and URS Corp:

- PBS&J provided local client liaison in Tallahassee. PBS&J was also responsible for the overall ground survey effort including management of field survey subcontractors – Allen Nobles & Associates, Inc. (ANA) and Diversified Design & Drafting Services, Inc. (3DS) – which performed the quality assurance/quality control (QA/QC) checkpoint surveys used for independent accuracy testing by Dewberry and URS. Mr. Glenn Bryan, PSM, of PBS&J, and Mr. Brett Wood, PSM, of 3DS, were the technical leads for the QA/QC surveys.

- Dewberry was responsible for the overall Work Plan and aerial survey effort, including management of LiDAR subcontractors that performed the LiDAR data acquisition and post-processing and produced LAS classified data. A staff of QA/QC specialists at Dewberry's office in Tampa, FL performed quality assessments of the breaklines and contours. Dewberry served as the single point of contact with FDEM and the add-on clients. Dr. David Maune, PSM, was Dewberry's technical lead for the digital orthophoto and LiDAR surveys and derived products.

- URS Corp. was responsible for data management and information management. URS developed the GeoCue Distributed Production Management System (DPMS), managed and tracked the flow of data, performed independent accuracy testing and quality assessments of FDEM's new LiDAR data acquired in 2007, tracked and reported the status of individual tiles during production, and produced all final deliverables for FDEM. Mr. Robert Ryan, CP, of URS, was the technical lead for this effort.

## Name of Company in Responsible Charge

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## Name of Responsible Surveyor

David F. Maune, PhD, PSM, PS, GS, CP, CFM
Florida Professional Surveyor and Mapper (PSM) No. LS6659

## Survey Area

The project area for this report encompasses 16 tiles, approximately 14.4 square miles, within the city of Live Oak, Florida, located within Suwannee County.

## Map Reference

There are no hardcopy map sheets for this project. The map at Appendix A provides graphical reference to the 5000-ft x 5000-ft tiles covered by this report.

## Summary of FDEM Baseline Specifications

All new data produced for the referenced contracts are required to satisfy the Florida Baseline Specifications included as appendices to PDS's Task Order C from FDEM, dated August 15, 2007, and Task Order D from FDEM, dated December 14, 2007. The tiling scheme, shown at Appendix A, is based on the Florida State Plane Coordinate System, North Zone.

The Florida Baseline Specifications required the LiDAR data to be collected using an approved sensor with a maximum field of view (FOV) of 20˚ on either side of nadir, with GPS baseline distances limited to 20 miles, with maximum post spacing of 4 feet in unobscured areas for random point data, and with vertical root mean square error ($RMSE_z$) ≤ 0.30 ft and Fundamental Vertical Accuracy (FVA) ≤ 0.60 ft at the 95% confidence level in open terrain (bare-earth and low grass); this accuracy is equivalent to 1 ft contours in open terrain when tested in accordance with the National Map Accuracy Standard (NMAS). In other land cover categories (brush lands and low trees, forested areas fully covered by trees, and urban areas), the Florida Baseline Specifications required the LiDAR data's $RMSE_z$ to be ≤ 0.61 ft with Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA) ≤ 1.19 ft at the 95% confidence level; this accuracy is equivalent to 2 ft contours when tested in accordance with the NMAS. *Low confidence areas*, originally called *obscured vegetated areas*, are defined for areas where the vertical data may not meet the data accuracy requirements due to heavy vegetation.

The Florida Baseline Specifications also require the horizontal accuracy to meet or exceed 3.8 feet at the 95% confidence level, using $RMSE_r$ x 1.7308. This means that the horizontal (radial) RMSE ($RMSE_r$) must meet or exceed 2.20 ft. This is the horizontal accuracy required of maps compiled at a scale of 1:1,200 (1" = 100') in accordance with the traditional National Map Accuracy Standard.

To meet and exceed these specifications, the PDS team established the following more-rigorous specifications for its LiDAR subcontractors:

- Instead of a 20˚ FOV on either side of nadir, the PDS team limited the FOV to 18˚
- Instead of GPS baselines ≤ 20 miles, the PDS team limited baseline lengths to ≤ 20 km, except in one small isolated area where the baseline length was approximately 23 km (14 miles).
- Instead of 4 foot post spacing which yields an average of 0.67 points per $m^2$, the PDS team chose 0.7 m point spacing and 50% sidelap that yields an average of 4 points per $m^2$. Thus, the PDS team's average point density is nearly 6 times higher than required by FDEM, greatly increasing the probability of LiDAR points penetrating through dense vegetation so as to minimize areas defined as *low confidence areas*. The PDS team defines *low confidence areas* as vegetated areas of ½ acre or larger that are considered obscured to the extent that adequate vertical data cannot be clearly determined to accurately define the DTM. Such areas indicate where the vertical data may not meet the data accuracy requirements due to heavy vegetation.

The first deliverable is LiDAR mass points, delivered to LAS 1.1 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, or 12, including vegetation, buildings, etc.
- Class 2 = Ground, includes accurate LiDAR points in overlapping flight lines
- Class 7 = Noise, includes LiDAR points in overlapping flight lines
- Class 9 = Water, includes LiDAR points in overlapping flight lines
- Class 12 = Overlap, including areas of overlapping flight lines which have been deliberately removed from Class 1 because of their reduced accuracy.

Per FDEM's Baseline Specifications, for each 500 square mile area a total of 120 "blind" QA/QC checkpoints were surveyed, totally unknown to (i.e., "blind" from) the LiDAR subcontractor. Each set of 120 QA/QC checkpoints had the goal to include 30 checkpoints in each of the following four land cover categories:

- Category 1 = bare-earth and low grass
- Category 2 = brush lands and low trees
- Category 3 = forested areas fully covered by trees
- Category 4 = urban areas

Because the 16 tiles for the city of Live Oak only encompassed 14.4 square miles instead of 500 square miles, only 2.88% of the normal 30 points per category (less than one point per category) is required. A total of five QA/QC checkpoints were used, as listed at Appendix D.

The following vertical accuracy guidelines were specified by the Florida Baseline Specifications:

- In category 1, the $RMSE_z$ must be ≤ 0.30 ft ($Accuracy_z$ ≤ 0.60 ft at the 95% confidence level); $Accuracy_z$ in Category 1 refers to Fundamental Vertical Accuracy (FVA) which defines how accurate the elevation data are when not complicated by asphalt or vegetation that may cause elevations to be either lower or higher than the bare earth terrain. This is equivalent to the accuracy expected of 1 ft contours in non-vegetated terrain.

- In category 2, the $RMSE_z$ must be ≤ 0.61 ft ($Accuracy_z$ ≤ 1.19 ft at the 95% confidence level); $Accuracy_z$ in Category 2 refers to Supplemental Vertical Accuracy (SVA) in brush lands and low trees and defines how accurate the elevation data are when complicated by such vegetation that frequently causes elevations to higher than the bare earth terrain. This is equivalent to the accuracy expected of 2 ft contours in such terrain.
- In category 3, the $RMSE_z$ must be ≤ 0.61 ft ($Accuracy_z$ ≤ 1.19 ft at the 95% confidence level); $Accuracy_z$ in Category 3 refers to Supplemental Vertical Accuracy (SVA) in forested areas fully covered by trees and defines how accurate the elevation data are when complicated by such vegetation that frequently causes elevations to be higher than the bare earth terrain. This is equivalent to the accuracy expected of 2 ft contours in such terrain.
- In category 4, the $RMSE_z$ must be ≤ 0.61 ft ($Accuracy_z$ ≤ 1.19 ft at the 95% confidence level); $Accuracy_z$ in Category 4 refers to Supplemental Vertical Accuracy (SVA) in urban areas typically paved with asphalt and defines how accurate the elevation data are when complicated by asphalt that frequently causes elevations to be lower than the bare earth terrain. This is equivalent to the accuracy expected of 2 ft contours in such terrain.
- In all land cover categories combined, the $RMSE_z$ must be ≤ 0.61 ft ($Accuracy_z$ ≤ 1.19 ft at the 95% confidence level); $Accuracy_z$ in all categories combined refers to Consolidated Vertical Accuracy (CVA).
- The terms FVA, SVA and CVA are explained in Chapter 3, *Accuracy Standards & Guidelines*, of "Digital Elevation Model Technologies and Applications: The DEM Users Manual," published by the American Society for Photogrammetry and Remote Sensing (ASPRS), January, 2007.

A second major deliverable consists of nine types of breaklines, produced in accordance with the PDS team's Data Dictionary at Appendix C:

1. Coastal shoreline features
2. Single-line hydrographic features
3. Dual-line hydrographic features
4. Closed water body features
5. Road edge-of-pavement features
6. Bridge and overpass features
7. Soft breakline features
8. Island features
9. Low confidence areas

Another major deliverable includes both one-foot and two-foot contours, produced from the mass points and breaklines, certified to meet or exceed NSSDA standards for one-foot contours. Two-foot contours within obscured vegetated areas are not required to meet NSSDA standards. These contours were also produced in accordance with the PDS team's Data Dictionary at Appendix C.

Table 1 is included below for ease in understanding the accuracy requirements when comparing the traditional National Map Accuracy Standard (NMAS) and the newer National Standard for Spatial Data Accuracy (NSSDA). This table is extracted from Table 13.2 of "Digital Elevation Model Technologies and Applications: The DEM Users Manual," published in January, 2007 by ASPRS. The traditional

NMAS uses Vertical Map Accuracy Standard (VMAS) to define vertical accuracy at the 90% confidence level, whereas the NSSDA uses $Accuracy_z$ to define vertical accuracy at the 95% confidence level. Both the VMAS and $Accuracy_z$ are computed with different multipliers for the very same $RMSE_z$ value which represents vertical accuracy at the 68% confidence level for each equivalent contour interval specified. The term $Accuracy_z$ (vertical accuracy at the 95% confidence level) is comparable to the terms described below as Fundamental Vertical Accuracy (FVA), Consolidated Vertical Accuracy (CVA) and Supplemental Vertical Accuracy (SVA) which also define vertical accuracy at the 95% confidence level. In open (non-vegetated) terrain, $Accuracy_z$ is exactly the same as FVA (both computed as $RMSE_z$ x 1.9600) because there is no logical justification for elevation errors to depart from a normal error distribution. In vegetated areas, vertical accuracy at the 95% confidence level ($Accuracy_z$) can also be computed as $RMSE_z$ x 1.9600; however, because vertical errors do not always have a normal error distribution in vegetated terrain, alternative guidelines from the National Digital Elevation Program (NDEP) and American Society for Photogrammetry and Remote Sensing (ASPRS) allow the 95$^{th}$ percentile method to be used (as with the CVA and SVA) to report the vertical accuracy at the 95% confidence level in land cover categories other than open terrain.

**Table 1. Comparison of NMAS/NSSDA Vertical Accuracy**

| **NMAS** Equivalent Contour Interval | **NMAS** VMAS (90 percent confidence level) | **NSSDA** $RMSE_z$ (68 percent confidence level) | **NSSDA** $Accuracy_z$, (95 percent confidence level) |
|---|---|---|---|
| 1 ft | 0.5 ft | 0.30 ft or 9.25 cm | 0.60 ft or 18.2 cm |
| 2 ft | 1.0 ft | 0.61 ft or 18.5 cm | 1.19 ft or 36.3 cm |

The next major deliverable includes metadata compliant with the Federal Geographic Data Committee's (FGDC) Content Standard for Spatial Metadata in an ArcCatalog-compatible XML format. Copies of all survey reports, including this Report of Specific Purpose LiDAR Survey, must be delivered in PDF format as attachments to the metadata.

The last major deliverable includes the Vertical Accuracy Report of Live Oak, based on independent comparison of the LiDAR data with the QA/QC checkpoints, surveyed and tested in accordance with guidelines of the National Standard for Spatial Data Accuracy (NSSDA), American Society for Photogrammetry and Remote Sensing (ASPRS), Federal Emergency Management Agency (FEMA), and National Digital Elevation Program (NDEP), and using the QA/QC checkpoints surveyed by PBS&J and listed at Appendix E. Unfortunately, with only five checkpoints total, and only one checkpoint in most land cover categories because of the small area involved, normal accuracy statistics cannot be run for the City of Live Oak. Alternative accuracy testing results are reported below; the average density of QA/QC checkpoints remains the same on average as with full countywide reports.

Datums and Coordinates: North American Datum of 1983 (NAD 83)/HARN for horizontal coordinates and North American Vertical Datum of 1988 (NAVD 88) for vertical coordinates. All coordinates are Florida State Plane Coordinate System (SPCS) in U.S. Survey Feet. The City of Live Oak, and all of Suwannee County, are in the Florida SPCS North Zone.

Appendix I to this report provides the Geodatabase structure for all digital vector deliverables in the city of Live Oak.

## Acronyms and Definitions

| | |
|---|---|
| 3DS | Diversified Design & Drafting Services, Inc. |
| $Accuracy_r$ | Horizontal (radial) accuracy at the 95% confidence level, defined by the NSSDA |
| $Accuracy_z$ | Vertical accuracy at the 95% confidence level, defined by the NSSDA |
| ANA | Allen Nobles & Associates, Inc. |
| ASFPM | Association of State Floodplain Managers |
| ASPRS | American Society for Photogrammetry and Remote Sensing |
| CFM | Certified Floodplain Manager (ASFPM) |
| CMAS | Circular Map Accuracy Standard, defined by the NMAS |
| CP | Certified Photogrammetrist (ASPRS) |
| CVA | Consolidated Vertical Accuracy, defined by the NDEP and ASPRS |
| DEM | Digital Elevation Model (gridded DTM) |
| DTM | Digital Terrain Model (mass points and breaklines to map the bare earth terrain) |
| DSM | Digital Surface Model (top reflective surface, includes treetops and rooftops) |
| FDEM | Florida Division of Emergency Management |
| FEMA | Federal Emergency Management Agency |
| FGDC | Federal Geographic Data Committee |
| FOV | Field of View |
| FVA | Fundamental Vertical Accuracy, defined by the NDEP and ASPRS |
| GS | Geodetic Surveyor |
| LAS | LiDAR data format as defined by ASPRS |
| LiDAR | Light Detection and Ranging |
| MHHW | Mean Higher High Water |
| MHW | Mean High Water, defines official shoreline in Florida |
| MLLW | Mean Lower Low Water |
| MLW | Mean Low Water |
| MSL | Mean Sea Level |
| NAD 83 | North American Datum of 1983 |
| NAVD 88 | North American Vertical Datum of 1988 |
| NDEP | National Digital Elevation Program |
| NMAS | National Map Accuracy Standard |
| NOAA | National Oceanic and Atmospheric Administration |
| NSSDA | National Standard for Spatial Data Accuracy |
| NSRS | National Spatial Reference System |
| NWFWMD | Northwest Florida Water Management District |
| PDS | Program & Data Solutions, joint venture between PBS&J, Dewberry and URS Corp |
| PS | Photogrammetric Surveyor |
| PSM | Professional Surveyor and Mapper (Florida) |
| QA/QC | Quality Assurance/Quality Control |
| $RMSE_h$ | Vertical Root Mean Square Error (RMSE) of ellipsoid heights |
| $RMSE_r$ | Horizontal (radial) Root Mean Square Error (RMSE) computed from $RMSE_x$ and $RMSE_y$ |
| $RMSE_z$ | Vertical Root Mean Square Error (RMSE) of orthometric heights |
| SLOSH | Sea, Lake, and Overland Surges from Hurricanes |
| SRWMD | Suwannee River Water Management District |
| SVA | Supplemental Vertical Accuracy, defined by the NDEP and ASPRS |
| TIN | Triangulated Irregular Network |
| VMAS | Vertical Map Accuracy Standard, defined by the NMAS |

## Ground Surveys and Dates

The GPS ground checkpoint surveys were executed on February 18, 2008.

The QA/QC checkpoints used for this county are listed at Appendix E.

## LiDAR Aerial Survey Areas and Dates

Terrapoint USA collected the LiDAR data for the City of Live Oak on January 22, 2008.

## LiDAR Processing Methodology

A LiDAR processing report from Terrapoint USA is included at Appendix D.

## LiDAR Vertical Accuracy Testing

URS performed the LiDAR vertical accuracy assessment for the City of Live Oak. Because there were fewer than 20 QA/QC checkpoints for this small area, normal procedures could not be used for accuracy testing in accordance with *ASPRS Guidelines, Vertical Accuracy Reporting for Lidar Data*, May 24, 2004, and Section 1.5 of the *Guidelines for Digital Elevation Data*, published by the National Digital Elevation Program (NDEP), May 10, 2004. These guidelines call for the mandatory determination of Fundamental Vertical Accuracy (FVA) and Consolidated Vertical Accuracy (CVA), and the optional determination of Supplemental Vertical Accuracy (SVA).

Using alternative procedures described below, the LiDAR dataset of the City of Live Oak passed the accuracy testing by URS as documented at Appendices E and F.

**Fundamental Vertical Accuracy (FVA)** is determined with QA/QC checkpoints located only in open terrain (grass, dirt, sand, and rocks) where there is a high probability that the LiDAR sensor detected the bare-earth ground surface, and where errors are expected to follow a normal error distribution. With a normal error distribution, the FVA at the 95 percent confidence level is computed as the vertical root mean square error ($RMSE_z$) of the checkpoints x 1.9600. The FVA is the same as $Accuracy_z$ at the 95% confidence level (for open terrain), as specified in Appendix 3-A of the *National Standard for Spatial Data Accuracy*, FGDC-STD-007.3-1998, see http://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3. For FDEM, the FVA standard is .60 feet at the 95% confidence level, corresponding to an $RMSE_z$ of 0.30 feet or 9.25 cm, the accuracy expected from 1-foot contours. ***In Live Oak, the only two errors in open terrain equaled 0.19 ft and 0.01 ft for checkpoints SU0001-1 and SU001-5 respectively. Thus, the FVA is 0.19 ft, smaller than the 0.60 ft FVA standard, and the FVA passes.***

**Consolidated Vertical Accuracy (CVA)** is determined with all checkpoints, representing open terrain and all other land cover categories combined. If errors follow a normal error distribution, the CVA can be computed by multiplying the consolidated $RMSE_z$ by 1.9600. However, because bare-earth elevation errors often vary based on the height and density of vegetation, a normal error distribution cannot be assumed, and $RMSE_z$ cannot necessarily be used to calculate the 95 percent confidence level. Instead, a nonparametric testing method, based on the $95^{th}$ percentile, may be used to determine CVA at the 95 percent confidence level. NDEP guidelines state that errors larger than the $95^{th}$ percentile should be documented in the quality control report and project metadata. For FDEM, the CVA specification for all classes combined should be less than or equal to 1.19 feet; this same CVA specification was used by NOAA. ***In Live Oak, the CVA computed using $RMSE_z$ x 1.9600 was equal to 1.04 ft, compared with the 1.19 ft specification of FDEM; and the CVA computed using the $95^{th}$ percentile was equal to 0.91 ft. URS and Dewberry determined that the dataset passed the CVA standard.***

**Supplemental Vertical Accuracy (SVA)** is determined separately for each individual land cover category, recognizing that the LiDAR sensor and post-processing may not have mapped the bare-earth ground surface, and that errors may not follow a normal error distribution. SVA specifications are "target" values and not mandatory, recognizing that larger errors in some categories are offset by smaller errors in other land cover categories, so long as the overall mandatory CVA specification is satisfied. For each land cover category, the SVA at the 95 percent confidence level equals the $95^{th}$ percentile error for all checkpoints in that particular land cover category. For FDEM's specification, the SVA target is 1.19 feet for each category; this same SVA target specification was used by NOAA**.** ***In Live Oak, using the only checkpoint in each land cover category as the SVA value, the SVA tested as 0.19 ft in open terrain, bare earth and low grass; 0.61 ft in brush lands and low trees; 0.99 ft in forested areas; and 0.17 ft in urban, built-up areas, passing the FDEM SVA baseline target specification of 1.19 ft in all land cover categories.***

The LiDAR Vertical Accuracy Report for Live Oak is at Appendix F.

## LiDAR Horizontal Accuracy Testing

The LiDAR data was compiled to meet 3.8 feet horizontal accuracy at the 95% confidence level.

Whereas FDEM baseline specifications call for horizontal accuracy testing, traditional horizontal accuracy testing of LiDAR data is not cost effective for the following reasons:

- Paragraphs 3.2.2 and 3.2.3 of the National Standard for Spatial Data Accuracy (NSSDA) states: "Horizontal accuracy shall be tested by comparing the planimetric coordinates of well-defined points in the dataset with coordinates of the same points from an independent source of higher accuracy … when a dataset, e.g., a gridded digital elevation dataset or elevation contour dataset does not contain well-defined points, label for vertical accuracy only." Similarly, in Appendix 3-C of the NSSDA, paragraph 1 explains well-defined points as follows: "A well-defined point represents a feature for which the horizontal position is known to a high degree of accuracy and position with respect to the geodetic datum. For the purpose of accuracy testing, well-defined points must be easily visible or recoverable on the ground, on the independent source of higher accuracy, and on the product itself. Graphic contour data and digital hypsographic data may not contain well-defined points."
- Paragraph 1.5.3.4 of the *Guidelines for Digital Elevation Data*, published in 2004 by the National Digital Elevation Program (NDEP), states: "The NDEP does not require independent testing of horizontal accuracy for elevation products. When the lack of distinct surface features makes horizontal accuracy testing of mass points, TINs, or DEMs difficult or impossible, the data producer should specify horizontal accuracy using the following statement: *Compiled to meet __ (meters, feet) horizontal accuracy at 95 percent confidence level*."
- Paragraph 1.2, Horizontal Accuracy, of *ASPRS Guidelines, Vertical Accuracy Reporting for Lidar Data*, published by the American Society for Photogrammetry and Remote Sensing (ASPRS) in 2004, further explains why it is difficult and impractical to test the horizontal accuracy of LiDAR data, and explains why ASPRS does not require horizontal accuracy testing of LiDAR-derived elevation products.

- ASPRS has been actively seeking to develop cost-effective techniques to use LiDAR intensity imagery to test the horizontal accuracy of LiDAR data. As recently as May 1, 2008, at the annual conference of ASPRS, the most relevant technique for doing so was in a paper entitled "New Horizontal Accuracy Assessment Tools and Techniques for Lidar Data," presented by the Ohio DOT. Whereas the technique had research value, it was neither practical nor affordable for use in horizontal accuracy testing of FDEM data.
- Appendix A of FDEM's Baseline Specifications require 20 horizontal test points for every 500 square mile area of digital orthophotos to be produced, and Appendix B of FDEM's Baseline Specifications requires 120 vertical test points for each 500 square mile area of LiDAR data to be produced. The PDS task orders included no funding for the more-expensive horizontal checkpoints that would be certain to appear on LiDAR intensity images as clearly-defined point features.
- In addition to LiDAR system factory calibration of horizontal and vertical accuracy, each of the PDS team's LiDAR subcontractors have different techniques for field calibration checks used to determine if bore-sighting is still accurate. Terrapoint's technique, used for the City of Live Oak, is explained in the LiDAR Processing Report at Appendix D.

## LiDAR Qualitative Assessments

In addition to vertical accuracy testing, URS also performed the LiDAR qualitative assessment.

An assessment of the vertical accuracy alone does not yield a complete picture with regard to the usability of LiDAR data for its intended purpose. It is very possible for a given set of LiDAR data to meet the accuracy requirements, yet still contain artifacts (non-ground points) in the bare-earth surface, or a lack of ground points in some areas that may render the data, in whole or in part, unsuitable for certain applications.

Based on the extremely large volume of elevation points generated, it is neither time efficient, cost effective, nor technically practical to produce a perfectly clean (artifact-free) bare-earth terrain surface. The purpose of the LiDAR Qualitative Assessment Report (see Appendix G) is to provide a qualitative analysis of the "cleanliness" of the bare-earth terrain surface for use in supporting riverine and coastal analysis, modeling, and mapping.

The main software programs used by URS in performing the bare-earth data cleanliness review include the following:

- *GeoCue*: a geospatial data/process management system especially suited to managing large LiDAR data sets
- *TerraModeler*: used for analysis and visualization
- *TerraScan*: runs inside of MicroStation; used for point classification and points file generation
- *GeoCue LAS EQC:* is also used for data analysis and edit

The following systematic approach was followed by URS in performing the cleanliness review and analysis:

- Uploaded data to the GeoCue data warehouse (enhanced data management)
    - LiDAR: cut the data into uniform tiles measuring 5,000 feet by 5,000 feet – using the State Plane tile index provided by FDEM

- Imagery: Best available orthophotography was used to facilitate the data review. Additional LiDAR Orthos were created from the LiDAR intensity data and used for review purposes.

- Performed coverage/gap check to ensure proper coverage of the project area
  - Created a large post grid (~30 meters) from the bare-earth points, which was used to identify any holes or gaps in the data coverage.
- Performed tile-by-tile analyses
  - Using TerraScan and LAS EQC, checked for gross errors in profile mode (noise, high and low points)
  - Reviewed each tile for anomalies; identified problem areas with a polygon, annotated comment, and screenshot as needed for clarification and illustration. Used ortho imagery when necessary to aid in making final determinations with regards to:
    - Buildings left in the bare-earth points file
    - Vegetation left in the bare-earth points file
    - Water points left in the bare-earth points file
    - Proper definition of roads
    - Bridges and large box culverts removed from the bare-earth points file
    - Areas that may have been "shaved off" or "over-smoothed" during the auto-filtering process
- Prepared and sent the error reports to LiDAR firm for correction
- Reviewed revisions and comments from the LiDAR firm
- Prepared and submitted final reports to FDEM

## Breakline Production Methodology

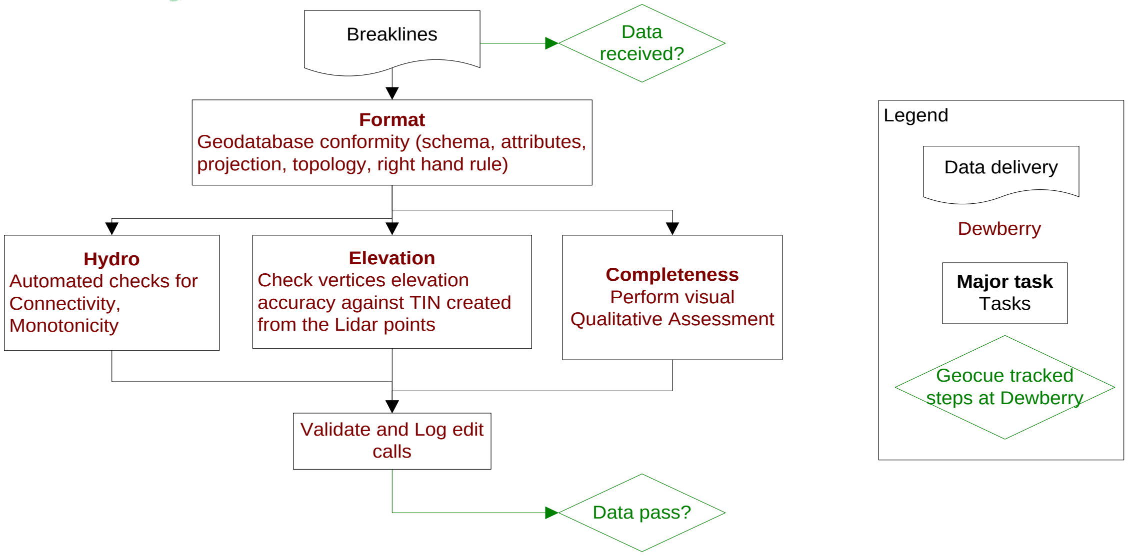
Dewberry used GeoCue software to develop LiDAR stereo models of Live Oak so the LiDAR derived data could be viewed in 3-D stereo using Socet Set softcopy photogrammetric software. Using LiDARgrammetry procedures with LiDAR intensity imagery, Dewberry stereo-compiled the nine types of breaklines in accordance with the Data Dictionary at Appendix C. The LiDARgrammetry was performed under the direct supervision of an ASPRS Certified Photogrammetrist. The breaklines conform with data format requirements outlined by the FDEM Baseline Specifications.

## Contour Production Methodology

Using proprietary procedures developed by Dewberry, the 2-foot and 1-foot contours were compiled from the breaklines and LiDAR data in accordance with the Data Dictionary at Appendix C. The contours conform with data format requirements outlined by the FDEM Baseline Specifications.

## Breakline Qualitative Assessments

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




In order to ensure a correct database format, Dewberry provided all subcontractors with geodatabase shells containing the required feature classes in the required format. Upon receipt of the data, Dewberry verified that the correct shell was used and validated the topology rules associated with it.

| Feature Class | Rule | Feature Class |
|---|---|---|
| SOFTFEATURE | Must Not Intersect | |
| OVERPASS | Must Not Intersect | |
| ROADBREAKLINE | Must Not Intersect | |
| HYDROGRAPHIC... | Must Not Intersect | |
| SOFTFEATURE | Must Not Overlap With | ROADBREAKLINE |
| SOFTFEATURE | Must Not Overlap With | HYDROGRAPHICF |
| ROADBREAKLINE | Must Not Overlap With | HYDROGRAPHICF |
| SOFTFEATURE | Must Not Self-Intersect | |
| OVERPASS | Must Not Self-Intersect | |
| ROADBREAKLINE | Must Not Self-Intersect | |
| HYDROGRAPHIC... | Must Not Self-Intersect | |

**Breaklines topology rules**

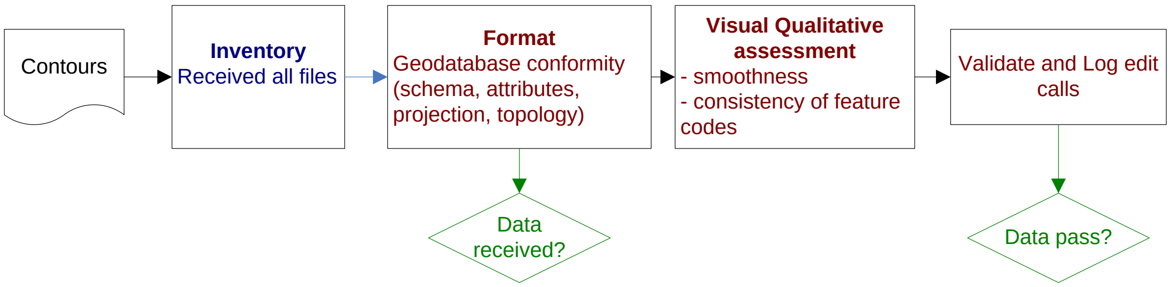
Then automated checks are applied on hydrofeatures to validate the 3D connectivity of the feature and the monotonicity of the hydrographic breaklines. Dewberry's major concern was that the hydrographic breaklines have a continuous flow downhill and that breaklines do not undulate. Error points are generated 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 TIN 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 do not differ too much from the LiDAR.

Dewberry's final check for the breaklines was to perform a full qualitative analysis of the breaklines. Dewberry compared the breaklines against LiDAR intensity images to ensure breaklines were captured in the required locations.

## Contour Qualitative Assessments

Dewberry also performed the qualitative assessments of the contours using the following workflow.




Upon receipt of each delivery area, the first step performed by Dewberry was a series of data topology validations. Dewberry checked for the following instances in the data:

1. Contours must not overlap
2. Contours must not intersect
3. Contours must not have dangles (except at project boundary)
4. Contours must not self-overlap
5. Contours must not self-intersect

After the topology and geodatabase format validation was complete, Dewberry checked the elevation attribute of each contour to ensure NULL values are not included. Finally, Dewberry loaded the contour data plus the Lidar intensity images into ArcGIS and performed a full qualitative review of the contour data for smoothness and consistency of feature codes.

Appendix H summarizes Dewberry's qualitative assessments of the breaklines and contours, with graphic examples of what the breaklines and contours look like.

## Deliverables

Except for the Final Report of Specific Purpose Survey, LiDAR & Photogrammetry Checkpoints Suwannee County, Florida, dated July 23, 2008, which was delivered separately by PBS&J, the deliverables listed at Table 2 are included on the external hard drive that accompanies this report.

**Table 2. Summary of Deliverables**

| Copies | Deliverable Description | Format | Location |
|---|---|---|---|
| 2 | Final Report of Specific Purpose Survey, LiDAR & Photogrammetry Checkpoints, Suwannee County, Florida, dated July 23, 2008 | Hardcopy and pdf | Submitted separately |
| 1 | Data Dictionary | pdf | Appendix C |
| 3 | LiDAR Processing Report | Hardcopy and pdf | Appendix D |
| 3 | LiDAR Vertical Accuracy Report | Hardcopy and pdf | Appendix F |
| 1 | LiDAR Qualitative Assessment Report | pdf | Appendix G |
| 1 | Breakline/Contour Qualitative Assessment Report | pdf | Appendix H |
| 1 | Breaklines, Contours, Network-Adjusted Control Points, Vertical accuracy checkpoints, Tiling Footprint, Lidar ground masspoints | Geodatabase | Submitted separately |

## References


ASPRS, 2007, *Digital Elevation Model Technologies and Applications: The DEM Users Manual*, 2nd edition, American Society for Photogrammetry and Remote Sensing, Bethesda, MD.

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FDEM, 2006, Florida GIS, *Baseline Specifications for Orthophotography and LiDAR*, Appendix B, *Terrestrial LiDAR Specifications*, Florida Division of Emergency Management, Tallahassee, FL, October, 2006.

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FGDC, 1998a, *Geospatial Positioning Accuracy Standards, Part I: Reporting Methodology*, Federal Geographic Data Committee, c/o USGS, Reston, VA, http://www.fgdc.gov/standards/standards_publications/.

FGDC, 1998b, *Geospatial Positioning Accuracy Standards, Part 2, Standards for Geodetic Networks*, Federal Geographic Data Committee, c/o USGS, Reston, VA, http://www.fgdc.gov/standards/standards_publications/

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FGDC, 1998d, Content Standard for Digital Geospatial Metadata (CSDGM), Federal Geographic Data Committee, c/o USGS, Reston, VA, www.fgdc.gov/metadata/contstan.html.

NDEP, 2004, *Guidelines for Digital Elevation Data*, Version 1.0, National Digital Elevation Program, May 10, 2004, http://www.ndep.gov/

NOAA, 1997, *Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm),* NOAA Technical Memorandum NOS NGS-58, November, 1997.

## General Notes

This report is incomplete without the external hard drives of the LiDAR masspoints, breaklines, contours, and control. See the Geodatabase structure at Appendix I.

This digital mapping data complies with the Federal Emergency Management Agency (FEMA) "Guidelines and Specifications for Flood Hazard Mapping Partners," Appendix A: *Guidance for Aerial Mapping and Surveying.*

The LiDAR vertical accuracy report at Appendix F does not conform with the National Standard for Spatial Data Accuracy (NSSDA) because fewer than 20 checkpoints were available to test the individual land cover categories.

The digital mapping data is certified to conform to Appendix B, *Terrestrial LiDAR Specifications*, of the "Florida Baseline Specifications for Orthophotography and LiDAR." This report is certified to conform with Chapter 61G17-6, Minimum Technical Standards, of the Florida Administrative Code, as pertains to a Specific Purpose LiDAR Survey.

**THIS REPORT IS NOT VALID WITHOUT THE SIGNATURE AND RAISED SEAL OF A FLORIDA PROFESSIONAL SURVEYOR AND MAPPER IN RESPONSIBLE CHARGE**.

**Surveyor and Mapper in Responsible Charge:**
David F. Maune, PhD, PSM, PS, GS, CP, CFM
Professional Surveyor and Mapper
License #LS6659

Signed: ________________________________ Date: ________________


DAVID F. MAUNE
LICENSE NUMBER
LS6659
STATE OF
FLORIDA
PROFESSIONAL SURVEYOR & MAPPER

## List of Appendices

A. Project Tiling Footprint
B. Geodetic Control Point
C. Data Dictionary
D. LiDAR Processing Report
E. QA/QC Checkpoints and Associated Discrepancies
F. LiDAR Vertical Accuracy Report
G. LiDAR Qualitative Assessment Report
H. Breakline/Contour Qualitative Assessment Report
I. Geodatabase Structure

# Appendix A: Project Tiling Footprint

16 Tiles delivered for City Live Oak

List of delivered Tiles (16):
052698_N
052699_N
053778_N
053779_N
053780_N
053781_N
054318_N
054319_N
054320_N
054321_N
052700_N
052701_N
053238_N
053239_N
053240_N
053241_N

## Appendix B: Geodetic Control Point

For LiDAR airborne GPS control, Terrapoint used control station SUWAPORT:

- West Longitude: -83 01 02.68267
- North Latitude: 30 18 08.42590
- Ellipsoid Height: 3.0363 meters

For GPS base station control of QA/QC checkpoints, PBS&J used PID BD0832, with NGS data sheet shown below.

### *The NGS Data Sheet*

```
1        National Geodetic Survey,   Retrieval Date = JANUARY 16, 2009
 BD0832
***********************************************************************
 BD0832  CBN          -  This is a Cooperative Base Network Control Station.
 BD0832  DESIGNATION -  U 151
 BD0832  PID          -  BD0832
 BD0832  STATE/COUNTY-  FL/SUWANNEE
 BD0832  USGS QUAD    -  LIVE OAK EAST (1993)
 BD0832
 BD0832                         *CURRENT SURVEY CONTROL
 BD0832  ___________________________________________________________________
 BD0832* NAD 83(2007)-  30 16 40.94914(N)    082 56 31.32049(W)     ADJUSTED
 BD0832* NAVD 88      -        32.735  (meters)     107.40    (feet)  ADJUSTED
 BD0832  ___________________________________________________________________
 BD0832  EPOCH DATE   -        2002.00
 BD0832  X            -     677,374.877 (meters)                     COMP
 BD0832  Y            -  -5,471,010.899 (meters)                     COMP
 BD0832  Z            -   3,197,031.428 (meters)                     COMP
 BD0832  LAPLACE CORR-           -0.64  (seconds)                    DEFLEC99
 BD0832  ELLIP HEIGHT-            4.684 (meters)          (02/10/07) ADJUSTED
 BD0832  GEOID HEIGHT-          -28.15  (meters)                     GEOID03
 BD0832  DYNAMIC HT   -          32.692 (meters)      107.26   (feet)  COMP
 BD0832
 BD0832  ------- Accuracy Estimates (at 95% Confidence Level in cm) --------
 BD0832  Type     PID     Designation                    North    East  Ellip
 BD0832  -------------------------------------------------------------------
 BD0832  NETWORK BD0832 U 151                             0.43    0.39   1.00
 BD0832  -------------------------------------------------------------------
 BD0832  MODELED GRAV-     979,329.8    (mgal)                       NAVD 88
 BD0832
 BD0832  VERT ORDER   -  FIRST     CLASS II
 BD0832
 BD0832.The horizontal coordinates were established by GPS observations
 BD0832.and adjusted by the National Geodetic Survey in February 2007.
 BD0832
 BD0832.The datum tag of NAD 83(2007) is equivalent to NAD 83(NSRS2007).
 BD0832.See National Readjustment for more information.
 BD0832.The horizontal coordinates are valid at the epoch date displayed
above.
 BD0832.The epoch date for horizontal control is a decimal equivalence
```

```
 BD0832.of Year/Month/Day.
 BD0832
 BD0832.The orthometric height was determined by differential leveling
 BD0832.and adjusted in June 1991.
 BD0832
 BD0832.The X, Y, and Z were computed from the position and the ellipsoidal
ht.
 BD0832
 BD0832.The Laplace correction was computed from DEFLEC99 derived
deflections.
 BD0832
 BD0832.The ellipsoidal height was determined by GPS observations
 BD0832.and is referenced to NAD 83.
 BD0832
 BD0832.The geoid height was determined by GEOID03.
 BD0832
 BD0832.The dynamic height is computed by dividing the NAVD 88
 BD0832.geopotential number by the normal gravity value computed on the
 BD0832.Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45
 BD0832.degrees latitude (g = 980.6199 gals.).
 BD0832
 BD0832.The modeled gravity was interpolated from observed gravity values.
 BD0832
 BD0832;                    North         East     Units Scale Factor
Converg.
 BD0832;SPC FL N     -   142,691.977   749,889.467   MT  0.99995029   +0 46
58.5
 BD0832;SPC FL N     -   468,148.59  2,460,262.36   sFT  0.99995029   +0 46
58.5
 BD0832;UTM  17      - 3,351,191.792   313,201.994   MT  1.00003050   -0 58
46.0
 BD0832
 BD0832!             -  Elev Factor  x  Scale Factor =   Combined Factor
 BD0832!SPC FL N     -   0.99999926  x   0.99995029  =   0.99994955
 BD0832!UTM  17      -   0.99999926  x   1.00003050  =   1.00002976
 BD0832
 BD0832                          SUPERSEDED SURVEY CONTROL
 BD0832
 BD0832  NAD 83(1999)-  30 16 40.94951(N)    082 56 31.32005(W) AD(        ) B
 BD0832  ELLIP H (05/31/01)    4.563  (m)                       GP(        ) 5
1
 BD0832  ELLIP H (06/02/94)    4.585  (m)                       GP(        ) 3
1
 BD0832  NAD 83(1990)-  30 16 40.94818(N)    082 56 31.31980(W) AD(        ) B
 BD0832  ELLIP H (09/13/90)    4.548  (m)                       GP(        ) 4
1
 BD0832  NAVD 88 (06/02/94)   32.74   (m)          107.4    (f) LEVELING    3
 BD0832  NGVD 29 (??/??/92)   32.951  (m)          108.11   (f) ADJ UNCH    1
2
 BD0832
 BD0832.Superseded values are not recommended for survey control.
 BD0832.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
 BD0832.See file dsdata.txt to determine how the superseded data were
derived.
 BD0832
 BD0832_U.S. NATIONAL GRID SPATIAL ADDRESS: 17RLP1320251192(NAD 83)
```

```
BD0832_MARKER: DB = BENCH MARK DISK
BD0832_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
BD0832_SP_SET: CONCRETE POST
BD0832_STAMPING: U 151 1954
BD0832_MARK LOGO: CGS
BD0832_PROJECTION: FLUSH
BD0832_MAGNETIC: O = OTHER; SEE DESCRIPTION
BD0832_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
BD0832+STABILITY: SURFACE MOTION
BD0832_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
BD0832+SATELLITE: SATELLITE OBSERVATIONS - November 20, 1997
BD0832
BD0832  HISTORY     - Date     Condition        Report By
BD0832  HISTORY     - 1954     MONUMENTED       CGS
BD0832  HISTORY     - 1958     GOOD             NGS
BD0832  HISTORY     - 1969     GOOD             NGS
BD0832  HISTORY     - 1979     GOOD             NGS
BD0832  HISTORY     - 1988     GOOD             NGS
BD0832  HISTORY     - 19890421 GOOD
BD0832  HISTORY     - 19930403 GOOD             NGS
BD0832  HISTORY     - 19971120 GOOD             DCJOHN
BD0832
BD0832                          STATION DESCRIPTION
BD0832
BD0832'DESCRIBED BY NATIONAL GEODETIC SURVEY 1958
BD0832'2.8 MI SE FROM LIVE OAK.
BD0832'2.75 MILES SOUTHEAST ALONG THE SEABOARD AIR LINE RAILROAD FROM
BD0832'THE STATION AT LIVE OAK, 150 YARDS NORTHWEST OF A POWER LINE
BD0832'CROSSING, 100 YARDS NORTH OF A FARMHOUSE, 71 FT. NORTHWEST OF
BD0832'THE CENTER LINE OF A PRIVATE DRIVEWAY LEADING TO THE FARMHOUSE,
BD0832'91 FT. SOUTHWEST OF THE CENTER LINE OF U.S. HIGHWAY 90, 179
BD0832'FT. SOUTHWEST OF THE SOUTHWEST RAIL, 10 FT. NORTHEAST OF A
BD0832'POWER POLE, 0.8 FT. NORTHEAST OF A FENCE, 14 POLES SOUTHEAST
BD0832'OF MILEPOST 713, SET IN THE TOP OF A CONCRETE POST WHICH PROJECTS
BD0832'0.1 FT. ABOVE THE GROUND.  NOTE-- A STEEL WITNESS POST WAS
BD0832'SET 1.4 FT. NW OF THE MARK.
BD0832
BD0832                          STATION RECOVERY (1969)
BD0832
BD0832'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1969
BD0832'RECOVERED IN GOOD CONDITION.
BD0832
BD0832                          STATION RECOVERY (1979)
BD0832
BD0832'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1979
BD0832'RECOVERED IN GOOD CONDITION.
BD0832
BD0832                          STATION RECOVERY (1988)
BD0832
BD0832'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1988
BD0832'THE STATION IS LOCATED ABOUT 15.37 KM (9.55 MI) NORTH OF MCALPIN,
BD0832'13.04 KM (8.10 MI) WEST OF WELLBORN, 4.51 KM (2.80 MI) EAST OF LIVE
BD0832'OAK AND 0.56 KM (0.35 MI) WEST OF A MICROWAVE TOWER.
BD0832'OWNERSHIP--HIGHWAY RIGHT-OF-WAY.
BD0832'TO REACH THE STATION FROM THE JUNCTION OF U.S. HIGHWAYS 129 AND 90 IN
BD0832'LIVE OAK, GO EAST FOR 0.56 KM (0.35 MI) ON HIGHWAY 90 TO THE RAILROAD
```

```
BD0832'CROSSING.  CONTINUE AHEAD FOR 2.09 KM (1.30 MI) ON HIGHWAY 90 TO A
BD0832'REVERSE FORK, COUNTY ROAD 10.  CONTINUE AHEAD FOR 1.77 KM (1.10 MI)
ON
BD0832'HIGHWAY 90 TO THE OPPORTUNITY STORE ON LEFT.  CONTINUE AHEAD FOR 0.80
BD0832'KM (0.50 MI) ON HIGHWAY 90 TO THE STATION ON RIGHT, IN THE FENCE
LINE,
BD0832'BETWEEN TWO POWERLINES PARALLEL TO HIGHWAY.
BD0832'LOCATED 25.60 M (84.0 FT) WEST FROM UTILITY POLE NUMBER 2 3883 3960
04
BD0832'WITH TRANSFORMER, 25.15 M (82.5 FT) WEST FROM TELEPHONE CABLE
PEDESTAL
BD0832'NUMBER 001, 22.74 M (74.6 FT) SOUTH-SOUTHWEST FROM THE APPROXIMATE
BD0832'CENTER OF HIGHWAY 90, 3.35 M (11.0 FT) NORTH FROM A UTILITY POLE ON
BD0832'SOUTH SIDE OF FENCE LINE AND 0.37 M (1.2 FT) SOUTHEAST FROM A METAL
BD0832'WITNESS POST.
BD0832'DESCRIBED BY R.W. MCALLISTER.
BD0832
BD0832                          STATION RECOVERY (1989)
BD0832
BD0832'RECOVERED 1989
BD0832'RECOVERED IN GOOD CONDITION.
BD0832
BD0832                          STATION RECOVERY (1993)
BD0832
BD0832'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1993
BD0832'THE STATION IS LOCATED ABOUT 15.37 KM (9.55 MI) NORTH OF MCALPIN,
BD0832'13.04 KM (8.10 MI) WEST OF WELLBORN, 4.51 KM (2.80 MI) EAST OF LIVE
BD0832'OAK AND 0.56 KM (0.35 MI) WEST OF A MICROWAVE TOWER.
BD0832'OWNERSHIP--HIGHWAY RIGHT-OF-WAY.
BD0832'TO REACH THE STATION FROM THE JUNCTION OF U.S. HIGHWAYS 90 AND 129 IN
BD0832'LIVE OAK, GO EAST FOR 2.75 KM (1.70 MI) ON U.S. HIGHWAY 90 TO A
BD0832'REVERSE FORK, COUNTY ROAD 10 A, CONTINUE EAST 0.50 KM (0.30 MI) ALONG
BD0832'U.S. HIGHWAY 90 TO THE JUNCTION OF COUNTY ROAD 49, CONTINUE EAST 0.57
BD0832'KM (0.35 MI) ALONG U.S. HIGHWAY 90 TO THE OPPORTUNITY STORE ON THE
BD0832'LEFT, CONTINUE AHEAD FOR 0.80 KM (0.50 MI) ALONG U.S. HIGHWAY 90 TO
BD0832'THE STATION ON THE RIGHT IN A FENCE LINE BETWEEN TWO POWERLINES
BD0832'PARALLEL TO HIGHWAY AND NORTH OF A UTILITY POLE.
BD0832'LOCATED 25.15 M (82.51 FT) WEST FROM UTILITY POLE NUMBER 2 3883 3960
BD0832'04 WITH A TRANSFORMER, 25.60 M (83.99 FT) WEST FROM TELEPHONE CABLE
BD0832'PEDESTAL NUMBER 001, 22.74 M (74.61 FT) SOUTH-SOUTHWEST FROM THE
BD0832'APPROXIMATE CENTERLINE OF U.S. HIGHWAY 90, 3.35 M (10.99 FT) NORTH
BD0832'FROM A UTILITY POLE ON SOUTH SIDE OF FENCE LINE AND 0.37 M (1.21 FT)
BD0832'EAST-SOUTHEAST FROM A METAL WITNESS POST.
BD0832'DESCRIBED BY RONNIE L. TAYLOR.
BD0832
BD0832                          STATION RECOVERY (1997)
BD0832
BD0832'RECOVERY NOTE BY DC JOHNSON ASSOC 1997 (CHX)
BD0832'RECOVERY NOTE BY DC JOHNSON AND ASSOC (CHX) .--  THE STATION WAS
BD0832'RECOVERED AS PREVIOUSLY DESCRIBED.
```

## Appendix C: Data Dictionary

# LiDARgrammetry Data Dictionary & Stereo Compilation Rules

FINAL

FDEM (Florida Department of Emergency Management)

January 25, 2008

## Table of Contents

## Horizontal and Vertical Datum

Horizontal datum shall be referenced to the appropriate Florida State Plane Coordinate System. The horizontal datum shall be North American Datum of 1983/HARN adjustment in US Survey Feet. The vertical datum shall be referenced to the North American Vertical Datum of 1988 (NAVD 88). Geoid03 shall be used to convert ellipsoidal heights to orthometric heights.

## Coordinate System and Projection

All data shall be projected to the appropriate Florida State Plane Coordinate System Zone, Units in US Survey Feet.

## Contour Topology Rules

The following contour topology rules have been incorporated into each geodatabase shell provided by PDS. The topology must be validated by each subcontractor prior to delivery to PDS. PDS shall further validate the topology before final submittal to FDEM.

| **Name: CONTOURS_Topology** | | | | Cluster Tolerance: 0.003<br>Maximum Generated Error Count: Undefined<br>State: Analyzed without errors |
|---|---|---|---|---|
| **Feature Class** | **Weight** | **XY Rank** | **Z Rank** | **Event Notification** |
| CONTOUR_1FT | 5 | 1 | 1 | No |
| CONTOUR_2FT | 5 | 1 | 1 | No |

**Topology Rules**

| **Name** | **Rule Type** | **Trigger Event** | **Origin** (*FeatureClass::Subtype*) | **Destination** (*FeatureClass::Subtype*) |
|---|---|---|---|---|
| Must not intersect | The rule is a line-no intersection rule | No | CONTOUR_1FT::All | CONTOUR_1FT::All |
| Must not intersect | The rule is a line-no intersection rule | No | CONTOUR_2FT::All | CONTOUR_2FT::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | CONTOUR_2FT::All | CONTOUR_2FT::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | CONTOUR_1FT::All | CONTOUR_1FT::All |

## Breakline Topology Rules

The following breakline topology rules have been incorporated into each geodatabase shell provided by PDS. The topology must be validated by each subcontractor prior to delivery to PDS. PDS shall further validate the topology before final submittal to FDEM.

| **Name: BREAKLINES_Topology** | | | Cluster Tolerance: 0.003<br>Maximum Generated Error Count: Undefined<br>State: Analyzed without errors | |
|---|---|---|---|---|
| **Feature Class** | **Weight** | **XY Rank** | **Z Rank** | **Event Notification** |
| COASTALSHORELINE | 5 | 1 | 1 | No |
| HYDROGRAPHICFEATURE | 5 | 1 | 1 | No |
| OVERPASS | 5 | 1 | 1 | No |
| ROADBREAKLINE | 5 | 1 | 1 | No |
| SOFTFEATURE | 5 | 1 | 1 | No |

### Topology Rules

| Name | Rule Type | Trigger Event | Origin (*FeatureClass::Subtype*) | Destination (*FeatureClass::Subtype*) |
|---|---|---|---|---|
| Must not intersect | The rule is a line-no intersection rule | No | SOFTFEATURE::All | SOFTFEATURE::All |
| Must not intersect | The rule is a line-no intersection rule | No | OVERPASS::All | OVERPASS::All |
| Must not intersect | The rule is a line-no intersection rule | No | ROADBREAKLINE::All | ROADBREAKLINE::All |
| Must not intersect | The rule is a line-no intersection rule | No | HYDROGRAPHICFEATURE::All | HYDROGRAPHICFEATURE::All |
| Must not intersect | The rule is a line-no intersection rule | No | COASTALSHORELINE::All | COASTALSHORELINE::All |
| Must not overlap | The rule is a line-no overlap line rule | No | SOFTFEATURE::All | ROADBREAKLINE::All |
| Must not overlap | The rule is a line-no overlap line rule | No | SOFTFEATURE::All | HYDROGRAPHICFEATURE::All |
| Must not overlap | The rule is a line-no overlap line rule | No | SOFTFEATURE::All | COASTALSHORELINE::All |
| Must not overlap | The rule is a line-no overlap line rule | No | ROADBREAKLINE::All | HYDROGRAPHICFEATURE::All |
| Must not overlap | The rule is a line-no overlap line rule | No | ROADBREAKLINE::All | COASTALSHORELINE::All |
| Must not overlap | The rule is a line-no overlap line rule | No | HYDROGRAPHICFEATURE::All | COASTALSHORELINE::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | SOFTFEATURE::All | SOFTFEATURE::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | OVERPASS::All | OVERPASS::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | ROADBREAKLINE::All | ROADBREAKLINE::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | HYDROGRAPHICFEATURE::All | HYDROGRAPHICFEATURE::All |
| Must not self-intersect | The rule is a line-no self intersect rule | No | COASTALSHORELINE::All | COASTALSHORELINE::All |

# Coastal Shoreline

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** COASTALSHORELINE
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polygon
**Annotation Subclass:** None

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| SHAPE_AREA | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| TYPE | Long Integer | No | 1 | Coast | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Coastal Shoreline | 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. Orthophotography will not be use to delineate this shoreline. | 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. For the polygon closure vertices and segments, null values or a value of 0 are acceptable since this is not an actual shoreline. The digital orthophotography is not a suitable source for capturing this feature. Efforts should be taken to gradually feather the difference between tidal conditions of neighboring flights. Stair-stepping of the breakline feature will not be allowed.<br><br>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.

## *Linear Hydrographic Features*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** HYDROGRAPHICFEATURE
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polyline
**Annotation Subclass:** None

### Description

This polyline feature class will depict linear hydrographic features with a length of 0.5 miles or longer as breaklines.

### 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| TYPE | Long Integer | No | 1 | HydroL | 0 | 0 | | Assigned by PDS |

### Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Single Line Feature | Linear hydrographic features such as streams, shorelines, canals, swales, embankments, etc. with an average width less than or equal to 8 feet. . In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other embankments fall into the soft breakline feature class | Capture linear hydro features as single breaklines. Average width shall be 8 feet or less to show as single line. Each vertex placed should maintain vertical integrity. |
| 2 | Dual Line Feature | Linear hydrographic features such as streams, shorelines, canals, swales, etc. with an average width greater than 8 feet. In the case of embankments, if the feature forms a natural dual line channel, then capture it consistent with the capture rules. Other embankments fall into the soft breakline feature class. | Capture features showing dual line (one on each side of the feature). Average width shall be great than 8 feet to show as a double line. Each vertex placed should maintain vertical integrity and data is not required to show "closed polygon".<br><br>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.

Note:  Carry through bridges for all linear hydrographic features.

# *Closed Water Body Features*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** WATERBODY
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polygon
**Annotation Subclass:** None

## Description

This polygon feature class will depict closed water body features and will have the associated water elevation available as an attribute.

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| SHAPE_AREA | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| WATERBODY_ELEVATION_MS | Double | Yes | | | 0 | 0 | | Assigned by PDS |
| TYPE | Long Integer | No | 1 | HydroP | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Water Body | 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 one-half acres in size or greater.<br><br>“Donuts” will exist where there are islands within a closed water body feature. | 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. The field “WATERBODY_ELEVATION_MS” shall be automatically computed from the z-value of the vertices.<br><br>An Island within a Closed Water Body Feature will also have a “donut polygon” compiled in addition to an Island polygon.<br><br>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.

# Road Features

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** ROADBREAKLINE
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polyline
**Annotation Subclass:** None

## Description

This polyline feature class will depict apparent edge or road pavement as breaklines but will not include bridges or overpasses.

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| TYPE | Long Integer | No | 1 | Road | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Edge of Pavement | Capture edge of pavement (non-paved or compact surfaces as open to compiler interpretability) on both sides of the road. Runways are not to be included. | DO NOT INCLUDE Bridges or Overpasses within this feature type. Capture apparent edge of pavement (including paved shoulders). Each vertex placed should maintain vertical integrity and data is not required to show “closed polygon”. Box culverts should be continued as edge of pavement unless a clear guardrail system is in place; in that case, feature should be shown as bridge / overpass. |

# *Bridge and Overpass Features*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** OVERPASS
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polyline
**Annotation Subclass:** None

## Description

This polyline feature class will depict bridges and overpasses as separate entities from the edge of pavement feature class.

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| TYPE | Long Integer | No | 1 | Bridge | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Bridge Overpass | Feature should show edge of bridge or overpass. | Capture apparent edge of pavement on bridges or overpasses. Do not capture guard rails or non-drivable surfaces such as sidewalks. Capture edge of drivable pavement only. Each vertex placed should maintain vertical integrity and data is not required to show “closed polygon”. Box culverts should be captured in this feature class if a clear guardrail system is in place; otherwise, show as edge-of-pavement. |

# Soft Features

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** SOFTFEATURE
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polyline
**Annotation Subclass:** None

## Description

This polyline feature class will depict soft changes in the terrain to support better hydrological modeling of the LiDAR data and sub-sequent contours.

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| TYPE | Long Integer | No | 1 | Soft | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Soft Breakline | Supplemental breaklines where LiDAR mass points are not sufficient to create a hydrologically correct DTM. Soft features shall include ridges, valleys, top of banks, etc.<br><br>Soft features may also include natural Embankments that act as small ponding areas. Top of Banks can also be included in the soft breakline class so long as it does not define the edge of a water feature. | Capture breaklines to depict soft changes in the elevation. If the elevation changes are easily visible, go light on the breakline capture. Each vertex placed should maintain vertical integrity. |

# *Island Features*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** ISLAND
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polygon
**Annotation Subclass:** None

## Description

This polygon feature class will depict natural and man-made islands as closed polygons.

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| SHAPE_AREA | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| TYPE | Long Integer | No | 1 | Island | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Island | Apparent boundary of natural or man-made island feature captured with a constant elevation.<br><br>Island features will be captured for features one-half acres in size or greater. | Island shall take precedence over Coastal Shore Line Features. Islands shall be captured as closed polygons with the land feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed around the island.<br><br>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.

# *Low Confidence Areas*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** CONFIDENCE
**Contains Z Values:** No
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polygon
**Annotation Subclass:** None

## Description

This polygon feature class will depict areas where the ground is obscured by dense vegetation meaning that the resultant contours may not meet the required accuracy specifications.

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| SHAPE_AREA | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| TYPE | Long Integer | No | 1 | Obscure | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Low Confidence Area | Apparent boundary of vegetated areas that are considered obscured to the extent that adequate vertical data cannot be clearly determined to accurately define the DTM. These features are for reference only to indicate areas where the vertical data may not meet the data accuracy requirements due to heavy vegetation. | Capture as closed polygon with the obscured area to the right of the line. Compiler does not need to worry about z-values of vertices; feature class will be 2-D only. |

Note: Area must be ½ acre or larger. Only outline areas where you are not sure about vegetative penetration of the LiDAR data. This is not the same as a traditional obscured area.

# *Masspoints*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** MASSPOINT
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Point
**Annotation Subclass:** None

## Description

This feature class depicts masspoints as determined by the LiDAR ground points (LAS Class 2).

## 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 PDS |
| TYPE | Long Integer | No | 1 | Masspoint | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Masspoint | Only the bare earth classification (Class 2) shall be loaded into the MASSPOINT feature class. | None. Data should be loaded from LAS Class 2 (Ground) |

# *1 Foot Contours*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** CONTOUR_1FT
**Contains Z Values:** No
**Z Resolution:** N/A
**Z Tolerance:** N/A

**Feature Type:** Polyline
**Annotation Subclass:** None

## Description

This polyline feature class will depict 1' contours modeled from the LiDAR ground points and the supplemental breaklines.

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| CONTOUR_TYPE_DESC | Long Integer | No | | dCONTOURTYPE | 0 | 0 | 50 | Assigned by PDS |
| CONTOUR_ELEVATION_MS | Double | No | | | 0 | 0 | | Calculated by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Intermediate | A contour line drawn between index contours. Depending on the contour interval there are three or four intermediate contours between the index contours. | They are normally continuous throughout a map, but may be dropped or joined with an index contour where the slope is steep and where there is insufficient space to show all of the intermediate lines. |
| 2 | Supplementary | Supplementary contours are used to portray important relief features that would otherwise not be shown by the index and intermediate contours (basic contours). They are normally added only in areas of low relief, but they may also be used in rugged terrain to emphasize features. Supplementary contours are shown as screened lines so that they are distinguishable from the basic contours, yet not | These dotted lines are placed in areas where elevation change is minimal. If there is a lot of space between Index and Intermediate Contours (as happens where the land is relatively flat), these lines are added to indicate that there *are* elevation measurements, even if they are few and far between.<br><br>If the horizontal distance between two adjacent contours is |

| | | | |
|---|---|---|---|
| | | unduly prominent on the published map. | larger than 1" at map scale (100'), then add appropriate supplemental contours from the 1FT_CONTOUR feature class. Supplemental contours do not have to be continuous but should have a minimum length of 200'. |
| 3 | Depression | Depression contours are closed contours that surround a basin or sink. They are shown by right-angle ticks placed on the contour lines, pointed inward (down slope). Fill contours are a special type of depression contours, used to indicate an area that has been filled to support a road or railway grade. | Use when appropriate. |
| 4 | Index | Index Contours are to be placed at every 5th contour interval (1, 5, 10, etc…) | No special rules |
| 5 | Intermediate Low Confidence | Intermediate contours (Code 1) that are located in low confidence area should be cut to the low confidence boundary and should be reclassified to this code. | No special collection rules are necessary as this is a geo-processing task. |
| 6 | Supplementary Low Confidence | Supplementary contours (Code 2) that are located in low confidence area should be cut to the low confidence boundary and should be reclassified to this code. | No special collection rules are necessary as this is a geo-processing task. |
| 7 | Depression Low Confidence | Depression contours (Code 3) that are located in low confidence area should be cut to the low confidence boundary and should be reclassified to this code. | No special collection rules are necessary as this is a geo-processing task. |
| 8 | Index Low Confidence | Index contours (Code 4) that are located in low confidence area should be cut to the low confidence boundary and should be reclassified to this code. | No special collection rules are necessary as this is a geo-processing task. |

# *2 Foot Contours*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** CONTOUR_2FT
**Contains Z Values:** No
**Z Resolution:** N/A
**Z Tolerance:** N/A

**Feature Type:** Polyline
**Annotation Subclass:** None

## Description

This polyline feature class will depict 1' contours modeled from the LiDAR ground points and the supplemental breaklines.

## 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| CONTOUR_TYPE_DESC | Long Integer | No | | dCONTOURTYPE | 0 | 0 | 50 | Assigned by PDS |
| CONTOUR_ELEVATION_MS | Double | No | | | 0 | 0 | | Calculated by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Intermediate | A contour line drawn between index contours. Depending on the contour interval there are three or four intermediate contours between the index contours. | They are normally continuous throughout a map, but may be dropped or joined with an index contour where the slope is steep and where there is insufficient space to show all of the intermediate lines. |
| 2 | Supplementary | Supplementary contours are used to portray important relief features that would otherwise not be shown by the index and intermediate contours (basic contours). They are normally added only in areas of low relief, but they may also be used in rugged terrain to emphasize features. Supplementary contours are shown as screened lines so that they are | These dotted lines are placed in areas where elevation change is minimal. If there is a lot of space between Index and Intermediate Contours (as happens where the land is relatively flat), these lines are added to indicate that there *are* elevation measurements, even if they are few and far between. |

| | | | |
|---|---|---|---|
| | | distinguishable from the basic contours, yet not unduly prominent on the published map. | If the horizontal distance between two adjacent contours is larger than 1” at map scale (100’), then add appropriate supplemental contours from the 1FT_CONTOUR feature class. Supplemental contours do not have to be continuous but should have a minimum length of 200’. |
| 3 | Depression | Depression contours are closed contours that surround a basin or sink. They are shown by right-angle ticks placed on the contour lines, pointed inward (down slope). Fill contours are a special type of depression contours, used to indicate an area that has been filled to support a road or railway grade. | Use when appropriate. |
| 4 | Index | Index Contours are to be placed at every $5^{th}$ contour interval (1, 5, 10, etc…) | No special rules |
| 5 | Intermediate Low Confidence | Intermediate contours (Code 1) that are located in low confidence area should be cut to the low confidence boundary and should be reclassified to this code. | No special collection rules are necessary as this is a geo-processing task. |
| 6 | Supplementary Low Confidence | Supplementary contours (Code 2) that are located in low confidence area should be cut to the low confidence boundary and should be reclassified to this code. | No special collection rules are necessary as this is a geo-processing task. |
| 7 | Depression Low Confidence | Depression contours (Code 3) that are located in low confidence area should be cut to the low confidence boundary and should be reclassified to this code. | No special collection rules are necessary as this is a geo-processing task. |
| 8 | Index Low Confidence | Index contours (Code 4) that are located in low confidence area should be cut to the low confidence boundary and should be reclassified to this code. | No special collection rules are necessary as this is a geo-processing task. |

# Ground Control

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** GROUNDCONTROL
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Point
**Annotation Subclass:** None

## Description

This feature class depicts the points used in the acquisition and calibration of the LiDAR and aerial photography collected by Aero-Metric, Sanborn and Terrapoint.

## 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 PDS |
| TYPE | Long Integer | No | 1 | Control | 0 | 0 | | Assigned by PDS |
| POINTID | String | Yes | | | | | 12 | Assigned by PDS |
| X_COORD | Double | Yes | | | 0 | 0 | | Assigned by PDS |
| Y_COORD | Double | Yes | | | 0 | 0 | | Assigned by PDS |
| Z_COORD | Double | Yes | | | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Control Point | Primary or Secondary PDS control points used for either base station operations or in the calibration and adjustment of the control. | None. |

# Vertical Accuracy Test Points

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** VERTACCTESTPTS
**Contains Z Values:** Yes
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Point
**Annotation Subclass:** None

## Description

This feature class depicts the points used by PDS to test the vertical accuracy of the data produced.

## 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 PDS |
| POINTID | String | Yes | | | | | 12 | Assigned by PDS |
| X_COORD | Double | Yes | | | 0 | 0 | | Assigned by PDS |
| Y_COORD | Double | Yes | | | 0 | 0 | | Assigned by PDS |
| Z_COORD | Double | Yes | | | 0 | 0 | | Assigned by PDS |
| LANDCOVER | Long Integer | No | 1 | dLANDCOVERTYPE | 0 | 0 | | Assigned by PDS |

## Feature Definition

| Code | Description | Definition | Capture Rules |
|---|---|---|---|
| 1 | Bare-Earth and Low Grass | None. | None. |
| 2 | Brush Lands and Low Trees | None. | None. |
| 3 | Forested Areas Fully Covered by Trees | None. | None. |
| 4 | Urban Areas | None. | None. |

## *Footprint (Tile Boundaries)*

**Feature Dataset:** TOPOGRAPHIC
**Contains M Values:** No
**XY Resolution:** Accept Default Setting
**XY Tolerance:** 0.003

**Feature Class:** FOOTPRINT
**Contains Z Values:** No
**Z Resolution:** Accept Default Setting
**Z Tolerance:** 0.001

**Feature Type:** Polygon
**Annotation Subclass:** None

### Description

This polygon feature class includes the Florida 5,000' x 5,000' tiles for each countywide geodatabase produced.

### 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 PDS |
| SHAPE_LENGTH | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| SHAPE_AREA | Double | Yes | | | 0 | 0 | | Calculated by PDS |
| CELLNUM | String | No | | | 0 | 0 | 8 | Assigned by PDS |

## *Contact Information*

Any questions regarding this document should be addressed to:

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# Appendix D: LiDAR Processing Report

**PROJECT REPORT**

Terrapoint #: 2007-205-U
Dewberry #: 07-HS-34-14-00-22-469 Task Order 20070525-4927
Florida (City of Live Oak) 2008 LiDAR Collection
Originally submitted: 2009-01-17
Revisions: 2009-01-16

Presented to:

Dewberry
Fairfax, Virginia

Submitted by:

Terrapoint
Houston, Texas

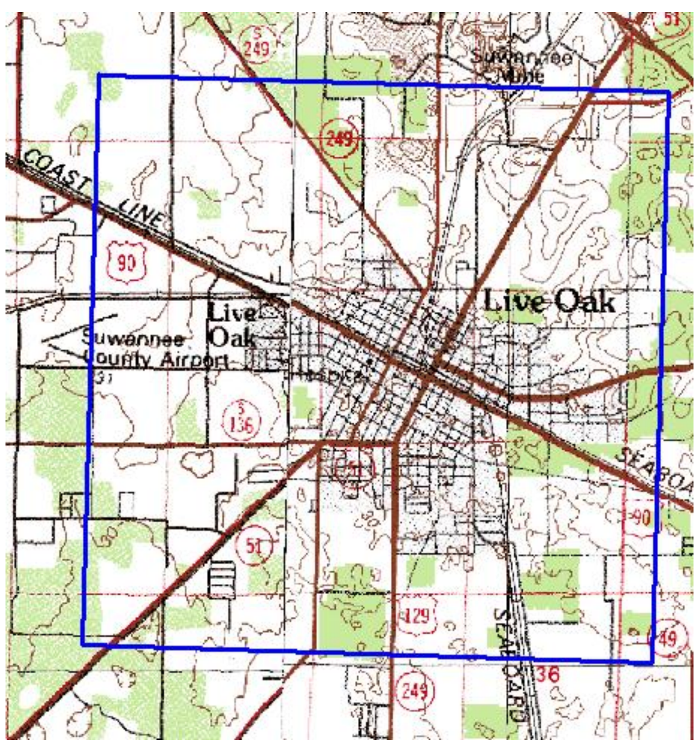
**EXECUTIVE SUMMARY**

This LiDAR project was to provide high accuracy, classified multiple return LiDAR, for 14.397 square miles, of the City of Live Oak, Florida. The LiDAR data were acquired and processed by Terrapoint USA to support FDEM. The product is a high density mass point dataset with an average point spacing of $1m^2$. The data is tiled without a buffer, stored in LAS 1.1 format, and LiDAR returns are classified in 4 ASPRS classes: Unclassified (1), Ground (2), Noise (7) and Water (9), Overlap (12).

The elevation data was verified internally prior to delivery to ensure it met fundamental accuracy requirements when compared kinematic to Terrapoint GPS checkpoints. Below is the summary for the project site.

- The Raw elevation measurements for the City of Live Oak have been tested to 0.128 US Survey Feet for vertical accuracy at 95 percent confidence level.

All data delivered meets and exceeds Terrapoint's deliverable product requirements as setout by Terrapoint's IPROVE program.



**CITY OF LIVE OAK PROJECT REPORT**

## Introduction

LiDAR data is remotely sensed high-resolution elevation data collected by an airborne collection platform. By positioning laser range finding with the use of 1 second GPS with 200 Hz inertial measurement unit corrections; Terrapoint's LiDAR instruments are able to make highly detailed geospatial elevation products of the ground, man-made structures and vegetation.

The LiDAR ground extraction process takes place by building an iterative surface model. This surface model is generated using three main parameters: building size, iteration angle and iteration distance.

The purpose of this LiDAR data was to produce high accuracy 3D terrain geospatial products for City of Live Oak.

This report covers the mission parameter and details, processing step outlines and deliverables.

This report is submitted as a supporting overview document for the FGDC metadata reports that are included as an addendum to this report.

**Acquisition**

## *Parameter Overview*

The Airborne LiDAR survey was conducted using two Optech 3100EA systems flying at a nominal height of 970 meters AGL with a total angular coverage of 18.1 degrees with a 4 degree cutoff. Flight line spacing was nominally 219.28 meters providing overlap of 55% on adjacent flight lines. Lines were flown in east/west and north/south orientated blocks to best optimize flying time considering the layout for the project. The aircraft was a Navajo, registrations C-FQQB, used for the survey. This aircrafts have a flight range of approximately 6 hours and was flown at an average altitude of 970 meters above sea level (ASL), thereby encountering flying altitudes of approximately 970 meters above ground level (AGL). The aircraft was staged from Suwannee County Airport (24J), Live Oak, Florida, and ferried daily to the project site for flight operations.

The Optech 3100EA system was configured in the following manner for the City of Live Oak:

Type of Scanner = Optech 3100EA
Data Acquisition Height = 970 meters AGL
Scanner Field of View = 18.1 degrees with a 4 degree cutoff
Scan Frequency = 55.2 Hertz
Pulse Repetition Rate = 100 Kilohertz
Aircraft Speed = 150 Knots
Swath Width = 487.29 m Nominal
Ground Sample Distance = 0.70 meters - no overlap
Number of Returns per Pulse = 4
Distance between Flight Lines = 219.28m

## *GPS Receivers*

A combination of Sokkia GSR 2600 and NovAtel DL-4+ dual frequency GPS receivers were used to support the airborne operations of this survey and to establish the GPS control network.

## *Missions Statistics*

For the City of Live Oak, a total of 1 mission was flown for this project with good meteorological and GPS conditions. 32 flight lines were flown over the project site to provide complete coverage.

The LiDAR mission for the City of Live Oak was carried out on January 22, 2008.

## *Reference Coordinate System Used*

### City of Live Oak

One existing NGS (National Geodetic Survey) monuments was observed in a GPS control network. Existing monument SUWAPORT was used as primary control for this project.

The published horizontal datum of the NGS stations is NAD83 HARN and the vertical datum NAVD88.

The following are the final coordinates of this control point used in this project:

Station_ID: SUWAPORT
West_Longitude: -83 01 02.68267
North_Latitude: 30 18 08.42590
Ellips_Elev: 3.0363

## *Geoid Model Used*

The Geoid03 geoid model, published by the NGS, was used to transform all ellipsoidal heights to orthometric.

**Processing**

## *Airborne GPS Kinematic*

Airborne GPS kinematic data was processed on-site using GrafNav kinematic On-The-Fly (OTF) software. Flights were flown with a minimum of 6 satellites in view ($13^0$ above the horizon) and with a PDOP of better than 4.5. Distances from base station to aircraft were kept to a maximum of 30 km, to ensure a strong OTF (On-The-Fly) solution. For all flights, the GPS data can be classified as excellent, with GPS residuals of 5cm average but no larger than 9 cm being recorded.

## *Generation and Calibration of Laser Points (raw data)*

Calibration is performed to eliminate systematic bias in the system, which would result in a bias in the data. By determining the bias they can then be modeled and the effects removed from the data. The manufacturer initially calibrates the system on manufacture. Subsequently each mission is checked and calibrated to ensure data quality.

Manufacturer Calibration

Manufacturer calibration was completed upon manufacture and upon delivery of the system to Terrapoint. The manufacturer maintains and calibrates each LiDAR system annually and upon any field visits to service the system.

Manufacturer calibration addresses both radiometric and geometric calibration. Radiometric calibration is to ensure that the laser meets specification for pulse energy, width, and rise time, frequency and beam divergence. These values are tested by the manufacturer and annually certified. Radiometric calibration also checks the alignment between transmitter and receiver and assures that alignment is optimal.

Geometric calibration is also conducted by the manufacturer both in the laboratory and with onsite flights in previously surveyed areas. Range calibration determines the first/last range offsets. Scanner calibration provides values for scanner offset and scale. Position orientation alignment provides Pos misalignment angles.

The Following are the manufacturer derived calibration values that are constant unless the IMU is changed:

AltmSerialNo= 05Sen183
ImuType= LN200A1
ImuRate= 200
ScannerScale= 1.0064
ScannerOffset= -0.0171
FirstPulseRange= -2.76
SecondPulseRange= -2.76
ThirdPulseRange= -2.76
LastPulseRange= -2.76
IMURoll= 0.031
IMUPitch= -0.008
IMUHeading= 0.000
UserToImuEx= -0.020
UserToImuEy= 0.005
UserToImuEz= -0.150
UserToImuDx= -0.09
UserToImuDy= -0.008
UserToImuDz= -0.096
UserToRefDx= -0.051
UserToRefDy= -0.030
UserToRefDz= -0.488
TimeLag= 0.000012
IntensityGainFor3070= 20
UseDroopCorrection= 15.0

Field Calibration is used to determine the roll, pitch, heading and scanner scale values. The roll pitch heading and scanner scale biases are determined by comparing overlapping and opposing flightlines. Each mission is flown to have two cross lines that intersect every flightline and these lines are used to determine the roll, pitch heading and scanner scale.

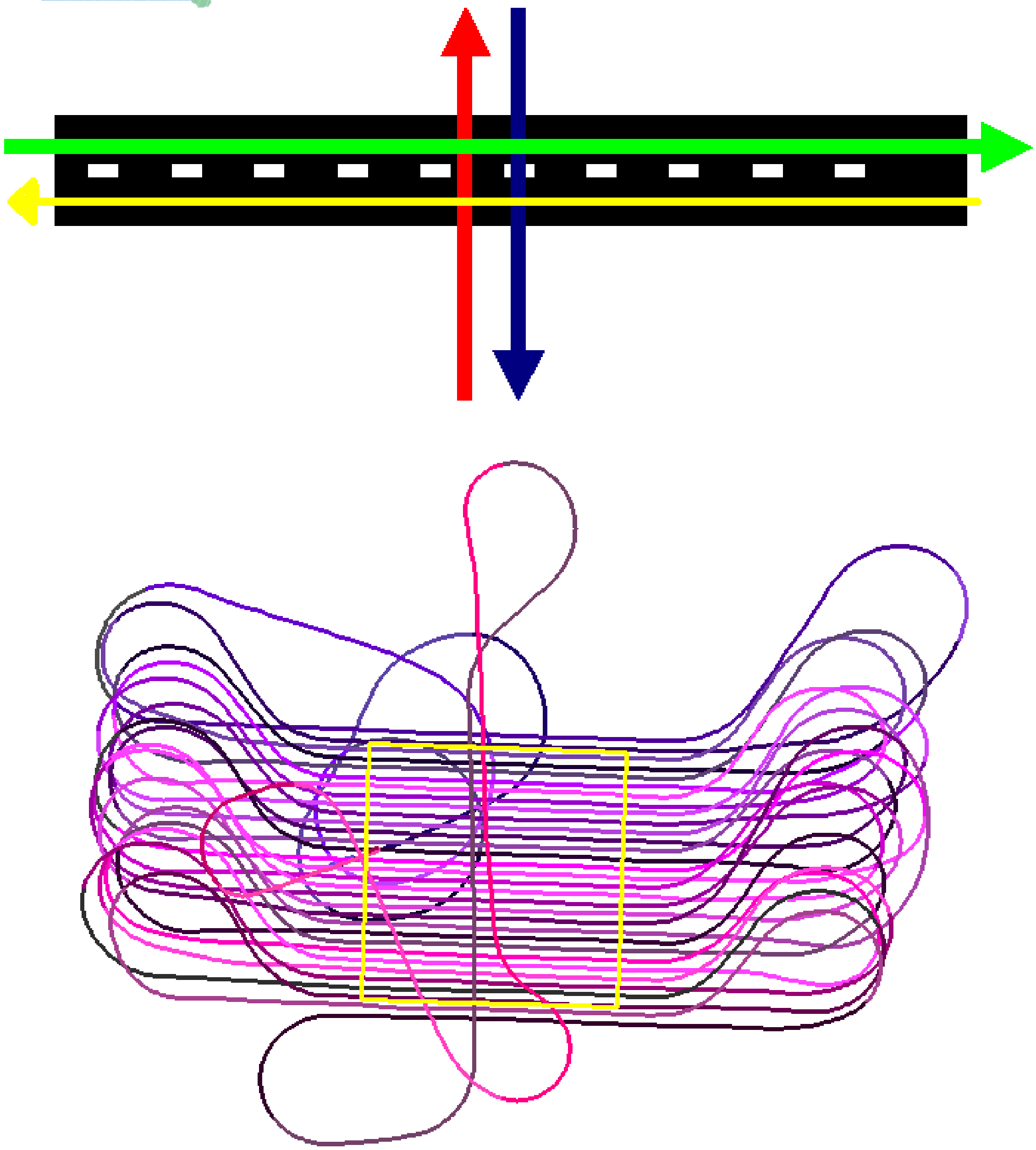


**Figure 1 Example of mission trajectory showing cross lines used to determine calibration values**

The mission data is initially output using the manufacturer calibration default values for the specific system. The data is then examined using a combination of Terrascan Terramodel and Terramatch and user input to determine the final roll, pitch, and heading and scanner scale. Once the values are finalized the mission data is output in LAS format.

The data is then checked against kinematic control data to ensure vertical accuracy. Each mission's data is based on the post-processed position of a base station. The base stations used were all tied into geodetic control points or were geodetic control points. Units are in US Survey Feet.

| Table 2: Kinematic Point Comparison | |
|---|---|
| Average dz | -0.118 |
| Minimum dz | -0.264 |
| Maximum dz | +0.027 |
| Average magnitude | 0.118 |
| Root mean square | 0.128 |
| Std deviation | 0.049 |

Because of this, the positional accuracy of the LiDAR data is ensured. The individual mission data can then be compared to adjoining missions to ensure both vertical and horizontal accuracy. If any offset either vertical of horizontal is found then the mission is reprocessed and checked for accuracy.

## *Vertical Bias Resolution*

Due to limitations in the Optech Dashmap software, occasionally the $D_z$ must be adjusted, post calibration, manually in Terrascan, to ensure that each missions ties to adjoining missions and GPS kinematic validation points. The City of Live Oak data did not require any adjustments to the Dz.

## *Data Classification and Editing*

The data was processed using the software Terrascan, and following the methodology described herein. The initial step is the setup of the Terrascan project, which is done by importing the Dewberry provided tile boundary index encompassing the entire project areas. The 3D laser point clouds, in binary format, were imported into the Terrascan project and divided in 16 tiles for the City of Live Oak, in LAS 1.1 format. Once tiled, the laser points were classified using a proprietary routine in Terrascan. This routine removes any obvious outliers from the dataset following which the ground layer is extracted from the 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 is 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 iteration. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model. The data is then manually quality controlled with the use of hillshading, cross-sections and profiles. Any points found to be of class vegetation, building or error during the quality control process, are removed from the ground model and placed on the appropriate layer. An integrity check is also performed simultaneously to verify that ground features such as rock cuts, elevated roads and crests are present. Once data has been cleaned and complete, it is then by a supervisor via manual inspection and through the use of a hillshade mosaic.

## *Deliverable Product Generation*

### Deliverable Tiling Scheme

All files were retiled in the provided tiling scheme with a total of 16 tiles for City of Live Oak.

## LiDAR Point Data

The LiDAR point data was delivered in LAS 1.1 adhering to the following ASPRS classification scheme:

Class 1 – Unclassified
Class 2 – Ground
Class 7 – Noise
Class 9 – Water
Class 12 - Overlap

Water body delineation was collected using hillshades and intensity images generated from ground DEM and LiDAR.

The LAS files contain the following fields of information (Precision reported in brackets):

Class (Integer)
GPS Week Time (0.0001 seconds)
Easting (0.01 meter)
Northing (0.01 meter)
Elevation (0.01 meter)
Echo Number (Integer 1 to 4)
Echo (Integer 1 to 4)
Intensity (8 Bit Integer)
Flightline (Integer)
Scan Angle (Integer Degree)

Please note that the LiDAR intensity is not calibrated or normalized. The intensity value is meant to provide relative signal return strengths for features imaged by the sensor.

Point data was clipped to the project boundary.

## FGDC Report

Separate metadata FGDC reports were delivered for the City of Live Oak. The reports are included as an addendum to this report.

## *Quality Control for Data Acquisition*

A daily calibration flight is key to the QC process since it helps identify any systematic issues in data acquisition or failures on the part of the GPS, IMU or other equipment that may not have been evident to the LiDAR operator during the mission. The aircraft initially performs a figure-8 manoeuvre over the selected calibration site to collect calibration data for use in post-processing. The calibration site is ideally selected in a relatively open, tree-less area where several large buildings are located. The buildings used for calibration are surveyed using both GPS and conventional survey methods. A local network of GPS points are established to provide a baseline for conventional traversing around the perimeter of the buildings.

Ground truth validation is used to assess the data quality and consistency over sample areas of the project. To facilitate a confident evaluation, existing survey control is used to validate the LiDAR data. Published survey control, where the orthometric height (elevation) has been determined by precise differential levelling observation, is deemed to be suitable.

Ground truth validation points may be collected for each of the any terrain categories that Dewberry requires to establish RMSE accuracies for the LIDAR project. These points must be gathered in flat or uniformly sloped terrain (<20% slope) away from surface features such as stream banks, bridges or embankments. If collected, these points will be used during data processing to test the $RMSE_z$ accuracy of the final LiDAR data products.

The LiDAR operator performs kinematic post-processing of the aircraft GPS data in conjunction with the data collected at the Reference Station in closest proximity to the area flown. Double difference phase processing of the GPS data is used to achieve the greatest accuracy. The GPS position accuracy is assessed by comparison of forward and reverse processing solutions and a review of the computational statistics. Any data anomalies are identified and the necessary corrective actions are implemented prior to the next mission.

The quality control of LIDAR data and data products has proven to be a key concern by Dewberry. Many specifications detail how to measure the quality of LiDAR data given RMSE statistical methods to a 95% confidence level. In order to assure meeting all levels of QC concerns, Terrapoint has quality control and assurance steps in both the data acquisition phase and the data processing phase. Any acquired data sets that fail these checks are flagged for re-acquisition.

QC Step 1 - The Data Acquisition (DAQ) software performs automatic system and subsystem tests on power-up to verify proper functionality of the entire data acquisition system. Any anomalies are immediately investigated and corrected by the LiDAR operator if possible. Any persistent problems are referred to the engineering staff, which can usually resolve the issue by telephone and/or email. In the unlikely event that these steps do not resolve the problem, a trained engineer is immediately dispatched to the project site with the appropriate test equipment and spare parts needed to repair the system.

QC Step 2 - The DAQ software continuously monitors the health and performance of all subsystems. Any anomalies are recorded in the System Log and reported to the LiDAR operator for resolution. If the operator is unable to correct the problem, the engineering staffs are immediately notified. They provide the operator with instructions or on-site assistance as needed to resolve the problem.

The DAQ software also provides real-time terrain viewers that allow the operator to directly monitor the data quality. Multiple returns from individual laser shots are color coded to provide the operator with an indication of the degree of penetration through dense vegetation. If any aspect of the data does not appear to be acceptable, the operator will review system settings to determine if an adjustment could improve the data quality. Navigation aids are provided to alert both the pilot and operator to any line following errors that could potentially compromise the data integrity. The pilot and operator review the data and determine whether an immediate re-flight of the line is required.

QC Step 3 - After the mission is completed, raw LiDAR data on the removable disk drive is transferred to the Field PC at the field operations staging area. An automated QA/QC program scans the System Log as well as the raw data files to detect potential errors. Any problems identified are reported to the operator for further analysis. Data is also retrieved from all GPS Reference Stations, which were active during the mission and transferred to the Field PC. The GPS data is processed and tested for internal consistency and overall quality. Any errors or limit violations are reported to the operator for more detailed evaluation.

QC Step 4 - The operators utilize a data viewer installed on the Field PC to review selected portions of the acquired LiDAR data. This permits a more thorough and detailed analysis than is possible in real-time during data collection. Corrupted files or problems in the data itself are noted. If the data indicates improper settings or operation of the LiDAR sensor, the operator determines the appropriate corrective actions needed prior to the next mission.

QC Step 5 - All LiDAR and GPS data is copied from the Field PC onto Hard Drives: one for transfer to data processing, and one for local backup. Each Hard drive is reviewed to ensure data completeness and readability.

## *Quality Control for Data Processing*

Quality assurance and quality control procedures for the raw LiDAR data and processed deliverables for the DEM and DTM products are performed in an iterative fashion through the entire data processing cycle. All final products pass through a seven-step QC control check to verify that the data meets the criteria specified by Dewberry.

Terrapoint has developed a rigorous and complete process, which does everything possible to ensure data will meet or exceed the technical specifications. Experience dealing with all ranges of difficulty in all types of topographic regions has led to the development of our quality assurance methods. Our goal is to confidently deliver a final product to Dewberry that is as precise as possible, the first time. Terrapoint will go to extraordinary lengths to make our customer completely satisfied. The following list provides a step-by-step explanation of the process used by Terrapoint to review the data prior to customer delivery.

<u>QC Step 1</u> - Data collected by the LiDAR unit is reviewed for completeness and to make sure all data is captured without errors or corrupted values. In addition, all GPS, aircraft trajectory, mission information, and ground control files are reviewed and logged into a database. At this time, the data will be confirmed to have been acquired using instrumentation that records first and last returns for each laser pulse, or multiple returns per laser pulse.

<u>QC Step 2</u> - The LiDAR data is post processed and calibrated for as a preliminary step for product delivery. At this time, the data are inspected for flight line errors, flight line overlap, slivers or gaps in the data, point data minimums, or issues with the LiDAR unit or GPS. Flight line swath overlap will be confirmed to have adjacent flight lines at the tolerance specified by Dewberry for overlap throughout the project area thus enabling an evaluation of data reproducibility throughout the areas.

<u>QC Step3</u> - The full-featured product is reviewed as a grid and as raw points and attention is placed on locating and eliminating any outlier or anomalous points beyond three-sigma values. These points may be spikes, unusually high points, or pits, unusually low points. LiDAR points returning from low clouds, birds, pollution, or noise in the system can cause spikes. Pit-like low returns can come from water features or damp soils or from system noise. Either type of point needs to be classified as an error point and eliminated from use by any grid

products. In addition to these outliers, the full-feature product is reviewed for NO DATA points and regular looking non-surface errors like scan lines appearing in the data. Also, steps between flight lines are measured and adjusted as needed.

Unusual or odd-looking features and questionable returns are checked for validity and compared against additional source material such as aerial photos, USGS digital maps, local maps, or by field inspection. Most errors found at this QC step can be resolved by re-calibration of the data set or by eliminating specific problem points.

QC Step 4 - After the full-feature data is at a clean stage, all points are classified as ground and unclassified features. Any non-regular structures or features like radio towers, large rock outcrops, water bodies, bridges, piers, are confirmed to be classified into the category specified by Dewberry for these feature types. Additional data sets like commercially available data sources or data sources provided by Dewberry may be used to assist and verify that points are assigned into correct classifications.

QC Step 5 - After the full-featured data set is certified as passing for completeness and for the removal of outliers, attention may be shifted to quality controlling the bare-earth model. This product may take several iterations to create it to the quality level that Dewberry is looking for. As both Terrapoint and Dewberry inspect the bare-earth model, adjustments are made to fine-tune and fix specific errors.

Adjustments to the bare-earth model are generally made to fix errors created by over-mowing the data set along mountaintops, shorelines, or other areas of high percent slope. Also, vegetation artefacts leave a signature surface that appears bumpy or rough. Every effort is made to remove spurious vegetation values and remnants from the bare-earth model. All adjustments are made by re-classifying points from ground to unclassified or vice versa. No adjustments are made to the final grid product, as other parties cannot easily reproduce these types of adjustments from the original, raw data set.

QC Step 6 - Both $RMSE_z$ and $RMSE_{xy}$ are inspected in the classified bare-earth model and compared to project specifications. $RMSE_z$ is examined in open, flat areas away from breaks and under specified vegetation categories. Neither $RMSE_z$ nor $RMSE_{xy}$ are compared to orthoimagery or existing building footprints. Comparison against imagery can skew the determination of accuracy because of the lean and shadows in the imagery.

Instead, a point to point comparison of a recently acquired or existing high confidence ground survey point to its nearest neighbour LiDAR laser return point. This is done in the raw data set and usually with Terrascan software. The tolerance for finding a near-by LiDAR point elevation to compare to a survey point elevation is that the two points must be within a 0.5m radius of each other in open flat areas is made. If no LiDAR points can be found within in this tolerance, then alternative methodologies are used to convert the LiDAR to a TIN, though this can introduce biases and processing errors in the end products and could cause the RMSE values to be skewed and fall beyond project specifications.

QC Step 7 - A final QC step is made against all deliverables before they are sent to Dewberry. The deliverables are checked for file naming convention, integrity checks of the files, conformance to file format requirements, delivery media readability, and file size limits. In addition, as data are delivered all requested reports would be delivered as they become available.

## *Positional Accuracy*

### Vertical Positional Accuracy

The elevation data was verified internally prior to delivery to Dewberry to ensure it met fundamental accuracy requirements when compared kinematic to Terrapoint GPS checkpoints. Below is the summary for the three sites.

- The LiDAR dataset for City of Live Oak was tested 0.039m vertical accuracy at 95 percent confidence level, based on consolidated $RMSE_z$ (0.035m) x 1.9600.

### Horizontal Positional Accuracy

Compiled to meet 1 meter horizontal accuracy at the 95 percent confidence level.

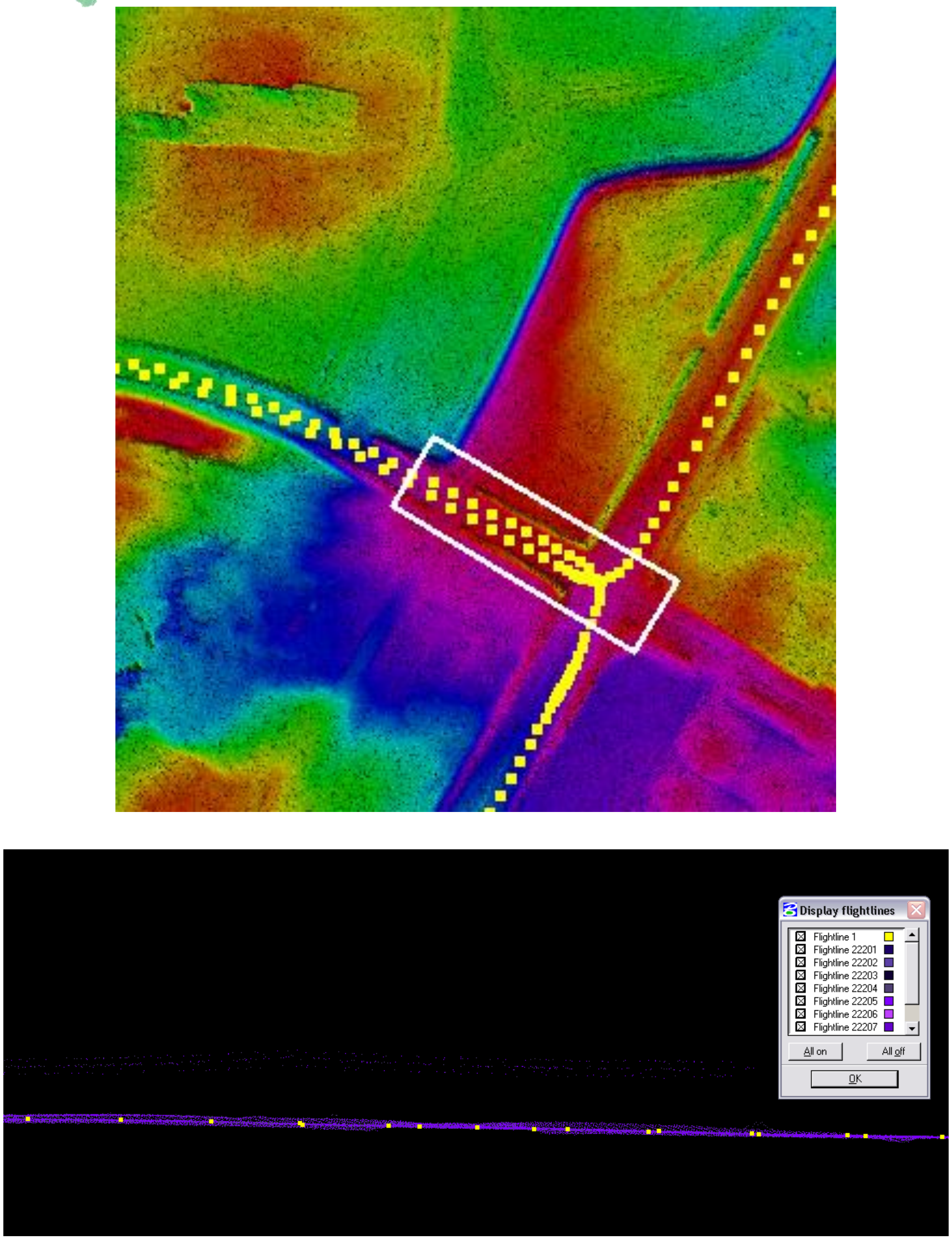



**Figure 2 Example of Control pts (flightline 1) loaded with the raw data to check vertical accuracy**

## Conclusion

Overall the LiDAR data products submitted to Dewberry meet and exceed both the absolute and relative accuracy requirements set out in the task order for this project. The quality control requirements required in Terrapoint's IPROVE program were adhered to throughout the project cycle to ensure product quality.

IDENTIFICATION_INFORMATION

Citation:
Citation_Information:
Originator: Terrapoint USA
Publication_Date: 20090116
Title: Dewberry FDEM City of Live Oak Task Order 20070525-4927 Contract No. 07-HS-34-14-00-22-469
Geospatial_Data_Presentation_Form: Map
Online_Linkage: none
Larger_Work_Citation:
Citation_Information:
Originator: Terrapoint USA
Publication_Date: 20090116
Title: Dewberry Dewberry FDEM City of Live Oak Contract No. 2007-205-U
Publication_Information:
Publication_Place: Houston, Texas
Publisher: Terrapoint USA
Online_Linkage: none
Description:
Abstract:
LIDAR data is remotely sensed high-resolution elevation data collected by an airborne collection platform. By positioning laser range finding with the use of 1 second GPS with 100hz inertial measurement unit corrections; Terrapoint's LIDAR instruments are able to make highly detailed geospatial elevation products of the ground, man-made structures and vegetation. The
LiDAR flightlines for this project was planned for a 55% acquisition overlap. The nominal resolution of this project without overlap is 1.25m. Four returns were recorded for each pulse in addition to an intensity value. GPS Week Time, Intensity, Flightline and number attributes were provided for each LiDAR point.
Data is provided as random points, in LAS v1.1 format, classified in following code list 1=Unclassified 2=Ground 7=Noise 9=Water 12=Overlap

Purpose:
The purpose of this LiDAR data was to produce high accuracy 3D elevation based geospatial products for mapping.

Supplemental_Information:
LiDAR Collection Specific Supplemental Information:

- General Overview:
The Airborne LiDAR survey was conducted using 1 OPTECH 3100EA system flying at a nominal height of 970m AGL with a total angular coverage of 20 degrees. Flight line spacing was nominally 219.28m providing overlap of 55% on adjacent flight lines. Lines were flown in east/west orientated blocks to best optimize flying time considering the layout for the project.

The total project size is 37.29 square kilometers

The aircraft was a PA-31 Navajos, registration C-FQQB,used for the survey. This aircraft has a flight range of approximately 6 hours and was flown at an average altitude of 970 meters above sea level (ASL). The aircraft was staged from the Suwannee County Airport, 24J, Live Oak, Florida, and ferried daily to the project site for flight operations.

Aircraft Speed = 150 Knots
Number of Scanners = 1
Swath Width 451.45m Nominal
Distance Between Flight Lines = 225.72m
Data Acquisition Height = 970 meters AGL
Pulse Repetition Rate = 100 kHz
Number of Returns Per Pulse = 4
Scanner Field Of View = +/- 20 degrees
Scan Frequency = 55.2 Hertz

- GPS Receivers
A combination of Sokkia GSR 2600 and NovAtel DL-4+ dual frequency GPS receivers were used to support the airborne operations of this survey and to establish the GPS control network.

- Number of Flights and Flight Lines
A total of 1 mission and 32 flightlines were flown for this project with flight times ranging approximately 6 hours under good meteorological and GPS conditions.

- Reference Coordinate System Used:
Existing monuments at SUWAPORT were used to control all flight missions and kinematic ground surveys.

The published horizontal datum of the NGS stations is NAD83 HARN and the vertical datum NAVD88. The following are the final coordinates of the newly established control points used in this project:

Station_ID: SUWAPORT
West_Longitude: -83 01 02.68267
North_Latitude: 30 18 08.42590
Ellips_Elev: -3.0363

- Geoid Model Used
The Geoid03 geoid model, published by the NGS, was used to transform all ellipsoidal heights to orthometric.

-General LiDAR notes

-Intensity
Please note that the LiDAR intensity is not calibrated or normalized. The intensity value is meant to provide relative signal return strengths for features imaged by the sensor.

-Waterbodies
Water is not included in the bare earth ground points for lakes, rather it is classified as water on Class 9. Water body delineation was collected using hillshades and intensity images generated from ground DEM and LiDAR.

Time_Period_of_Content:
  Time_Period_Information:
    Range_of_Dates/Times:
      Beginning_Date: 20080122
      Ending_Date: 20080122
  Currentness_Reference: Ground Condition
Status:
  Progress: Complete
  Maintenance_and_Update_Frequency: None planned
Spatial_Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate: -83.02
    East_Bounding_Coordinate: -82.95
    North_Bounding_Coordinate: 30.32
    South_Bounding_Coordinate: 30.26

Keywords:
  Theme:
    Theme_Keyword_Thesaurus: None
    Theme_Keyword: ASPRS standards
    Theme_Keyword: DEM
    Theme_Keyword: digital elevation model
    Theme_Keyword: elevation
    Theme_Keyword: LAS_v1.1
    Theme_Keyword: laser
    Theme_Keyword: LiDAR
    Theme_Keyword: OPTECH_3100EA
    Theme_Keyword: surface model
  Place:
    Place_Keyword_Thesaurus: None
    Place_Keyword: clay/Putnam Counties
    Place_Keyword: Florida
    Place_Keyword: United States of America
    Place_Keyword: Southeast

Access_Constraints:
All deliverable data and documentation shall be free from restrictions regarding use and distribution. Data and documentation provided under this task order shall be freely distributable by government agencies.

Use_Constraints:
Any conclusions from results of the analysis of this LiDAR are not the responsibility of Terrapoint. The LiDAR data was thoroughly visually verified to represent the true ground conditions at time of collection. Users should be aware of this limitations of this dataset if using for critical applications.

Point_of_Contact:
  Contact_Information:
    Contact_Organization_Primary:
      Contact_Organization: Florida DEM
    Contact_Address:
      Address_Type: mailing and physical address
      Address: 2555 Shumard Oak Boulevard
      City: Tallahassee
      State_or_Province: FL
      Postal_Code: 32399-2100
      Country: USA
    Contact_Voice_Telephone: 850-413-9907
    Contact_Facsimile_Telephone: 850-488-1016

Contact_Electronic_Mail_Address: gis@dca.state.fl.us

DATA_QUALITY_INFORMATION

Attribute_Accuracy:
Attribute_Accuracy_Report:
Raw elevation measurements have been tested to 0.128 US Survey Ft for vertical accuracy at 95 percent confidence level

Logical_Consistency_Report:
All LiDAR files delivered were verified and tested to ensure they open and are positioned properly.
Completeness_Report:
According to Terrapoint standards; the following aspects of the LiDAR data was verified during the course of the project processing:
-Data completeness and integrity
-Data accuracy and errors
-Anomaly checks through full-feature hillshades
-Post automated classification Bare-earth verification
-RMSE inspection of final bare-earth model using kinematic GPS
-Final quality control of deliverable products; ensuring integrity; graphical quality; conformance to Terrapoint standards are met for all delivered products.
-Special note for this dataset: On a project level, a coverage check is carried out to ensure no slivers are present; however due to resale nature of this task order and the desire to maximize coverage, some minor slivers were detected and reported to the client via polygon shape files. The slivers were reflown and filled.
Positional_Accuracy:
Horizontal_Positional_Accuracy:
Horizontal_Positional_Accuracy_Report:
Compiled to meet 1 meter horizontal accuracy at the 95 percent confidence level
Vertical_Positional_Accuracy:
Vertical_Positional_Accuracy_Report:
Tested to 0.128 US Survey Ft for vertical accuracy at the 95 percent confidence level
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator: Terrapoint USA
Publication_Date: 20090116

Title: Dewberry FDEM City of Live Oak
Edition: One
Geospatial_Data_Presentation_Form: map
Publication_Information:
Publication_Place: Houston, Texas
Publisher: Terrapoint USA
Online_Linkage: www.terrapoint.com
Larger_Work_Citation:
Citation_Information:
Originator: Terrapoint USA
Publication_Date: 20090116
Title: Dewberry FDEM City of Live Oak
Publication_Information:
Publication_Place: Houston, Texas
Publisher: Terrapoint USA
Online_Linkage: www.terrapoint.com
Type_of_Source_Media: Hard Drive
Source_Time_Period_of_Content:
Time_Period_Information:
Range_of_Dates/Times:
Beginning_Date: 20080122
Ending_Date: 20080417
Source_Currentness_Reference: Ground Condition
Source_Citation_Abbreviation: none
Source_Contribution: none

Process_Step:
Process_Description:
- Airborne GPS Kinematic
Airborne GPS kinematic data was processed on-site using GrafNav kinematic On-The-Fly (OTF) software. Flights were flown with a minimum of 6 satellites in view (13o above the horizon) and with a PDOP of better than 4.5. Distances from base station to aircraft were kept to a maximum of 30 km, to ensure a strong OTF (On-The-Fly) solution. For all flights, the GPS data can be classified as excellent, with GPS residuals of 5cm average but no larger than 9 cm being recorded.
Source_Used_Citation_Abbreviation: GPS Processing
Process_Date: 200801
Source_Produced_Citation_Abbreviation: GPS
Process_Contact:
Contact_Information:
Contact_Person_Primary:

Contact_Organization: Terrapoint USA
Contact_Person: Peggy Cobb
Contact_Position: Production Manager
Contact_Address:
Address_Type: mailing and physical address
Address: 251216 Grogan's Park Drive
City: The Woodlands
State_or_Province: Texas
Postal_Code: 77380
Country: USA
Contact_Voice_Telephone: 1-877-999-7687
Contact_Facsimile_Telephone: 1-281-296-0869
Contact_Electronic_Mail_Address: peggy.cobb@terrapoint.com
Hours_of_Service: Monday to Friday, 8 - 5, CST
Process_Step:
Process_Description:
- Generation and Calibration of laser points (raw data)

The initial step of calibration is to verify availability and status of all needed GPS and Laser data against field notes and compile any data if not complete.

Subsequently the mission points are output using Optech's Dashmap, initially with default values from Optech or the last mission calibrated for system. The initial point generation for each mission calibration is verified within Microstation/Terrascan for calibration errors. If a calibration error greater than specification is observed within the mission, the roll pitch and scanner scale corrections that need to be applied are calculated. The missions with the new calibration values are regenerated and validated internally once again to ensure quality. All missions are validated against the adjoining missions for relative vertical biases and collected GPS kinematic ground truthing points for absolute vertical accuracy purposes.

On a project level, a coverage check is carried out to ensure no slivers are present.

Source_Used_Citation_Abbreviation: Calibration
Process_Date: 200801
Source_Produced_Citation_Abbreviation: CAL
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization: Terrapoint USA
Contact_Person: Peggy Cobb
Contact_Position: Production Manager
Contact_Address:

Address_Type: mailing and physical address
Address: 251216 Grogan's Park Drive
City: The Woodlands
State_or_Province: Texas
Postal_Code: 77380
Country: USA
Contact_Voice_Telephone: 1-877-999-7687
Contact_Facsimile_Telephone: 1-281-296-0869
Contact_Electronic_Mail_Address: peggy.cobb@terrapoint.com
Hours_of_Service: Monday to Friday, 8 - 5, CST
Process_Step:
Process_Description:
- Vertical Bias Resolution
Due to limitations in the Optech Dashmap software, the following Dz adjustments were adjusted post calibration manually in Terrascan to the following missions to ensure they tie to adjoining missions and GPS kinematic validation points:
System;Year;Mission;Delta_Z_Adjustment_(cm):
Source_Used_Citation_Abbreviation: Vertical Bias Resolution
Process_Date: 200801
Source_Produced_Citation_Abbreviation: Dz
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization: Terrapoint USA
Contact_Person: Peggy Cobb
Contact_Position: Production Manager
Contact_Address:
Address_Type: mailing and physical address
Address: 251216 Grogan's Park Drive
City: The Woodlands
State_or_Province: Texas
Postal_Code: 77380
Country: USA
Contact_Voice_Telephone: 1-877-999-7687
Contact_Facsimile_Telephone: 1-281-296-0869
Contact_Electronic_Mail_Address: peggy.cobb@terrapoint.com
Hours_of_Service: Monday to Friday, 8 - 5, CST
Process_Step:
Process_Description:
- Data Classification and Editing
The data was processed using the software TerraScan, and following the methodology described herein. The initial step is the setup of the TerraScan project, which is done by importing client provided tile boundary index

encompassing the entire project areas. The 3D laser point clouds, in binary format, were imported into the TerraScan project and divided in 16 tiles.
Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine removes any obvious outliers from the dataset following which the ground layer is extracted from the 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 is 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 an iteration.
A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model. The data is then manually quality controlled with the use of hillshading, cross-sections and profiles. Any points found to be of class vegetation, building or error during the quality control process, are removed from the ground model and placed on the appropriate layer. An integrity check is also performed simultaneously to verify that ground features such as rock cuts, elevated roads and crests are present. Once data has been cleaned and complete, it is then reviewed by a supervisor via manual inspection and through the use of a hillshade mosaic of the entire project area.

Source_Used_Citation_Abbreviation: Processing
Process_Date: 20080220
Source_Produced_Citation_Abbreviation: PRD
Process_Contact:
  Contact_Information:
    Contact_Person_Primary:
      Contact_Organization: Terrapoint USA
      Contact_Person: Peggy Cobb
    Contact_Position: Production Manager
    Contact_Address:
      Address_Type: mailing and physical address
      Address: 251216 Grogan's Park Drive

City: The Woodlands
State_or_Province: Texas
Postal_Code: 77380
Country: USA
Contact_Voice_Telephone: 1-877-999-7687
Contact_Facsimile_Telephone: 1-281-296-0869
Contact_Electronic_Mail_Address: peggy.cobb@terrapoint.com
Hours_of_Service: Monday to Friday, 8 - 5, CST
Process_Step:
Process_Description:
-Deliverable Product Generation
>LiDAR Point Data
The LiDAR point data was delivered in LAS 1.0 adhering to the following ASPRS classification scheme:
Class 1 - Non-ground; Class 2 - Ground; Class 7 - Noise; Class 9 - Water
The LAS files contain the following fields of information (Precision reported in brackets):
Class (Integer); GPS Week Time (0.0001 seconds); Easting (0.01 meter); Northing (0.01 meter);
Elevation (0.01 meter); Echo Number (Integer 1 to 4); Echo (Integer 1 to 4); Intensity (8 Bit Integer);
Flightline (Integer); Scan Angle (Integer Degree)
Point data was clipped to the project boundary.
Water body delineation was collected using hillshades
and intensity images generated from ground DEM and LiDAR.
>FGDC Report
Source_Used_Citation_Abbreviation: Processing_Deliverables
Process_Date: 20080407
Source_Produced_Citation_Abbreviation: PRD_DEL
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Organization: Terrapoint USA
Contact_Person: Peggy Cobb
Contact_Position: Production Manager
Contact_Address:
Address_Type: mailing and physical address
Address: 251216 Grogan's Park Drive
City: The Woodlands
State_or_Province: Texas
Postal_Code: 77380
Country: USA
Contact_Voice_Telephone: 1-877-999-7687
Contact_Facsimile_Telephone: 1-281-296-0869
Contact_Electronic_Mail_Address: peggy.cobb@terrapoint.com

Hours_of_Service: Monday to Friday, 8 - 5, CST

SPATIAL_REFERENCE_INFORMATION

Horizontal_Coordinate_System_Definition:
Planar:
Grid_Coordinate_System:
Grid_Coordinate_System_Name: State Plane Coordinate System 1983
State_Plane_Coordinate_System:
SPCS_Zone_Identifier: 0901
Transverse_Mercator:
Scale_Factor_at_Central_Meridian: 0.9999
Longitude_of_Central_Meridian: -81
Latitude_of_Projection_Origin: 30
False_Easting: 600000
False_Northing: 0.000000
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method: Coordinate pair
Coordinate_Representation:
Abscissa_Resolution: 0.01
Ordinate_Resolution: 0.01
Planar_Distance_Units: US Survey Feet
Geodetic_Model:
Horizontal_Datum_Name: North American Datum of 1983 HARN
Ellipsoid_Name: GRS 80
Semi-major_Axis: 6378137.0000000
Denominator_of_Flattening_Ratio: 298.26
Vertical_Coordinate_System_Definition:
Altitude_System_Definition:
Altitude_Datum_Name: North American Vertical Datum of 1988
Altitude_Resolution: 0.01
Altitude_Distance_Units: US Survey Feet
Altitude_Encoding_Method: Explicit elevation coordinate included with horizontal coordinates

ENTITY_AND_ATTRIBUTE_INFORMATION

Overview_Description:
Entity_and_Attribute_Overview:
Original LiDAR point data in LAS 1.0, all deliverables in LAS binary 1.1. The LAS binary files contain the following fields of information (Precision reported in brackets):
Easting (0.01 meter); Northing (0.01 meter); Elevation (0.01 meter); Class (Integer); Description; Flightline; Timestamp; Echo (return); Intensity; Scan Angle; Echo number
Entity_and_Attribute_Detail_Citation: none

DISTRIBUTION_INFORMATION

Distributor:
  Contact_Information:
    Contact_Organization_Primary:
      Contact_Organization: Florida Division of Emergency Management
    Contact_Address:
      Address_Type: mailing and physical address
      Address: 2555 Shumard Oak Blvd
      City: Tallahassee
      State_or_Province: FL
      Postal_Code: 32399
      Country: USA
    Contact_Voice_Telephone: 850-413-9907
    Contact_Facsimile_Telephone: 850-488-1016
    Contact_Electronic_Mail_Address: EOC-GIS@em.myflorida.com
Resource_Description:
  The LiDAR data was captured for Dewberry for
  Proposed flood mapping purposes
Distribution_Liability:
  Users must assume responsibilty to determine the
  appropriate use of this LiDAR dataset.

  Data is representative of ground conditions at time of
  acquisition only.
Standard_Order_Process:
  Digital_Form:
    Digital_Transfer_Information:
      Format_Name:LAS binary
    Digital_Transfer_Option:
      Offline_Option:
        Offline_Media: Harddrive
        Recording_Format: Windows Compatible
        Compatibility_Information: Windows Compatible
  Fees: Current Handling and Processing Terrapoint Fees
  Ordering_Instructions:
    Proper release required from Dewberry for
    orders outside of Dewberry. Please contact Terrapoint
    sales for general Terrapoint LiDAR library sales.

METADATA_REFERENCE_INFORMATION

Metadata_Date: 20090116

Metadata_Review_Date: 20090116
Metadata_Contact:
  Contact_Information:
    Contact_Person_Primary:
      Contact_Person: Richard Butgereit
      Contact_Organization: Florida DEM
    Contact_Position: GIS Administrator
    Contact_Address:
      Address_Type: mailing and physical address
      Address: 2555 Shumard Oak Boulevard
      City: Tallahassee
      State_or_Province: FL
      Postal_Code: 32399-2100
      Country: USA
    Contact_Voice_Telephone: 850-413-9907
    Contact_Facsimile_Telephone: 850-488-1016
    Contact_Electronic_Mail_Address: richard.butgereit@em.myflorida.com
Metadata_Standard_Name: FGDC CSDGM
Metadata_Standard_Version: FGDC-STD-001-1998

## Appendix E: QA/QC Checkpoints and Associated Discrepancies

CHECK NAD83(HARN)FL-E ZONE NAVD88

| POINT | NORTHING | EASTING | HEIGHT | DESC | CATEGORY |
|---|---|---|---|---|---|
| SU001-1 | 478216.98 | 2449838.11 | 114.60 | GND | 1 |
| SU001-2 | 472349.14 | 2444073.23 | 100.22 | GND | 2 |
| SU001-3 | 475217.30 | 2447359.45 | 105.00 | GND | 3 |
| SU001-4 | 471753.31 | 2447795.02 | 94.64 | PVM | 4 |
| SU001-5 | 479192.30 | 2445137.39 | 99.43 | MARK ON FACE ORTHO OF CONC GUTTER | |

# Appendix F: LiDAR Vertical Accuracy Report

## City of Live Oak, FL – Vertical Accuracy Test (note only on checkpoint cluster containing 5 points)

| Point No | Land Cover Class | Survey - Z | ΔZ | $ΔZ^2$ | ABS ΔZ |
|---|---|---|---|---|---|
| SU001-1 | 1 - Bare-earth | 114.60 | 0.19 | 0.03 | 0.19 |
| SU001-2 | 2 - Tall weeds | 100.22 | 0.61 | 0.37 | 0.61 |
| SU001-3 | 3 - Forested | 105.00 | 0.99 | 0.98 | 0.99 |
| SU001-4 | 4 - Urban | 94.64 | 0.17 | 0.03 | 0.17 |
| SU001-5 | 5 - Orthos | 99.43 | 0.01 | 0.00 | 0.01 |

| Geo-Referencing | |
|---|---|
| Horiz | NAD83(1992) |
| Vert. | NAVD88 (Geoid99) |
| Units | US Survey Feet |

| RMSE Calculation |
|---|
| Sqare Root of ∑(Zn-Z'n)²/N |
| Zn = LiDAR Dem Heights |
| Z'n = Checkpoint Heights |
| N = The numberof check points |

| | |
|---|---|
| sum of dz² | 1.41 |
| count | 5.00 |
| sum dz2/count | 0.28 |
| RMSE | 0.53 |
| 1.96 * RMSE | 1.04 |
| mean | 0.39 |
| median | 0.19 |
| skew | 0.96 |
| std dev | 0.40 |
| **95th percentile** | **0.91** |

| Accuracy Targets 95% confidence based on 95th percentile | | | Actual Fit to Checkpoints | | Dz Min/Max |
|---|---|---|---|---|---|
| **Ground Cover CAT** | **RMSEz (Ft) ≤** | **ACCURACYz (Ft) ≤** | **Actual RMSEz** | **95% Acc Z** | 0.01 |
| COMBINED | 0.61 | 1.19 | 0.53 | 1.04 | 0.99 |

# Appendix G: LiDAR Qualitative Assessment Report

## LiDAR Qualitative Assessment
## City of Live Oak, FL

PDS conducted a qualitative assessment on 16 LiDAR files provided for the City of Live Oak add-on in Florida. The City of Live Oak LiDAR dataset was a new LiDAR collection which was collected and processed by Merrick.

The qualitative assessment process flow for the City of Live Oak, FL incorporated the following reviews:

1. *Statistical Analysis*- A statistical analysis routine was run on the .LAS files upon receipt to verify that the .LAS files met project specifications. This routine checked for the presence of Variable Length Records, verified .LAS classifications, verified header records for min/max x,y,z, and parsed the .LAS point file to confirm that the min/max x,y,z matched the header records. These statistics were run on the all-return point data set as well as the bare-earth point data set for every deliverable tile.
   a. All LAS files contained Variable Length Records with georeferencing information.
   b. All LiDAR points in the LAS files were classified in accordance with project specifications: Class 1 - Unclassified, Class 2 - Ground, Class 7 - Noise, Class 9 – Water, and Class 12 – Overlap Points.
   c. Min/max x,y,z values matched the header files.

2. *Spatial Reference Checks*- The .LAS files were imported into the GeoCue processing environment. As part of the URS process workflow the GeoCue import produced a minimum bounding polygon for each data file. This minimum bounding polygon was one of the tools used in conjunction with the statistical analysis to verify spatial reference integrity. No issues were identified with the spatial referencing of this dataset.

3. *Initial Data Verification:* PDS performs an initial 10% random check of the data delivery by looking at each tile individually in great detail utilizing TIN surfaces and profiles. If the data set passes the 10 % the tiles continue through the process work flow where every tile is reviewed. If the data set fails the 10% check it is normally due to a systematic process error and the data set is rejected.

4. *Data Density/Elevation checks:* The .LAS files are used to produce a Digital Elevation Model. These DEMs are produced using the software package QT Modeler which produces a 3dimensional data model. This data model is created from the Class 2 ground points using the project density deliverable requirement for unobscured areas. This product was also used to verify that gaps in the ground surface were caused by acceptable features such as buildings and water bodies.

   The QC for City of Live Oak was done at the most stringent data density requirement. For the FDEM project this requirement was that LiDAR point cloud data meet a maximum post spacing of 4 ft in un- obscured areas for random point data. Model statistics were produced and characterized by density as well as elevation. This data model was created from class 2 ground points and model statistics were characterized by density, scale, intensity as well as elevation.

(Figure 2) The low confidence area polygons were referenced with the density grids to ensure that all low confidence areas are properly identified with a low confidence area polygon. Again, these products were produced for Quality Assessment purposes only.

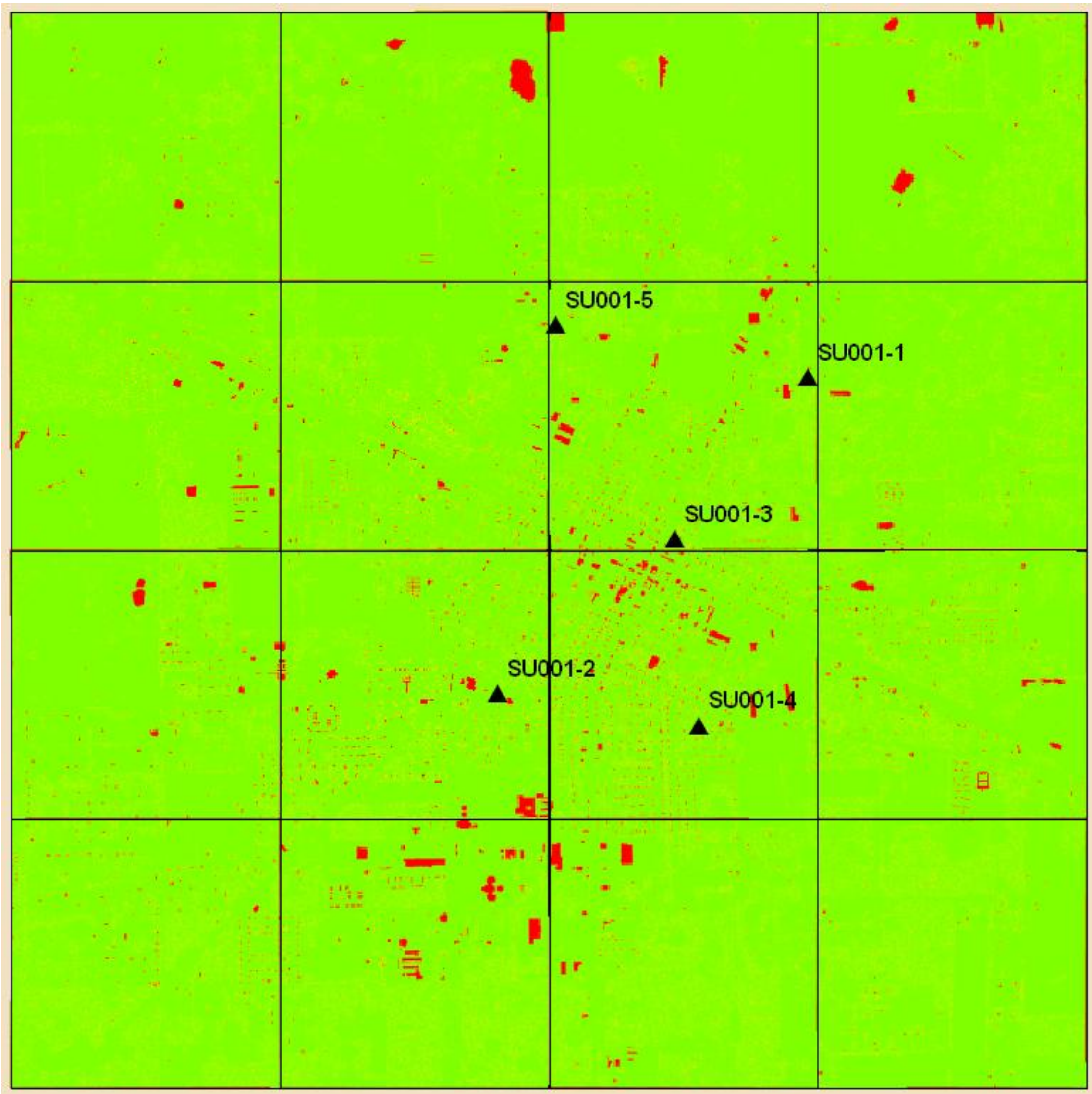



**Figure 1 City of Live Oak density grid**

*Density grids were created at a 4 foot cell size using a green to red color ramp. Green areas indicate that the grid meets the 4 foot specification. Yellow to Red indicates a gap in the 4 foot grid. All gaps were found to be acceptable and caused by buildings and/or water features.*

5. *Artifact Anomaly Checks.* The final step was to review every tile for anomalies that may exist in the bare-earth terrain surface. Items that were checked include, but are not limited to: buildings,

bridges, vegetation and water points classified as Class 2 points and elevation "steps" that may occur in the overlap between adjacent flight lines. Any issues found are addressed in the below "General comments and issues".

**General comments and issues.**

City of Live Oak, Florida is characterized by urban areas, some heavily vegetated areas, and additional man-made features such as a quarry. There are no national or state forests (Figure 4)

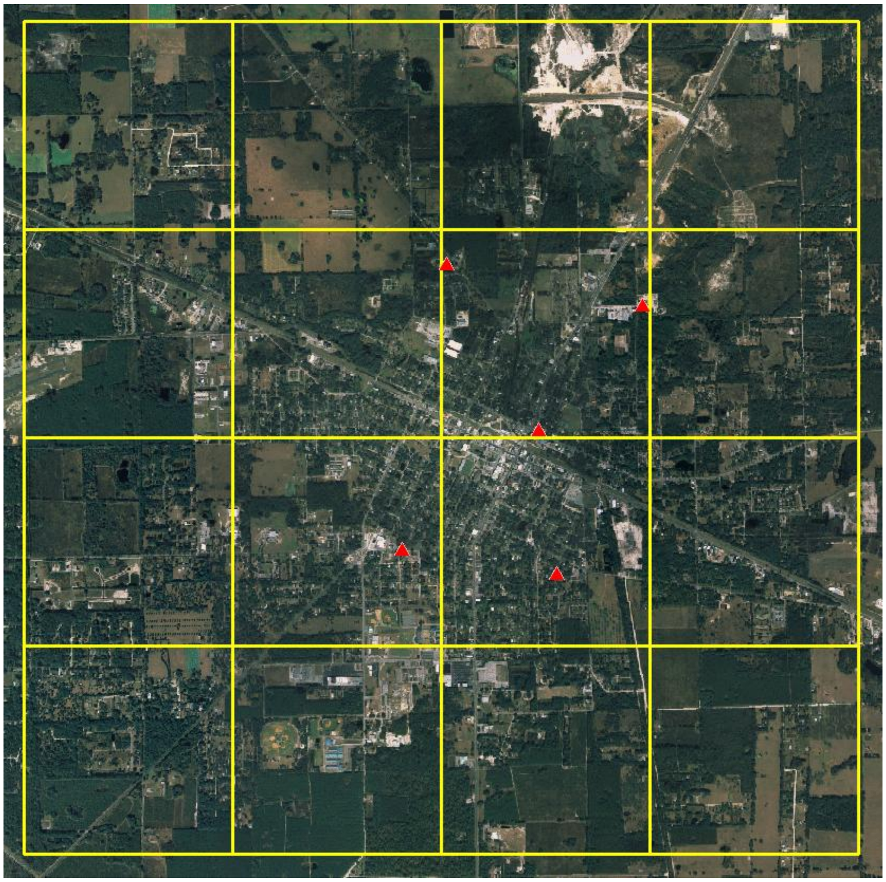


**Figure 2 Ortho of City of Live Oak Florida with tile layout and ground survey points**

No significant issues were found with this dataset. In tile 54320, a negative elevation spike was found that exceeded the specifications of the project. This spike was subsequently corrected in the tile.

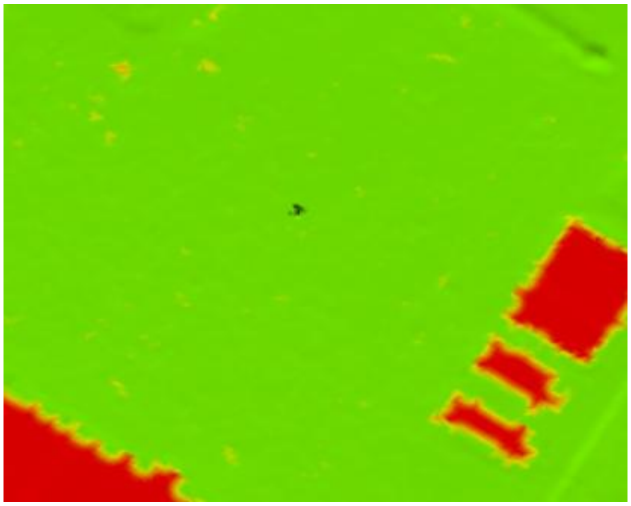
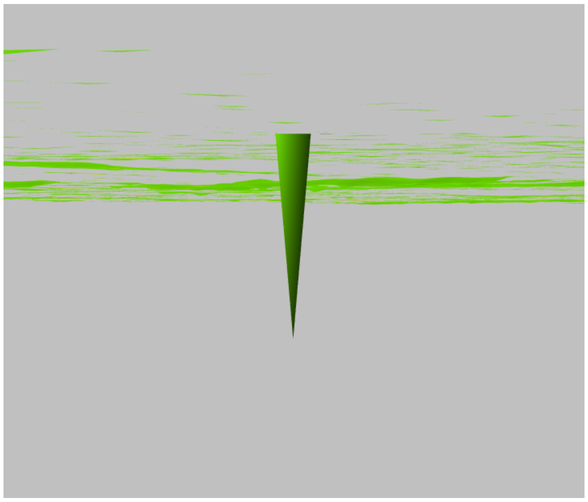



**Figure 3 Ortho of City of Live Oak Florida with tile layout and ground survey points**

Conclusion

Overall the data meets the project specifications. The processing was performed well given the low relief and highly urbanized and vegetated areas. The dense data collection specification helped with vegetation penetration. One data spike was found and corrected.

# Appendix H: Breakline/Contour Qualitative Assessment Report

**Closed Water Body Features**

Closed water body features with an area of one-half acre or greater are correctly captured as two-dimensional closed polygons with a constant elevation that reflects the best estimate of the water elevation at the time of data capture. "Donuts" exist where there are islands within a closed water body feature. Figure 3 shows example breaklines and contours of closed water body features.

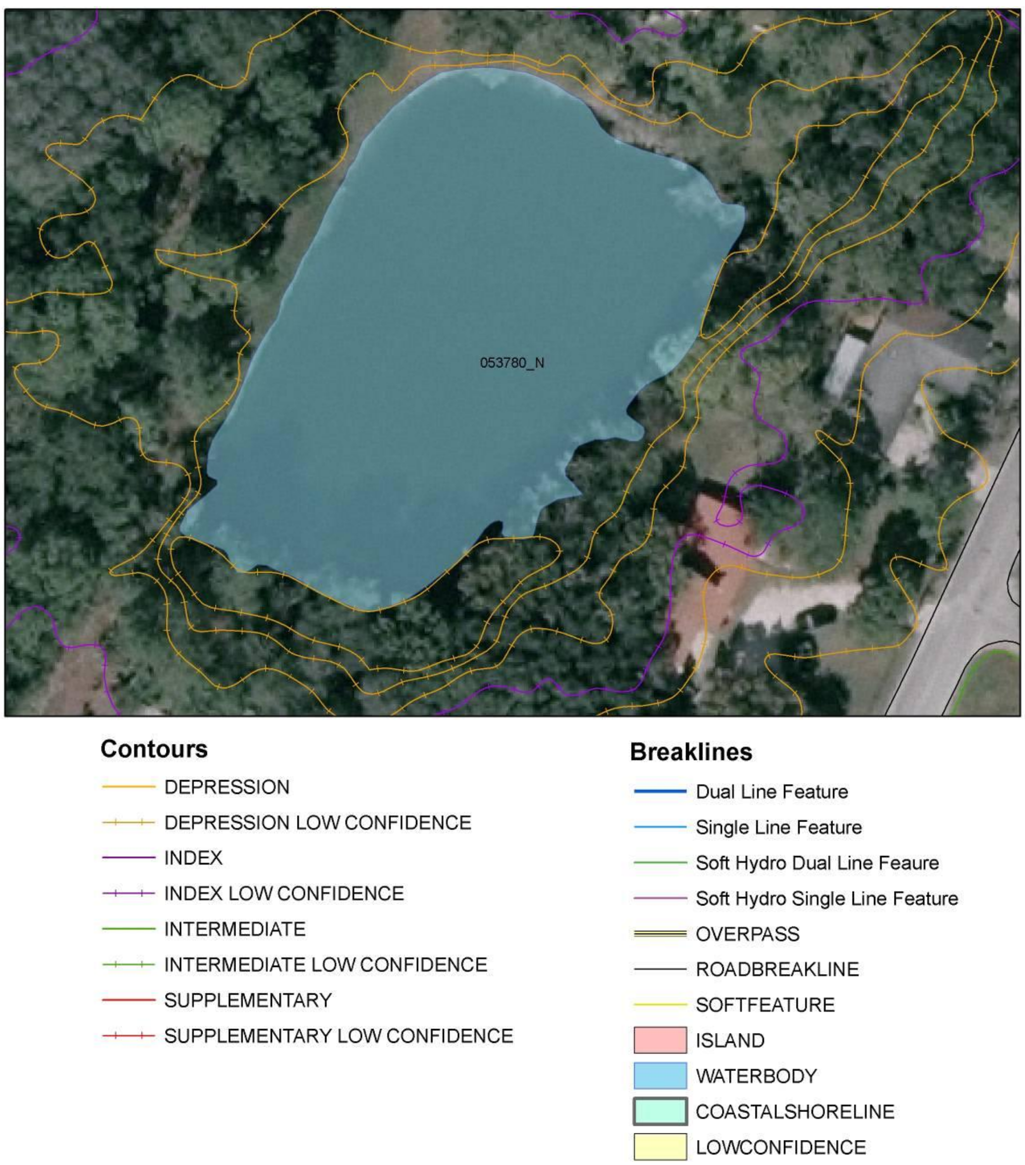



**Figure 3. Example closed water body feature breaklines and contours from tile #53780**

**Road Features**

Road edge of pavement features are correctly captured as three-dimensional breaklines on both sides of paved roads. Box culverts are continued as edge of pavement unless a clear guardrail system is in place; in that case, culverts are captured as a bridge or overpass feature. Each vertex maintains vertical integrity. Figure 4 shows example breaklines and contours of road features.


**Figure 4. Example road feature breaklines and contours from tiles #53780**

**Soft Features**

Soft features such as ridges, valleys, top of banks, etc. are correctly captured as three-dimensional breaklines so as to support better hydrological modeling of the LiDAR data and contours. Each vertex maintains vertical integrity. Figure 6 shows example breaklines and contours of soft features.

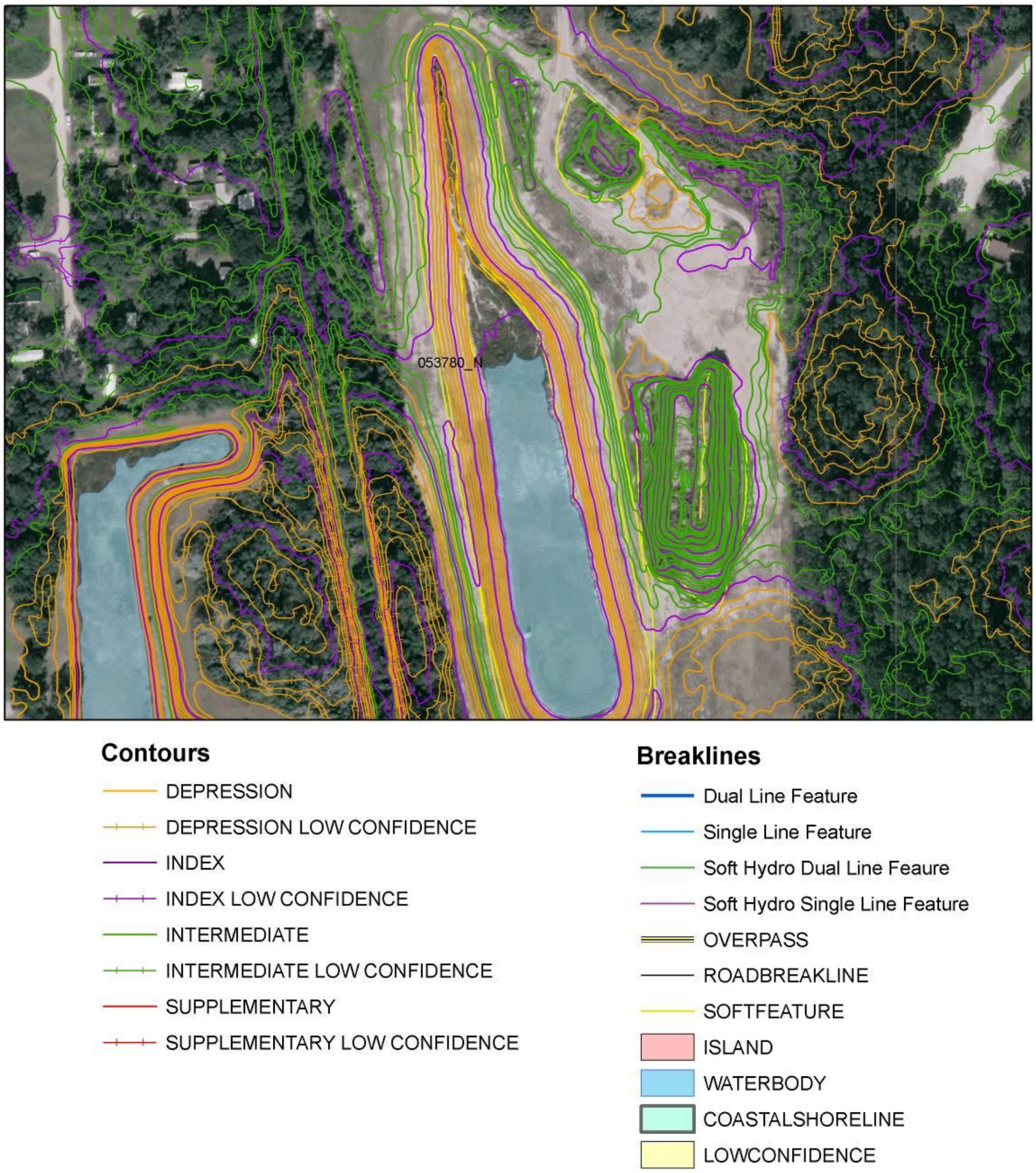



**Figure 6. Example soft feature breaklines and contours from tile #53780**

## Low Confidence Areas

The apparent boundary of vegetated areas (1/2 acre or larger) that are considered obscured to the extent that adequate vertical data cannot be clearly determined to accurately define the DTM are correctly captured as two-dimensional features with no z-values. Figure 8 shows example breaklines and contours for low confidence areas.

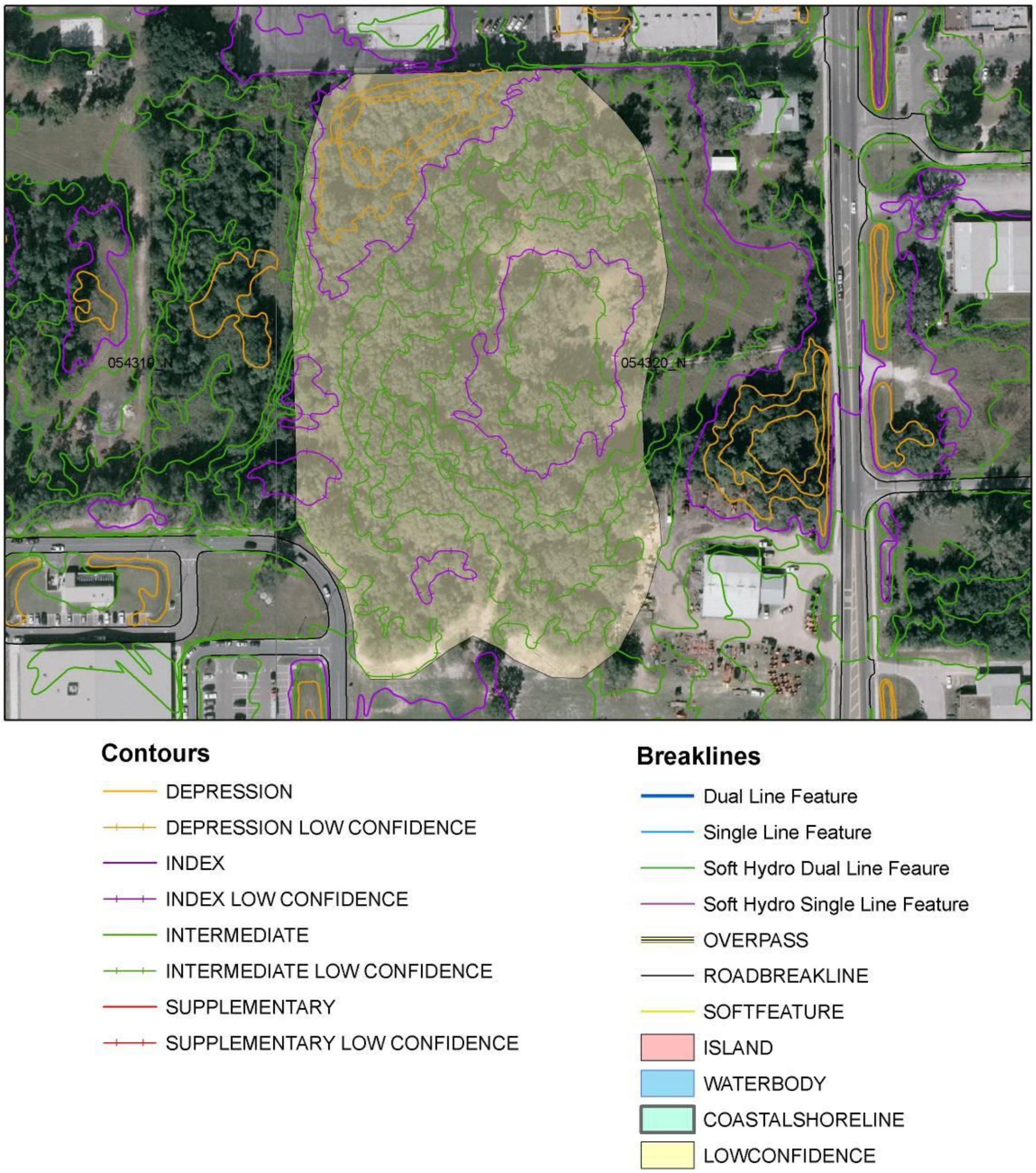



**Figure 8. Example low confidence area feature breaklines and contours from tile #54320**

# Appendix I:  Geodatabase Structure