Minimum Technical Standards
Final Report of Specific Purpose Survey
Digital Photogrammetric Contour Mapping

ST. JOHNS COUNTY 2013

COUNTYWIDE DIGITAL PHOTOGRAMMETRIC CONTOUR MAPPING PROJECT

ST. JOHNS COUNTY, FLORIDA

CONTRACT NUMBER: 07-11

TASK ORDER NUMBER: 28

Woolpert Project Number: 72829
Issued: January 12, 2015

WOOLPERT
DESIGN | GEOSPATIAL | INFRASTRUCTURE

MINIMUM TECHNICAL STANDARDS

FINAL REPORT OF SPECIFIC PURPOSE SURVEY:

St. Johns County 2013—Countywide Digital Photogrammetric Contour Mapping Project

Contract 07-11, Task Order 28

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FINAL MTS REPORT OF SPECIFIC PURPOSE SURVEY: ST. JOHNS COUNTY 2013 – COUNTYWIDE DIGITAL PHOTOGRAMMETRIC CONTOUR MAPPING PROJECT CONTRACT 07-11, TASK ORDER 28

Purpose/Type of Survey

St. Johns County, Florida County has developed a comprehensive countywide base mapping and GIS enhancements to support master drainage planning, transportation planning, and preliminary engineering and wetland preservation studies. As part of this effort, Woolpert was contracted by Jones, Edmunds & Associates (JEA) to develop the new imagery and new DTM. The project consists of new 6-inch 4-Band Orthoimagery, new 1-meter max lidar, new 1-foot contours, updating of topographic/planimetric features. The area for the St. Johns County 2013 – Countywide Digital Photogrammetric Contour Mapping Project is approximately ±776 square miles of St. Johns County in Florida. (Refer to Exhibit A, ALS70 lidar Flight Plan and Ground Control Diagram). The end product complies with the Florida Administrative Code 61G17, Minimum Technical Standards for Surveying and Mapping.

Lidar data was acquired at 1-meter max post spacing for digital terrain model (DTM) development. Woolpert acquired multi-spectral digital imagery using the Leica ADS80 (82) sensor (panchromatic, red, green, blue and near infrared) at a ground sample distance (GSD) of 0.5 feet to support photogrammetric QC and enhancement of the lidar DTM, with hydrologically significant features collected as breaklines. (Refer to Exhibit B, ADS80/82 Digital Imagery Flight Plan and Ground Control Diagram).

The planimetric/topographic and orthoimagery mapping will meet or exceed National Map Accuracy Standards (NMAS) at a 90% confidence level for the following options:

Table 1 – Accuracy Standards RMSEz

Map Scale	Horizontal Accuracy	Vertical Accuracy (DTM*)	Vertical Accuracy (Contours)
1″=100′	±2.10-feet	±0.60-feet	±0.60-feet

The county-wide contours were developed for graphical visualization purpose only, and not intended for traditional/historical cartographically pleasing contours associated with conventional topographic mapping. The lidar mass point data was delivered in LAS 1.2 format. The LAS files were clipped to the FL Statewide 5,000' x 5,000' tile system. The breaklines and contours were each provided as a county-wide ArcGIS File Geodatabase.

The St. Johns County Survey and Mapping Division field crews surveyed 93 (lidar QC) ground survey quality (QC) checkpoints throughout the project area. The QC checkpoint locations in the county are illustrated on Exhibit A, ALS70 lidar Flight Plan and Ground Control Diagram. The ground survey QC checkpoints were provided to Woolpert and used to confirm the accuracy of the lidar data. The accuracy analysis was based on methods outlined in the Geospatial Positioning Accuracy Standards, Part 3:

National Standards for Spatial Data Accuracy (NSSDA) developed by the Federal Geodetic Data Committee (FGDC-STD-007.3-1998).

Sensor Description

All lidar data was acquired using the Leica ALS70 lidar sensor, sensor number 7177. The ALS70 has a laser pulse rate of up to 500 kilohertz, records up to 4 returns per pulse, and records intensities for 3 laser returns per pulse. The St. Johns County lidar data was collected at 6,500' above ground level, at an average airspeed of 150 knots.

All digital imagery data was acquired using the Leica ADS80 digital sensor, serial number 30027. Both the red, green, blue and near infrared bands were acquired simultaneously. The maximum ground sample distance was 0.5 feet, and this imagery was used for the photogrammetric QC and enhancement of the lidar DTM.

Project Area

The project area encompasses eight hundred and sixty-seven (867) 5,000' by 5,000' tiles, based on the Florida Statewide Tile System. The project covers approximately ± seven hundred and seventy-six (776) square miles, including all of St. Johns County, Florida.

Date of Ground Control Survey

All ground control field operations for the lidar QC points took place between June 4, 2013 and August 19, 2013. All ground control field operations for the ortho photo control took place between January 28, 2013 and February 14, 2013.

Dates of Lidar Acquisition

The lidar data was acquired using the Leica ALS70 lidar sensor. A total of seven (7) missions were completed for the entire project area as follows.

Julian Day	Missions	Date
011	1	January 11, 2013
012	1	January 12, 2013
014	1	January 14, 2013
017	1	January 17, 2013
020	1	January 20, 2013
022	1	January 22, 2013
025	1	January 25, 2013

Dates of Digital Image Acquisition

The aerial digital imagery was acquired using the Leica ADS80 digital sensor. A total of nine (9) missions were completed for the entire project area as follows:

Julian Day	Missions	Date
012	1	January 12, 2013
013	1	January 13, 2013
017	1	January 17, 2013
023	1	January 23, 2013
024	1	January 24, 2013
031	1	January 31, 2013
032	1	February 1, 2013
033	1	February 2, 2013
034	1	February 3, 2013

Name of Responsible Surveyor

Patricia Gail Oliver P.S.M.
St Johns County Surveying and Mapping
500 San Sebastian View
St. Augustine, FL 32084
Professional Surveyor and Mapper Number: 4564

Name of Company

Woolpert, Inc.
1 Purlieu Place
Suite 122
Winter Park, FL 32792
Florida Certificate of Authorization Number: LB-0006777

Abbreviations

2D – Two-Dimensional
3D – Three-Dimensional
ABGPS – Airborne GPS
AGL – Above Ground Level
AT – Aerial Triangulation
CP – Certified Photogrammetrist
DEM – Digital Elevation Model
DOI – Digital Orthophoto Imagery or Image Raster Map
DTM – Digital Terrain Model
FGCC – Federal Geodetic Control Committee
FDOT – Florida Department of Transportation
FEMA – Federal Emergency Management Agency
FL - Florida

ft – United States Survey Feet
FY – Fiscal Year
GeoTIFF – Georeferenced Tag(ged) Image File Format
GPS – Global Positioning System
GSD – Ground Sample Distance
ID – Identification
IMU – Inertial Measurement Unit
Inc, - Incorporated
lidar – Light Detection and Ranging
MTS – Florida Minimum Technical Standards
NAD 83/90- North American Datum 1983, 1990 adjustment
NAVD88 – North American Vertical Datum of 1988
NGS – National Geodetic Survey
NMAS – National Map Accuracy Standards
NOAA – National Oceanic and Atmosphere Administration
NSSDA – National Standards for Spatial Data Accuracy
PID – Photo Identifiable Point (feature)
PSM – Florida Licensed Professional Surveyor and Mapper
QA – Quality Assurance
QC – Quality Control
RGB – Red, Green, Blue or True Color
RMSE – Root-Mean-Square-Error
RMSE P – Resultant Root-Mean-Square-Error
RTK – Real Time Kinematic
STD – Standard
TIIF – Tag(ged) Image File Format
TIN – Triangulated Irregular Network
TGO – Trimble Geomatics Office
USGS – United States Geological Survey
US – United States
Vx – Residual Horizontal Error in the X Direction
Vy – Residual Horizontal Error in the Y Direction
Vxy – Residual Horizontal Error in the XY Direction (Resultant)
XYZ – Easting, Northing, and Elevation grid coordinates (ASCII format)

Definitions

GeoTIFF: GeoTIFF refers to TIFF files which have georeferencing information embedded as tags within the TIFF file. The georeferencing information includes projections, coordinate systems, ellipsoids, and datums that can be used to establish the exact spatial reference for the TIFF image file. The TIFF file structure allows for both the georeferencing information and the image data to be encoded into the same file.

Digital Orthophoto Image: A digital orthophoto image (raster) map produced from a series of aerial photographs and/or image strips that have been rectified to correct for aircraft tilt, terrain relief, and camera lens distortion. The resulting image has a consistent scale throughout, allowing the user to take direct measurements such as distances, angles, positions, and areas. The digital raster image is comprised of a digital grid of pixels, or picture elements. Each pixel has a row and column "address" (an X,Y coordinate) and an intensity value ranging from 0 to 255. Each pixel within an RGB image will have an intensity value for red, green, and blue bands.

Aerial Triangulation (AT): A method of ground control extension or densification performed mathematically and in conjunction with a limited number of ground control points. ABGPS XYZ coordinates, and aircraft trajectory data from the sensor's IMU. This method of control extension or densification has been proven to be accurate and is in common use within the photogrammetric community.

Bare Earth Coverage: A set of discrete XYZ values representing the terrain surface.

Obscured Area: An area of the Earth's surface containing natural or manmade features that occlude directly imaging or sampling the ground surface with an airborne optical imaging and/or lidar sensor. Obscured areas are clearly denoted in digital map files, with the area identified with a text label. When generating contours within an obscured area, the industry standard calls for the contours to be dashed. Dashed contours should indicate to the user that the accuracy of the spatial data is degraded and/or indeterminate.

Unobscured Area: An area on the Earth's surface that is not totally obscured. Unobscured areas include paved areas, gravel and dirt roads, low grass, low scrub, and low trees. The elevation data captured through remote sensing methods within these areas meet or exceed the defined standards.

Map Accuracy

Vertical Accuracy of DTM/Mass Point Data in Unobscured Areas: Woolpert exceeded the Florida GIS Baseline Specifications for lidar by acquiring the lidar data at a 1-meter average. Based on the County's QC survey checks and Woolpert's accuracy analysis (see Appendix B, DTM Accuracy Analysis), the tested fundamental vertical accuracy of the DTM/Mass-Points data is ±0.45 foot in unobscured areas.

Contours Vertical Accuracy in Unobscured Areas: Woolpert exceeded the vertical accuracy requirement for 2-foot contours, with supplemental 1-foot contours, of the Florida GIS Baseline Specifications for lidar. Based on the County's QC survey check points and Woolpert's accuracy analysis (see Appendix C, Contour Accuracy Analysis), the tested fundamental vertical accuracy of contours is ±0.45 foot in unobscured areas.

Vertical Accuracy of DTM/Mass Point Data in Obscured Areas: There is not a County accuracy specification for obscured points, low confidence areas, on this project. Additionally, there are not published National Map Accuracy Standards or industry standards for obscured points. Obscured points, low confidence areas, are defined as areas where the ground is not measurable using photogrammetric methods. Therefore, the user should exercise caution when working with mass points and breaklines within obscured/vegetation polygons, as this data is generally assumed to be in the range of twice the error of unobscured areas, or totally unreliable.

Datum/Coordinate System

The lidar DTM and line-drawn (vector) topographic features map data are in State Plane Coordinates, Florida East Zone, referenced to North American Datum 1983, adjustment of 1990 (NAD83/1990), expressed in US Survey Feet. The vertical datum is the North American Vertical Datum of 1988 (NAVD88), also in US Survey Feet. The GEOID model used to reduce satellite derived elevations to orthometric height is GEOID12A.

Data Sources

Original Control Point Coordinates: St. Johns County
Surveying and Mapping/GIS Division
500 San Sebastian View
St. Augustine, Florida 32084
Phone: (904) 209-0764
Fax: (904) 209-0771
Email: goliver@sjcfl.us
http://www.sjcfl.us/

Woolpert, Inc.
1 Purlieu Place
Suite 122
Winter Park, FL 32792
Phone: (407) 381-2192
Fax: (407) 384-1185
http://www.woolpert.com

Methodology

The purpose of the FY2013 St. Johns County, Florida Countywide Digital Mapping project was to update planimetric and DTM surface to generate 2-foot contours. Airborne lidar was collected photogrammetrically reviewed with digital aerial photography, and limited planimetric features were collected. The project area encompassed all of St. Johns County, Florida, approximately seven hundred and seventy-six (776) square miles.

To support the development of a DTM for St. Johns County, forty-two (42) flight lines (swaths) of high density lidar data (1 meter NPS) were obtained at an altitude of 6500-feet AGL. Photogrammetric methods were employed to assist in QC and enhancement of the lidar data and the compilation of limited planimetric features. Aerial digital imagery was acquired at a 5.8 inch GSD from an altitude of 4,774-feet AGL. The aerial digital imagery was triangulated and stereo models were generated for a 3D review of the lidar data on a softcopy photogrammetric workstation. Using the new 3D digital imagery and aerial lidar, breaklines were captured where needed in order to support the DTM and 2' contours. The bare earth lidar data was imported into the workstation and superimposed over the stereo models. The lidar data was stereoscopically verified to fit the ground surface. The DTM was then used to generate 2' contours at 1"=100' output scale mapping with supplemental 1' contours provided for graphical/visualization purpose, only.

The lidar mass point data was delivered in LAS 1.2 format. The LAS files were clipped to the FL Statewide 5,000' x 5,000' tile system. The breaklines and contours were each provided as a county-wide ArcGIS File Geodatabase.

Lidar Ground Control Survey

The purpose of the survey was to obtain x, y, and z values of varying terrain as designated by Woolpert for the St Johns County AOI. The positional accuracies for the control points were as follows: Horizontal = 0.20 feet, plus or minus and Vertical = 0.25, plus or minus. The horizontal Datum for the survey is North American Datum (NAD) 83/90 Florida East Zone in units of survey feet. The vertical datum for the survey is North American Vertical Datum (NAVD) 1988, GEOID12A. The horizontal and vertical positions of the points were derived using the St. Johns County (SJC) CORS (Continuously Operating Reference Stations - CORS Stations are BART and PEDRO – (Leica GRX1200GG Pro Reference Receiver with AX1202GG Antenna) with RTK (Real Time Kinematic) Rover Units (Leica RX1250X System, 1200 GPS Controller, and ATX1230GG Smart Antenna). Single baseline solutions were used from the nearest SJC CORS. The horizontal components of the SJC CORS are referenced to the control established in the Survey Report for St. Johns County Continuously Operating Reference Stations dated February 2008. For report information refer to: http://www.sjcfl.us/BCC/Land_Management/Surveying_and_Mapping/index.aspx.

The vertical components of the CORS are based on published Bench Marks as follows: BART - Florida Department of Environmental Protection marker “K 497”, National Geodetic Survey Point Identification “DE5756” and PEDRO - Florida Department of Transportation marker “I95 K 6”, National Geodetic Survey Point Identification “AQ0374”. For additional information about the bench marks go to www.labins.org.

QC Checkpoint Ground Control Survey

To support the accuracy analysis of the lidar, the St. Johns County Survey and Mapping Division field crews acquired 93 new field survey QC checkpoints with RTK GPS ground survey. The checkpoints were surveyed in areas of various ground cover including Bare Earth/Open Terrain, Urban, Forested and Fully Grown, and Brush Lands and Trees. The QC checkpoint locations in the County are illustrated on Exhibit A (Ground Survey QC).

Aerial Digital Imagery

The digital image data was acquired using the Leica ADS80 digital sensor, serial number 30027. Both the RGB and near infrared bands were acquired simultaneously. The maximum acquisition ground sampling distance was 0.5-feet. Forty-two (42) flight lines of digital imagery were acquired at an altitude of 4,774-feet AGL. The digital imagery was used solely for QC of the lidar data and breakline development. The ADS80 aerial digital imagery flight plan is illustrated on Exhibit B, ADS80 Digital Imagery Flight Plan and Ground Control Diagram.

Processing Software

Aerial triangulation was performed to extend or densify the network of control points established by the ground control survey. Aerial triangulation provides the proper number and pattern of control points for each stereo model derived from the image strips. This data is necessary to orientate the imagery to the ground for the QC of the lidar data and breakline compilation. The software utilized for the digital image processing and aerial triangulation, developed by Leica GeoSystems, was: Leica's Xpro 5.0, Leica's IPAS Pro 1.3 and Applanix POSPac 6.1 software.

Lidar

The lidar data was acquired using a Leica ALS70 lidar sensor. Forty-two (42) flight lines of lidar data were acquired January 11, 2013 through January 25, 2013. The raw lidar data was collected to be 1 meter NPS. The ALS70 lidar flight plan is illustrated on Exhibit A, ALS70 lidar Flight Plan and Ground Control Diagram.

The ABGPS data collected during lidar acquisition was reduced using POSGNSS v5.20 by Applanix Corporation, and combined with the IMU data into a refined solution using IPAS Pro v1.35 by Leica Geosystems. The initial lidar point cloud was derived through the ALS Post Processor software by Leica Geosystems.

Once the initial lidar point cloud was derived, Woolpert performed QC to look for any systematic error within the lidar flights using proprietary software. Any systematic error was identified and removed, the individual lidar flights were clipped to remove overlap between the adjacent flights lines and to provide a homogeneous coverage over the project extents. Using the homogeneous coverage, above ground features were classified and removed using proprietary software to produce the bare-earth coverage.

Lidar QC/Photogrammetric Compilation

The bare-earth lidar data was subdivided into stereo model units derived from the triangulated ADS80 aerial digital imagery over the project area. These units were imported into a softcopy stereo plotter and superimposed over the respective stereo models. The photogrammetric technician then verified stereoscopically that the lidar data was consistent with the ground.

Hard and soft breakline features were compiled as 2D and 3D features in the softcopy environment using DATEM's Summit Evolution Capture software on an Intel® Core™ i7 – 3770 CPU @ 3.40GHz photogrammetric workstation. DATEM, Inc. of Anchorage, Alaska distributes the Summit software. The DTM was delivered as lidar mass points in LAS version 1.2 and the breaklines were delivered in an ArcGIS File Geodatabase.

Accuracy Checks

The vertical accuracy of the final lidar DTM/Mass-Point Data mapping was verified using the field survey QC data. Results of those field verifications are included in Appendix B.

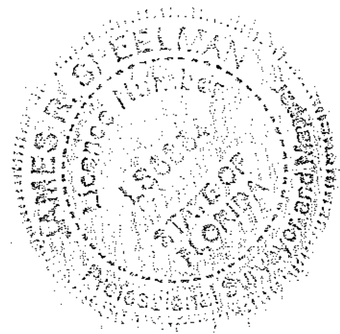
References

http://nationalmap.gov/standards/nmas.html - USGS Internet Site for National Map Accuracy Standards.

THIS REPORT IS NOT VALID WITHOUT THE SIGNATURE AND RAISED SEAL OF A FLORIDA LICENSED SURVEYOR AND MAPPER.

1/12/15

James R. Speelman, PSM **Date 1/12/2015** **Seal**



Professional Surveyor and Mapper No. LS-0006864

APPENDIX A: GROUND SURVEY QC

The St. Johns County Survey and Mapping Division field crews surveyed 93 ground survey quality (QC) checkpoints throughout the project area. The QC checkpoint locations in the County are illustrated on Exhibit A, ALS70 lidar Flight Plan and Ground Control Diagram. The ground survey QC checkpoints were provided to Woolpert and used to confirm the accuracy of the lidar data. The accuracy analysis was based on methods outlined in the Geospatial Positioning Accuracy Standards, Part 3: National Standards for Spatial Data Accuracy (NSSDA) developed by the Federal Geodetic Data Committee (FGDC-STD-007.3-1998).

Imagery snapshots illustrate the QC checkpoints used for the lidar DTM analysis.

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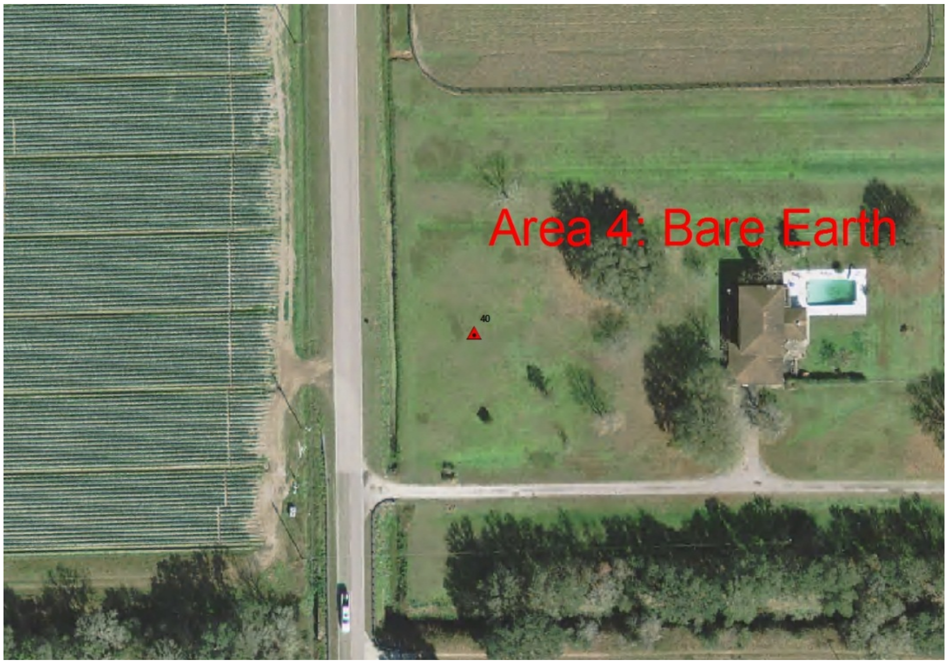
St Johns County Tile Number 24472 2013 Digital Orthophoto

St Johns County Tile Number 25065 2013 Digital Orthophoto



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St Johns County Tile Number 29876 2013 Digital Orthophoto

St Johns County Tile Number 33780 2013 Digital Orthophoto

St Johns County Tile Number 32268 2013 Digital Orthophoto

St Johns County Tile Number 22674 2013 Digital Orthophoto

St Johns County Tile Number 25057 2013 Digital Orthophoto

St Johns County Tile Number 26866 2013 Digital Orthophoto

St Johns County Tile Number 29573 2013 Digital Orthophoto

St Johns County Tile Number 23265 2013 Digital Orthophoto

St Johns County Tile Number 25660 2013 Digital Orthophoto

St Johns County Tile Number 29580 2013 Digital Orthophoto

St Johns County Tile Number 27766 2013 Digital Orthophoto

St Johns County Tile Number 28075 2013 Digital Orthophoto

St Johns County Tile Number 31677 2013 Digital Orthophoto

St Johns County Tile Number 32565 2013 Digital Orthophoto

St Johns County Tile Number 34067 2013 Digital Orthophoto

St Johns County Tile Number 28361 2013 Digital Orthophoto

St Johns County Tile Number 20870 2013 Digital Orthophoto

St Johns County Tile Number 30773 2013 Digital Orthophoto

St Johns County Tile Number 32565 2013 Digital Orthophoto

St Johns County Tile Number 34067 2013 Digital Orthophoto

St Johns County Tile Number 34378 2013 Digital Orthophoto

St Johns County Tile Number 32575 2013 Digital Orthophoto

St Johns County Tile Number 29566 2013 Digital Orthophoto

St Johns County Tile Number 25057 2013 Digital Orthophoto

St Johns County Tile Number 25660 2013 Digital Orthophoto

St Johns County Tile Number 28072 2013 Digital Orthophoto

St Johns County Tile Number 33779 2013 Digital Orthophoto

St Johns County Tile Number 25973 2013 Digital Orthophoto

St Johns County Tile Number 24471 2013 Digital Orthophoto

St Johns County Tile Number 21774 2013 Digital Orthophoto

St Johns County Tile Number 23861 2013 Digital Orthophoto

St Johns County Tile Number 24158 2013 Digital Orthophoto

St Johns County Tile Number 25065 2013 Digital Orthophoto

St Johns County Tile Number 26589 2013 Digital Orthophoto

St Johns County Tile Number 28079 2013 Digital Orthophoto

St Johns County Tile Number 28066 2013 Digital Orthophoto

St Johns County Tile Number 31369 2013 Digital Orthophoto

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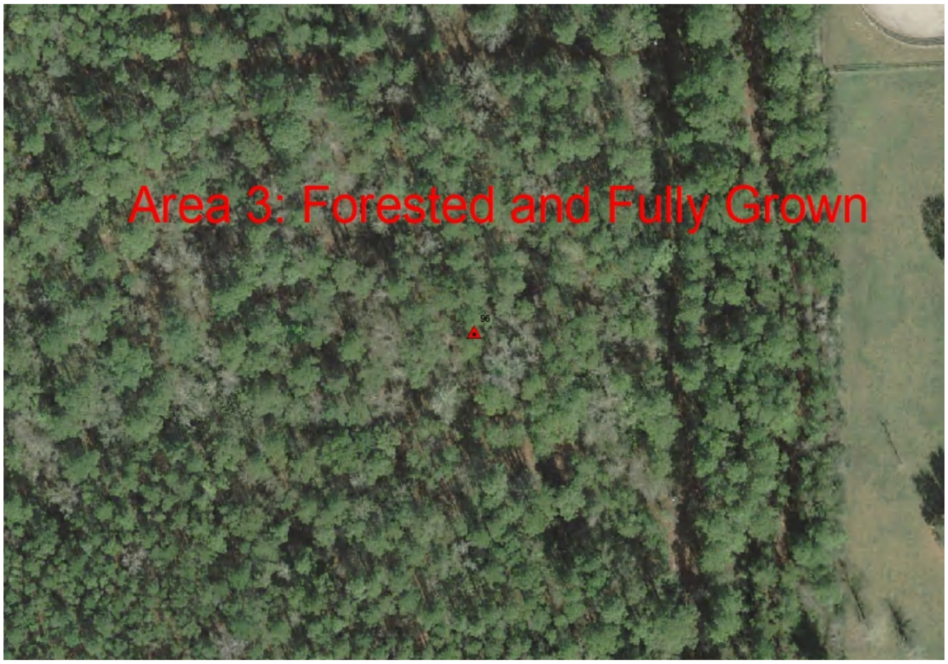

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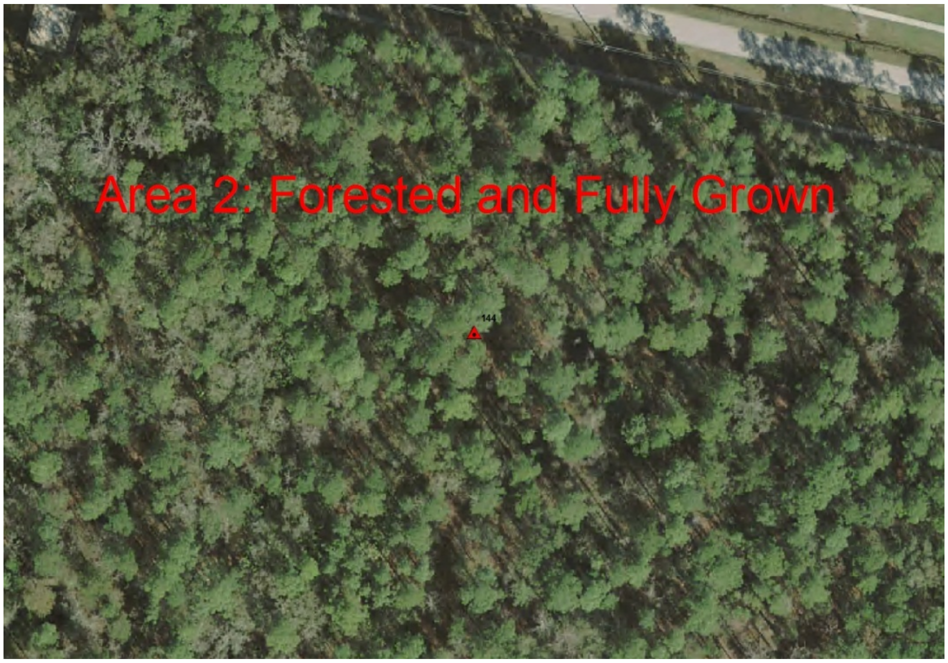

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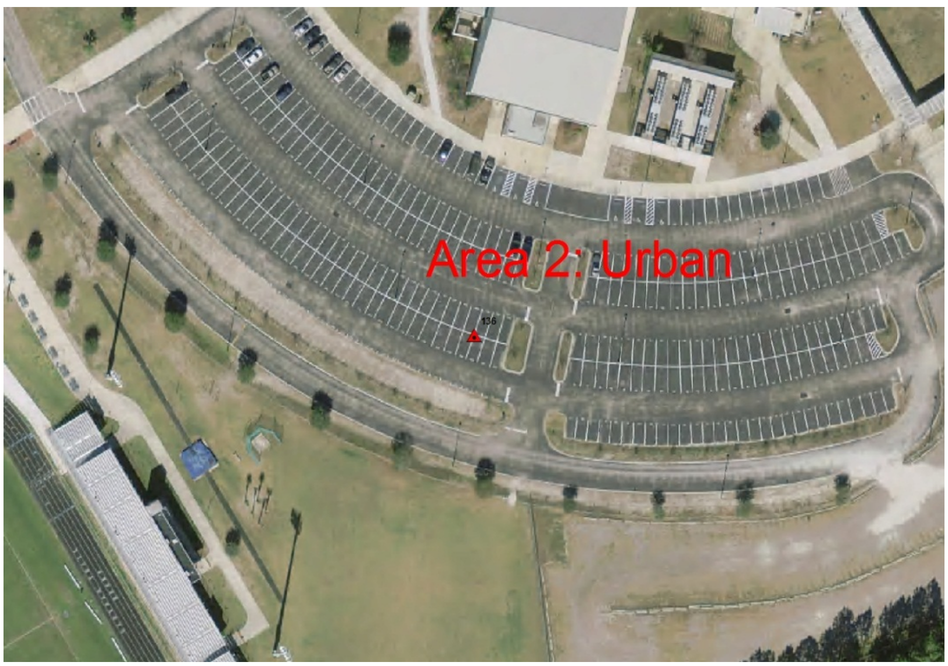

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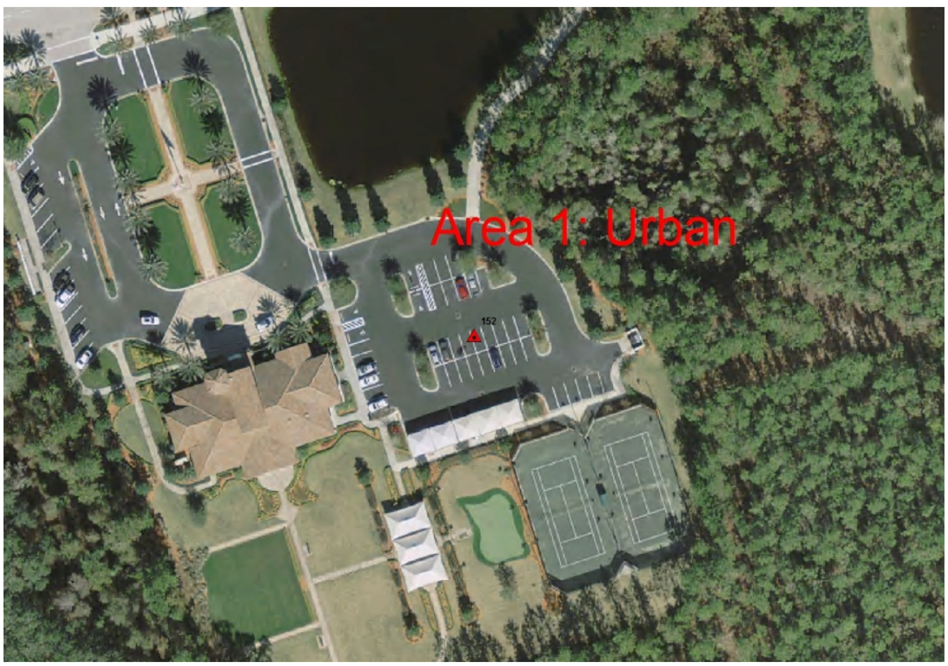
St Johns County Tile Number 22074 2013 Digital Orthophoto



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St Johns County Tile Number 23858 2013 Digital Orthophoto

St Johns County Tile Number 25064 2013 Digital Orthophoto

St Johns County Tile Number 25973 2013 Digital Orthophoto

St Johns County Tile Number 26568 2013 Digital Orthophoto

St Johns County Tile Number 27167 2013 Digital Orthophoto

St Johns County Tile Number 28071 2013 Digital Orthophoto

APPENDIX B: LIDAR ACCURACY CHECKS

The vertical accuracy of the lidar data was verified by comparison of the DTM/TIN against the field survey QC points. A total of 93QC test points were captured across the project. For the FY 2013 St. Johns County, Florida Countywide Digital Contour Mapping Project, St. Johns County Survey and Mapping Division field crews observed and established 3-dimensional coordinates on 93 quality control ground control points. The observations were performed on four different types of terrain, Bare Earth/Open Terrain, Forested/Fully Grown, Bush Lands and Trees, and Urban.

The horizontal and vertical positions of the points were derived using the St. Johns County (SJC) CORS (Continuously Operating Reference Stations - CORS Stations are BART and PEDRO – (Leica GRX1200GG Pro Reference Receiver with AX1202GG Antenna) with RTK (Real Time Kinematic) Rover Units (Leica RX1250X System, 1200 GPS Controller, and ATX1230GG Smart Antenna). Single baseline solutions were used from the nearest SJC CORS. The vertical components of the CORS are based on published Bench Marks as follows: BART - Florida Department of Environmental Protection marker “K 497”, National Geodetic Survey Point Identification “DE5756” and PEDRO - Florida Department of Transportation marker “I95 K 6”, National Geodetic Survey Point Identification “AQ0374”.

The accuracy analysis itself was based on methods outlined in the Geospatial Positioning Accuracy Standards, Part 3: National Standards for Spatial Data Accuracy (NSSDA) developed by the Federal Geodetic Data Committee (FGDC-STD-007.3-1998). The first step was to generate a TIN from the DTM. Each point along individual profiles was then compared against its corresponding TIN elevation. The difference between ground survey and DTM/TIN elevation represents the residual error (DZ) at that point. A statistical analysis was then performed on the residual errors.

Overall Statistical Summary:					
All un-obscured Points			**All obscured Points**		
RMSE Z	0.23	ft	RMSE Z	0.40	ft
NSSDA @ 95%	0.46	ft	NSSDA @ 95%	0.79	ft
Stdev	0.24	ft	Stdev	0.36	ft
Avg Error	0.01	ft	Avg Error	0.18	ft
Max Error	0.52	ft	Max Error	1.15	ft
Min Error	-0.43	ft	Min Error	-0.45	ft
Count	48		Count	45	

Based on the County's QC survey checks and Woolpert's accuracy analysis, the tested fundamental vertical accuracy of the DTM/Mass-Points data is +/-0.6-foot in un-obscured areas.

Statistical Summary By Class					
Bare Earth - un-obscured			**Brush Lands and Trees - obscured**		
Average	-0.01	ft	Average	-0.32	ft
RMSE	0.25	ft	RMSE	0.47	ft
NSSDA @ 95%	0.49	ft	NSSDA @ 95%	0.92	ft
Stdev	0.25	ft	Stdev	0.35	ft
Max	0.51	ft	Max	0.26	ft
Min	-0.38	ft	Min	-1.17	ft
Count	24		Count	22	
Urban/Hard Surface - un-obscured			**All Points – un-obscured and obscured**		
Average	-0.04	ft	Average	-0.11	ft
RMSE	0.21	ft	RMSE	0.32	ft
NSSDA @ 95%	0.41	ft	NSSDA @ 95%	0.63	ft
Stdev	0.21	ft	Stdev	0.30	ft
Max	0.40	ft	Max	0.51	ft
Min	-0.49	ft	Min	-1.17	ft
Count	24		Count	93	
Forested and Fully Grown - obscured					
Average	-0.10	ft			
RMSE	0.31	ft			
NSSDA @ 95%	0.60	ft			
Stdev	0.28	ft			
Max	0.32	ft			
Min	-0.73	ft			
Count	23				

As illustrated in the table above, Woolpert's accuracy analysis of the vertical accuracy of the TIN is 0.64-foot at the 95% confidence level for both un-obscured and obscured points using RMSEz x 1.96. The QA/QC points in the following table are organized by un-obscured and obscured, and feature class.

DTM Accuracy Analysis								
Station	Survey (US SV FT)			lidar Elev.	Residual Error (US SV FT)			
Name	Northing	Easting	Elevation	(US SV FT)	unobscured	obscured	Feature	Tile
171	2100336.65	473072.77	25.85	25.57	-0.28		Bare Earth	23861
150	2092327.70	525954.60	36.42	36.55	0.14		Bare Earth	24472
126	2081483.04	490665.14	29.18	29.17	-0.01		Bare Earth	25065
40	1978144.45	521199.53	31.73	31.80	0.08		Bare Earth	31371
115	2031385.97	524912.54	43.56	43.43	-0.13		Bare Earth	28071
216	2151759.91	516642.93	17.01	17.31	0.30		Bare Earth	20870
139	2065546.59	531902.74	38.74	38.58	-0.16		Bare Earth	25973
61	1996972.48	499919.94	22.02	22.28	0.26		Bare Earth	30166

DTM Accuracy Analysis								
Station	Survey (US SV FT)			lidar Elev.	Residual Error (US SV FT)			
Name	Northing	Easting	Elevation	(US SV FT)	unobscured	obscured	Feature	Tile
35	2004219.44	545076.46	33.51	33.63	0.12		Bare Earth	29876
17	1936641.98	565058.11	23.07	23.38	0.32		Bare Earth	33780
47	1960578.79	509075.85	27.85	28.04	0.19		Bare Earth	32268
222	2121073.24	538946.72	11.22	11.13	-0.09		Bare Earth	22674
129	2083722.03	451524.77	30.49	30.24	-0.25		Bare Earth	25057
102	2050603.63	495196.01	21.49	21.06	-0.43		Bare Earth	26866
70	2008738.41	532527.09	37.08	37.48	0.40		Bare Earth	29573
160	2113277.68	491890.02	23.25	22.96	-0.29		Bare Earth	23265
103	2072880.75	469618.53	31.20	31.11	-0.09		Bare Earth	25660
12	2008374.21	567845.91	9.17	9.21	0.05		Bare Earth	29580
87	2039893.03	497249.74	19.93	19.85	-0.08		Bare Earth	27766
246	2034400.43	544157.98	32.03	32.39	0.36		Bare Earth	28075
21	1971431.74	551201.83	35.43	35.76	0.33		Bare Earth	31677
54	1956000.82	494943.64	7.68	7.65	-0.03		Bare Earth	32565
59	1930916.59	501777.96	18.68	18.71	0.03		Bare Earth	34067
76	2029498.50	470548.43	12.20	11.99	-0.21		Bare Earth	28361
212	2152520.86	517554.01	17.21	17.46	0.25		Urban	20870
243	2030017.28	563231.53	7.90	8.05	0.15		Urban	28379
34	2009823.35	554663.05	17.87	18.02	0.15		Urban	29577
33	2009047.94	566497.56	9.02	9.15	0.13		Urban	29580
22	1984218.21	554533.16	31.32	31.52	0.21		Urban	31077
20	1971820.51	551232.76	31.80	32.12	0.32		Urban	31677
46	1960632.76	508632.47	26.80	27.32	0.52		Urban	32268
48	1956325.25	495390.26	6.32	6.38	0.07		Urban	32566
10	1990569.94	571879.79	15.15	15.01	-0.14		Urban	30481
18	1938151.31	564857.99	23.40	23.45	0.05		Urban	33779
136	2076457.68	463052.78	33.26	32.99	-0.27		Urban	25359
205	2131968.44	535760.96	9.10	9.10	0.01		Urban	22074
152	2094476.68	528015.35	22.07	22.38	0.31		Urban	24472
245	2032985.77	548035.12	9.90	10.03	0.14		Urban	28076
8	1957973.71	582167.00	17.76	17.91	0.15		Urban	32583
198	2152680.85	532576.84	9.80	9.78	-0.02		Urban	20873
128	2083568.15	451747.37	29.27	28.88	-0.39		Urban	25057
159	2112635.50	492456.75	24.70	24.28	-0.42		Urban	23265
175	2103721.37	458113.47	14.39	14.43	0.04		Urban	23858
127	2081500.85	488120.43	30.30	30.02	-0.28		Urban	25064
140	2065329.54	531922.87	39.08	39.05	-0.03		Urban	25973
100	2056743.84	508447.82	30.02	29.72	-0.30		Urban	26568
90	2046267.53	500877.80	26.15	25.94	-0.21		Urban	27167
114	2031973.30	524622.80	44.88	44.62	-0.26		Urban	28071
199	2153032.53	515048.57	19.96	20.36		0.40	Brush Lands and Trees	20870
39	1989157.40	531311.59	44.03	44.16		0.13	Brush Lands and Trees	30773
55	1957883.72	494894.78	6.96	7.56		0.60	Brush Lands and Trees	32565
60	1931078.57	501898.64	17.64	17.75		0.11	Brush Lands and Trees	34067

DTM Accuracy Analysis								
Station	Survey (US SV FT)			lidar Elev.	Residual Error (US SV FT)			
Name	Northing	Easting	Elevation	(US SV FT)	unobscured	obscured	Feature	Tile
19	1929906.78	555311.76	29.65	29.72		0.07	Brush Lands and Trees	34378
24	1956280.09	542422.32	40.09	40.11		0.02	Brush Lands and Trees	32575
62	2006073.07	496608.03	22.46	22.68		0.22	Brush Lands and Trees	29566
130	2083377.85	450484.66	25.73	26.00		0.27	Brush Lands and Trees	25057
104	2072797.11	469288.53	30.03	30.22		0.19	Brush Lands and Trees	25660
116	2030332.18	526196.43	41.53	41.52		-0.01	Brush Lands and Trees	28072
16	1935393.84	564701.00	23.56	24.10		0.54	Brush Lands and Trees	33779
149	2065953.04	532223.49	36.18	36.70		0.52	Brush Lands and Trees	25973
151	2092592.94	522469.32	38.90	39.29		0.39	Brush Lands and Trees	24471
206	2135434.81	539742.64	15.78	16.92		1.15	Brush Lands and Trees	21774
172	2100720.81	474013.36	24.52	24.27		-0.25	Brush Lands and Trees	23861
178	2097223.13	459899.93	15.26	15.32		0.06	Brush Lands and Trees	24158
133	2081294.82	490054.79	28.00	27.69		-0.31	Brush Lands and Trees	25065
256	2056271.40	510771.46	31.27	31.21		-0.06	Brush Lands and Trees	26589
242	2031563.49	562190.46	1.03	2.10		1.07	Brush Lands and Trees	28079
73	2033324.78	498845.87	19.45	19.71		0.26	Brush Lands and Trees	28066
45	1976437.07	511017.47	33.89	34.38		0.49	Brush Lands and Trees	31369
27	1987885.83	552073.20	30.56	31.24		0.68	Brush Lands and Trees	30777
164	2066754.73	535622.29	17.48	18.10		0.62	Forested and Fully Grown	25974
121	2057280.16	511400.20	28.97	29.04		0.07	Forested and Fully Grown	26569
123	2051199.95	494266.31	20.66	20.72		0.06	Forested and Fully Grown	26865
97	2040235.84	497677.00	21.29	21.13		-0.16	Forested and Fully Grown	27466
96	2030321.73	470717.21	10.52	10.57		0.05	Forested and Fully Grown	28061
78	2032104.26	495618.38	13.29	12.97		-0.32	Forested and Fully Grown	28066
122	2031649.69	525803.95	35.89	35.80		-0.09	Forested and Fully Grown	28066
255	2031915.75	540153.13	31.37	31.93		0.56	Forested and Fully Grown	28075
95	2005963.07	493679.69	19.13	19.13		0.00	Forested and Fully Grown	29585
30	1957926.63	541855.97	38.24	38.97		0.73	Forested and Fully Grown	30773
38	1989382.50	531005.82	41.66	41.66		0.00	Forested and Fully Grown	25065
228	2152128.13	518527.37	14.00	13.83		-0.17	Forested and Fully Grown	31369
43	1979156.82	513066.95	27.64	27.66		0.03	Forested and Fully Grown	32565
66	1956076.33	492713.91	8.76	9.05		0.30	Forested and Fully Grown	32575
53	1931431.85	501284.08	18.23	18.56		0.33	Forested and Fully Grown	34067
230	2133788.38	536907.78	6.22	6.64		0.42	Forested and Fully Grown	22074
254	2123176.35	533953.53	4.14	4.52		0.39	Forested and Fully Grown	22673
163	2093262.75	528903.53	17.78	18.01		0.23	Forested and Fully Grown	24472
145	2082445.43	490464.34	26.99	26.75		-0.24	Forested and Fully Grown	25065
182	2103946.08	473046.73	18.55	18.26		-0.29	Forested and Fully Grown	23861
181	2097248.26	458888.06	13.57	13.35		-0.22	Forested and Fully Grown	24158
144	2083037.15	449849.02	20.87	20.42		-0.45	Forested and Fully Grown	25056
124	2072832.14	468247.52	23.81	23.51		-0.30	Forested and Fully Grown	25660

APPENDIX C: CONTOURS/TIN ACCURACY CHECKS

The accuracy of the TIN generated from breaklines and mass points was verified using field survey methods. The results of the accuracy analysis area as follows:

Overall Statistical Summary:					
All unobscured Points			**All obscured Points**		
RMSE Z	0.23	ft	RMSE Z	0.39	ft
NSSDA @ 95%	0.45	ft	NSSDA @ 95%	0.76	ft
Stdev	0.23	ft	Stdev	0.33	ft
Avg Error	-0.03	ft	Avg Error	-0.20	ft
Max Error	0.51	ft	Max Error	0.32	ft
Min Error	-0.49	ft	Min Error	-1.17	ft
Count	48		Count	45	

Based on the County's QC survey check points and Woolpert's accuracy analysis, the tested fundamental vertical accuracy of contours is +/-0.45 foot in un-obscured areas.

Statistical Summary By Class					
Bare Earth - un-obscured			**Brush Lands and Trees - obscured**		
Average	-0.01	ft	Average	-0.32	ft
RMSE	0.25	ft	RMSE	0.47	ft
NSSDA @ 95%	0.49	ft	NSSDA @ 95%	0.92	ft
Stdev	0.25	ft	Stdev	0.35	ft
Max	0.51	ft	Max	0.26	ft
Min	-0.38	ft	Min	-1.17	ft
Count	24		Count	22	
Urban/Hard Surface - un-obscured			**All Points – un-obscured and obscured**		
Average	-0.04	ft	Average	-0.11	ft
RMSE	0.21	ft	RMSE	0.32	ft
NSSDA @ 95%	0.41	ft	NSSDA @ 95%	0.63	ft
Stdev	0.21	ft	Stdev	0.30	ft
Max	0.40	ft	Max	0.51	ft
Min	-0.49	ft	Min	-1.17	ft
Count	24		Count	93	
Forested and Fully Grown - obscured					
Average	-0.10	ft			
RMSE	0.31	ft			
NSSDA @ 95%	0.60	ft			
Stdev	0.28	ft			
Max	0.32	ft			
Min	-0.73	ft			
Count	23				

As illustrated in the table above, Woolpert's accuracy analysis of the vertical accuracy of the TIN generated from the contours is 0.63-foot at the 95% confidence level for both unobscured and obscured points.

The QA/QC points in the following table are organized by unobscured and obscured, and feature class.

DTM Accuracy Analysis								
Station	Survey (US SV FT)			lidar Elev.	Residual Error (US SV FT)			
Name	Northing	Easting	Elevation	(US SV FT)	unobscured	obscured	Feature	Tile
171	2100336.65	473072.77	25.85	25.57	-0.28		Bare Earth	23861
150	2092327.70	525954.60	36.42	36.55	0.14		Bare Earth	24472
126	2081483.04	490665.14	29.18	29.17	-0.01		Bare Earth	25065
40	1978144.45	521199.53	31.73	31.80	0.08		Bare Earth	31371
115	2031385.97	524912.54	43.56	43.43	-0.13		Bare Earth	28071
216	2151759.91	516642.93	17.01	17.31	0.30		Bare Earth	20870
139	2065546.59	531902.74	38.74	38.58	-0.16		Bare Earth	25973
61	1996972.48	499919.94	22.02	22.28	0.26		Bare Earth	30166

DTM Accuracy Analysis								
Station	Survey (US SV FT)			lidar Elev.	Residual Error (US SV FT)			
Name	Northing	Easting	Elevation	(US SV FT)	unobscured	obscured	Feature	Tile
35	2004219.44	545076.46	33.51	33.63	0.12		Bare Earth	29876
17	1936641.98	565058.11	23.07	23.38	0.32		Bare Earth	33780
47	1960578.79	509075.85	27.85	28.04	0.19		Bare Earth	32268
222	2121073.24	538946.72	11.22	11.13	-0.09		Bare Earth	22674
129	2083722.03	451524.77	30.49	30.24	-0.25		Bare Earth	25057
102	2050603.63	495196.01	21.49	21.06	-0.43		Bare Earth	26866
70	2008738.41	532527.09	37.08	37.48	0.40		Bare Earth	29573
160	2113277.68	491890.02	23.25	22.96	-0.29		Bare Earth	23265
103	2072880.75	469618.53	31.20	31.11	-0.09		Bare Earth	25660
12	2008374.21	567845.91	9.17	9.21	0.05		Bare Earth	29580
87	2039893.03	497249.74	19.93	19.85	-0.08		Bare Earth	27766
246	2034400.43	544157.98	32.03	32.39	0.36		Bare Earth	28075
21	1971431.74	551201.83	35.43	35.76	0.33		Bare Earth	31677
54	1956000.82	494943.64	7.68	7.65	-0.03		Bare Earth	32565
59	1930916.59	501777.96	18.68	18.71	0.03		Bare Earth	34067
76	2029498.50	470548.43	12.20	11.99	-0.21		Bare Earth	28361
212	2152520.86	517554.01	17.21	17.46	0.25		Urban	20870
243	2030017.28	563231.53	7.90	8.05	0.15		Urban	28379
34	2009823.35	554663.05	17.87	18.02	0.15		Urban	29577
33	2009047.94	566497.56	9.02	9.15	0.13		Urban	29580
22	1984218.21	554533.16	31.32	31.52	0.21		Urban	31077
20	1971820.51	551232.76	31.80	32.12	0.32		Urban	31677
46	1960632.76	508632.47	26.80	27.32	0.52		Urban	32268
48	1956325.25	495390.26	6.32	6.38	0.07		Urban	32566
10	1990569.94	571879.79	15.15	15.01	-0.14		Urban	30481
18	1938151.31	564857.99	23.40	23.45	0.05		Urban	33779
136	2076457.68	463052.78	33.26	32.99	-0.27		Urban	25359
205	2131968.44	535760.96	9.10	9.10	0.01		Urban	22074
152	2094476.68	528015.35	22.07	22.38	0.31		Urban	24472
245	2032985.77	548035.12	9.90	10.03	0.14		Urban	28076
8	1957973.71	582167.00	17.76	17.91	0.15		Urban	32583
198	2152680.85	532576.84	9.80	9.78	-0.02		Urban	20873
128	2083568.15	451747.37	29.27	28.88	-0.39		Urban	25057
159	2112635.50	492456.75	24.70	24.28	-0.42		Urban	23265
175	2103721.37	458113.47	14.39	14.43	0.04		Urban	23858
127	2081500.85	488120.43	30.30	30.02	-0.28		Urban	25064
140	2065329.54	531922.87	39.08	39.05	-0.03		Urban	25973
100	2056743.84	508447.82	30.02	29.72	-0.30		Urban	26568
90	2046267.53	500877.80	26.15	25.94	-0.21		Urban	27167
114	2031973.30	524622.80	44.88	44.62	-0.26		Urban	28071
199	2153032.53	515048.57	19.96	20.36		0.40	Brush Lands and Trees	20870
39	1989157.40	531311.59	44.03	44.16		0.13	Brush Lands and Trees	30773
55	1957883.72	494894.78	6.96	7.56		0.60	Brush Lands and Trees	32565
60	1931078.57	501898.64	17.64	17.75		0.11	Brush Lands and Trees	34067

DTM Accuracy Analysis								
Station	Survey (US SV FT)			lidar Elev.	Residual Error (US SV FT)			
Name	Northing	Easting	Elevation	(US SV FT)	unobscured	obscured	Feature	Tile
19	1929906.78	555311.76	29.65	29.72		0.07	Brush Lands and Trees	34378
24	1956280.09	542422.32	40.09	40.11		0.02	Brush Lands and Trees	32575
62	2006073.07	496608.03	22.46	22.68		0.22	Brush Lands and Trees	29566
130	2083377.85	450484.66	25.73	26.00		0.27	Brush Lands and Trees	25057
104	2072797.11	469288.53	30.03	30.22		0.19	Brush Lands and Trees	25660
116	2030332.18	526196.43	41.53	41.52		-0.01	Brush Lands and Trees	28072
16	1935393.84	564701.00	23.56	24.10		0.54	Brush Lands and Trees	33779
149	2065953.04	532223.49	36.18	36.70		0.52	Brush Lands and Trees	25973
151	2092592.94	522469.32	38.90	39.29		0.39	Brush Lands and Trees	24471
206	2135434.81	539742.64	15.78	16.92		1.15	Brush Lands and Trees	21774
172	2100720.81	474013.36	24.52	24.27		-0.25	Brush Lands and Trees	23861
178	2097223.13	459899.93	15.26	15.32		0.06	Brush Lands and Trees	24158
133	2081294.82	490054.79	28.00	27.69		-0.31	Brush Lands and Trees	25065
256	2056271.40	510771.46	31.27	31.21		-0.06	Brush Lands and Trees	26589
242	2031563.49	562190.46	1.03	2.10		1.07	Brush Lands and Trees	28079
73	2033324.78	498845.87	19.45	19.71		0.26	Brush Lands and Trees	28066
45	1976437.07	511017.47	33.89	34.38		0.49	Brush Lands and Trees	31369
27	1987885.83	552073.20	30.56	31.24		0.68	Brush Lands and Trees	30777
164	2066754.73	535622.29	17.48	18.10		0.62	Forested and Fully Grown	25974
121	2057280.16	511400.20	28.97	29.04		0.07	Forested and Fully Grown	26569
123	2051199.95	494266.31	20.66	20.72		0.06	Forested and Fully Grown	26865
97	2040235.84	497677.00	21.29	21.13		-0.16	Forested and Fully Grown	27466
96	2030321.73	470717.21	10.52	10.57		0.05	Forested and Fully Grown	28061
78	2032104.26	495618.38	13.29	12.97		-0.32	Forested and Fully Grown	28066
122	2031649.69	525803.95	35.89	35.80		-0.09	Forested and Fully Grown	28066
255	2031915.75	540153.13	31.37	31.93		0.56	Forested and Fully Grown	28075
95	2005963.07	493679.69	19.13	19.13		0.00	Forested and Fully Grown	29585
30	1957926.63	541855.97	38.24	38.97		0.73	Forested and Fully Grown	30773
38	1989382.50	531005.82	41.66	41.66		0.00	Forested and Fully Grown	25065
228	2152128.13	518527.37	14.00	13.83		-0.17	Forested and Fully Grown	31369
43	1979156.82	513066.95	27.64	27.66		0.03	Forested and Fully Grown	32565
66	1956076.33	492713.91	8.76	9.05		0.30	Forested and Fully Grown	32575
53	1931431.85	501284.08	18.23	18.56		0.33	Forested and Fully Grown	34067
230	2133788.38	536907.78	6.22	6.64		0.42	Forested and Fully Grown	22074
254	2123176.35	533953.53	4.14	4.52		0.39	Forested and Fully Grown	22673
163	2093262.75	528903.53	17.78	18.01		0.23	Forested and Fully Grown	24472
145	2082445.43	490464.34	26.99	26.75		-0.24	Forested and Fully Grown	25065
182	2103946.08	473046.73	18.55	18.26		-0.29	Forested and Fully Grown	23861
181	2097248.26	458888.06	13.57	13.35		-0.22	Forested and Fully Grown	24158
144	2083037.15	449849.02	20.87	20.42		-0.45	Forested and Fully Grown	25056
124	2072832.14	468247.52	23.81	23.51		-0.30	Forested and Fully Grown	25660

EXHIBIT A:

ALS70 LIDAR FLIGHT PLAN AND GROUND CONTROL DIAGRAM

The ALS70 lidar Flight Plan and Ground Control Diagram is shown on the following page.

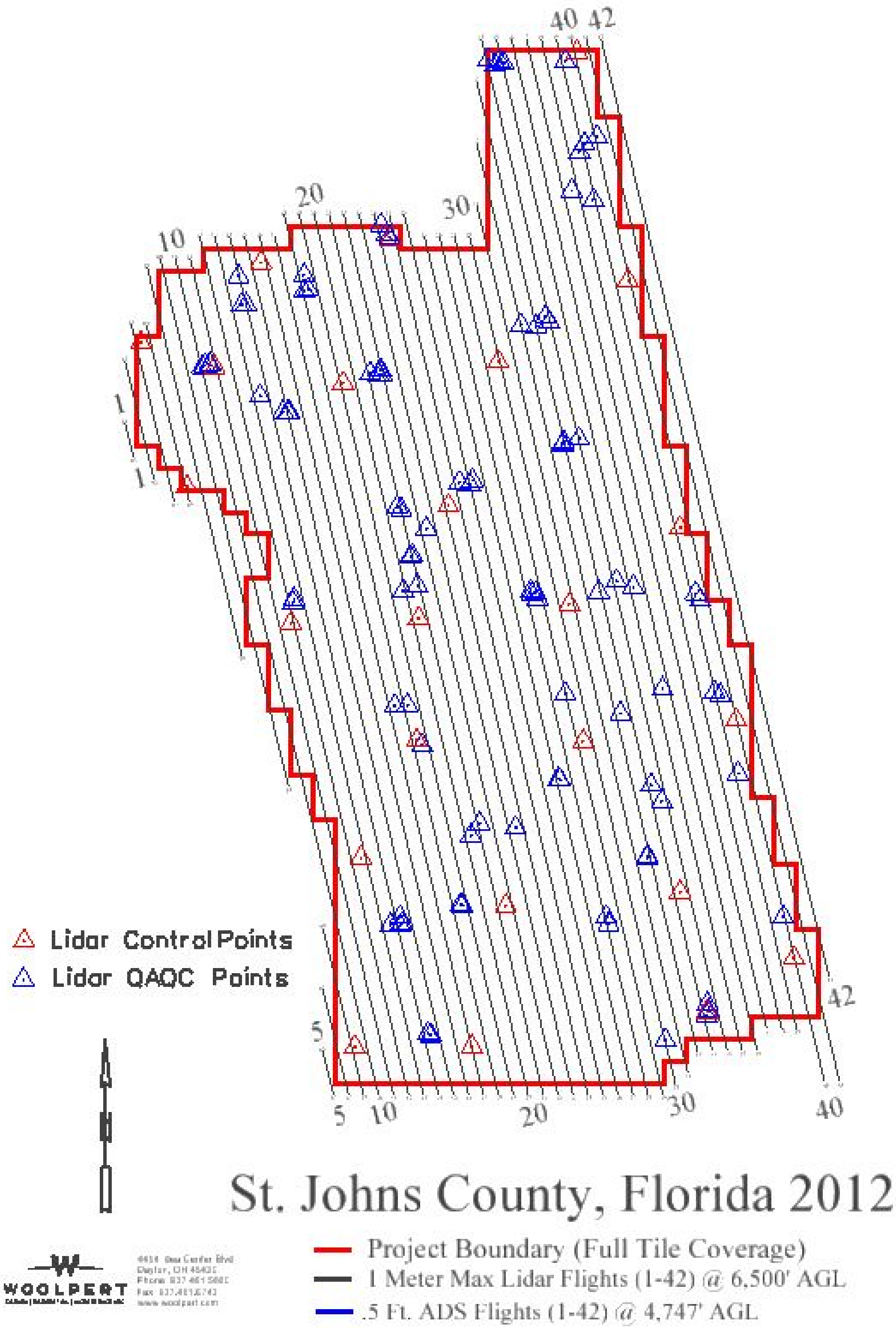
Lidar Control Points
Lidar QAQC Points
St. Johns County, Florida 2012
Project Boundary (Full Tile Coverage)
1 Meter Max Lidar Flights (1-42) @ 6,500' AGL
.5 Ft. ADS Flights (1-42) @ 4,747' AGL
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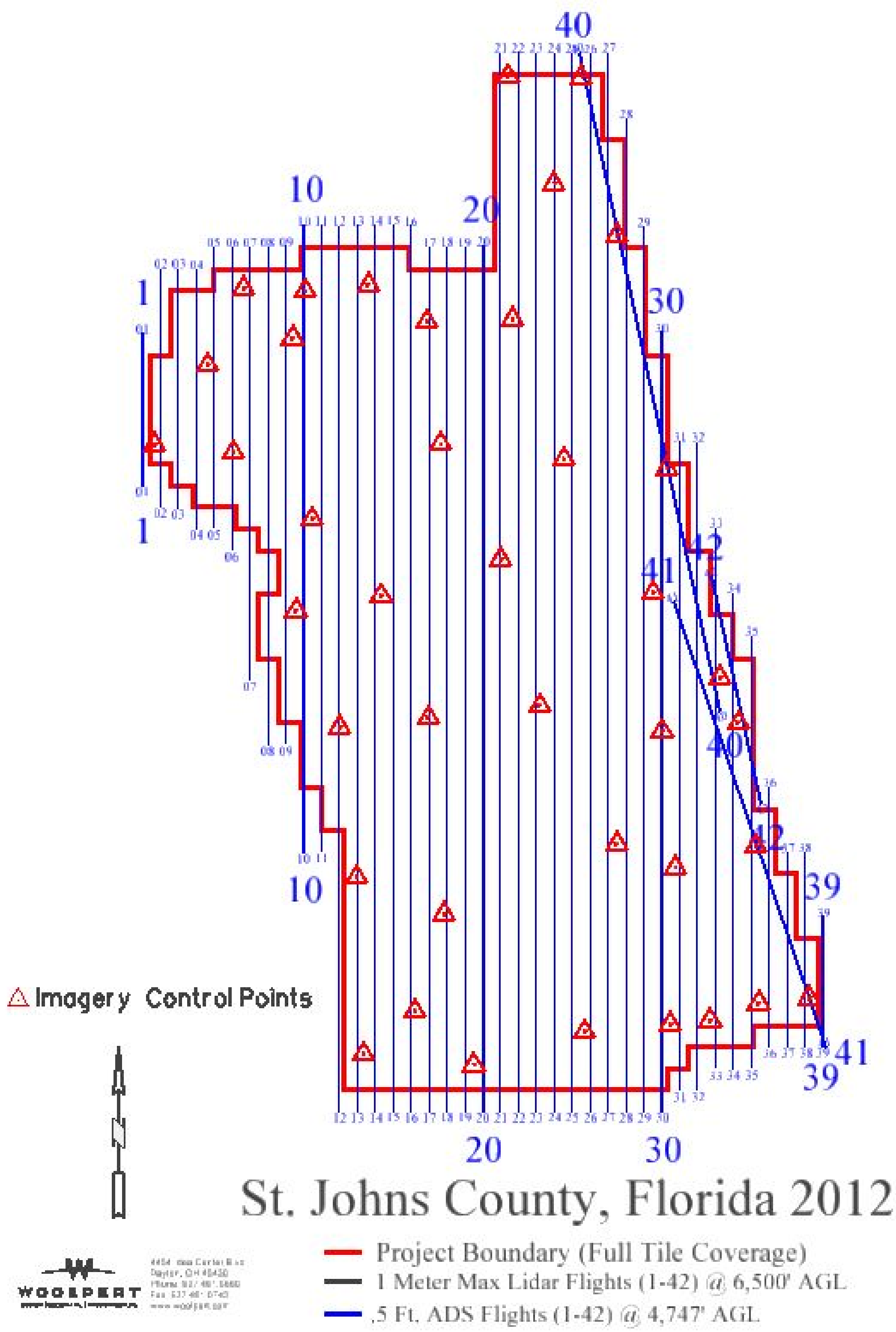
EXHIBIT B:

ADS80 DIGITAL IMAGERY FLIGHT PLAN AND GROUND CONTROL DIAGRAM

The ADS80 Digital Imagery Flight Plan and Ground Control Diagram is shown on the following page.


St. Johns County, Florida 2012
Imagery Control Points
Project Boundary (Full Tile Coverage)
1 Meter Max Lidar Flights (1-42) @ 6,500' AGL
,5 Ft. ADS Flights (1-42) @ 4,747' AGL
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