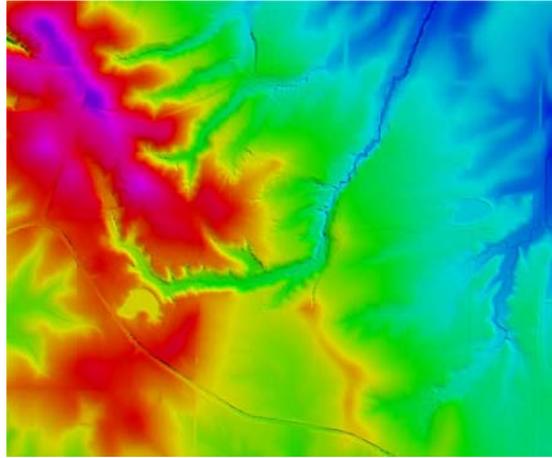


# AIRBORNE LIDAR PROJECT REPORT



## 4 GA COUNTIES OF ELEVATION DATA NOAA COASTAL SERVICES CENTER (CSC) BURKE, RICHMOND, LINCOLN, AND COLUMBIA COUNTIES, GEORGIA

Woolpert Project Number: 71511

JUNE 2012

# TABLE OF CONTENTS

Section 1: Project Description .....	1-1
Section 2: Aerial Platform / Sensor Information .....	2-1
Section 3: File Information .....	3-1
Section 4: GPS/IMU Collection and QA/QC.....	4-1
Section 5: LiDAR Data Processing and QA/QC .....	5-1

## FIGURES

Figure 1.1: LiDAR Flight Diagram of Burke and Richmond Counties, Georgia .....	1-2
Figure 1.2: LiDAR Flight Diagram of Lincoln County, Georgia.....	1-3
Figure 1.3: LiDAR Flight Diagram of Columbia County, Georgia .....	1-4
Figure 4.1: GPS Base Station Location - Columbia County.....	4-2
Figure 4.2: GPS Base Station Location - Burke and Richmond Counties .....	4-3
Figure 4.3: GPS Base Station Location - Lincoln County .....	4-4
Figure 4.4: Sample Horizontal and Vertical Positional Accuracies from Day 347 (ALS60_6157).....	4-6
Figure 4.5: Sample GPS Combined Separation from Day 347 (ALS60_6157) .....	4-7
Figure 4.6: Sample GPS Altitude Plot from Day 347 (ALS60_6157).....	4-8
Figure 4.7: Sample horizontal GPS distance from base station from Day 347 (ALS60_6157).....	4-8
Figure 4.8: Sample PDOP Plot from Day 347 (ALS60_6157).....	4-9
Figure 4.9: Flight Trajectory from Day 347 (ALS60_6157).....	4-10

## TABLES

Table 2.1: LiDAR Acquisition Specifications .....	2-1
Table 2.2: LiDAR Flight Summary. 1-Meter Nominal Post Spacing .....	2-2
Table 2.3: ALS 60 LiDAR System Specifications.....	2-3
Table 2.4 ALS 50-II LiDAR System Specifications .....	2-4
Table 2.5 Optech Gemini LiDAR System Specifications .....	2-5

Table 4.1: GNSS Base Stations Used..... 4-1

Table 4.2: Mission Specific Base Stations, Combined Separation, Estimated Positional Accuracy and PDOP .....4-11

Table 5.1: Fundamental Vertical Accuracy Statistics for Burke, Richmond, and Lincoln Counties: ..... 5-6

Table 5.2: Supplemental Vertical Accuracy Statistics for Burke, Richmond, and Lincoln Counties: .... 5-6

Table 5.3: Combined Vertical Accuracy Statistics for Burke, Richmond, and Lincoln Counties ..... 5-6

Table 5.4: Fundamental Vertical Accuracy Statistics for Columbia County ..... 5-7

Table 5.5 Approved By ..... 5-7

# SECTION 1: PROJECT DESCRIPTION

This report contains a comprehensive outline of the airborne LiDAR data acquisition for Burke, Richmond, Lincoln, and Columbia Counties, GA as part of the 4 Georgia Counties of Elevation Data task order; Contract Number EA133C11CQ0010; Requisition Order Number NCNP0000-11-02615, for the NOAA Coastal Services Center (CSC).

The task order area for Burke and Richmond Counties was approximately 1235 square miles, the task order area for Lincoln County was approximately 264 square miles, and the task order area for Columbia County was 322 square miles which included a minimum buffer of 200\*NPS buffer within the interior of Georgia and 600\*NPS buffer along the state boundary. The LiDAR data was collected and processed to meet a Nominal Post Spacing (NPS) of 1.0 meter. The NPS assessment is made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath.

Figure 1.1: LiDAR Flight Diagram of Burke and Richmond Counties, Georgia

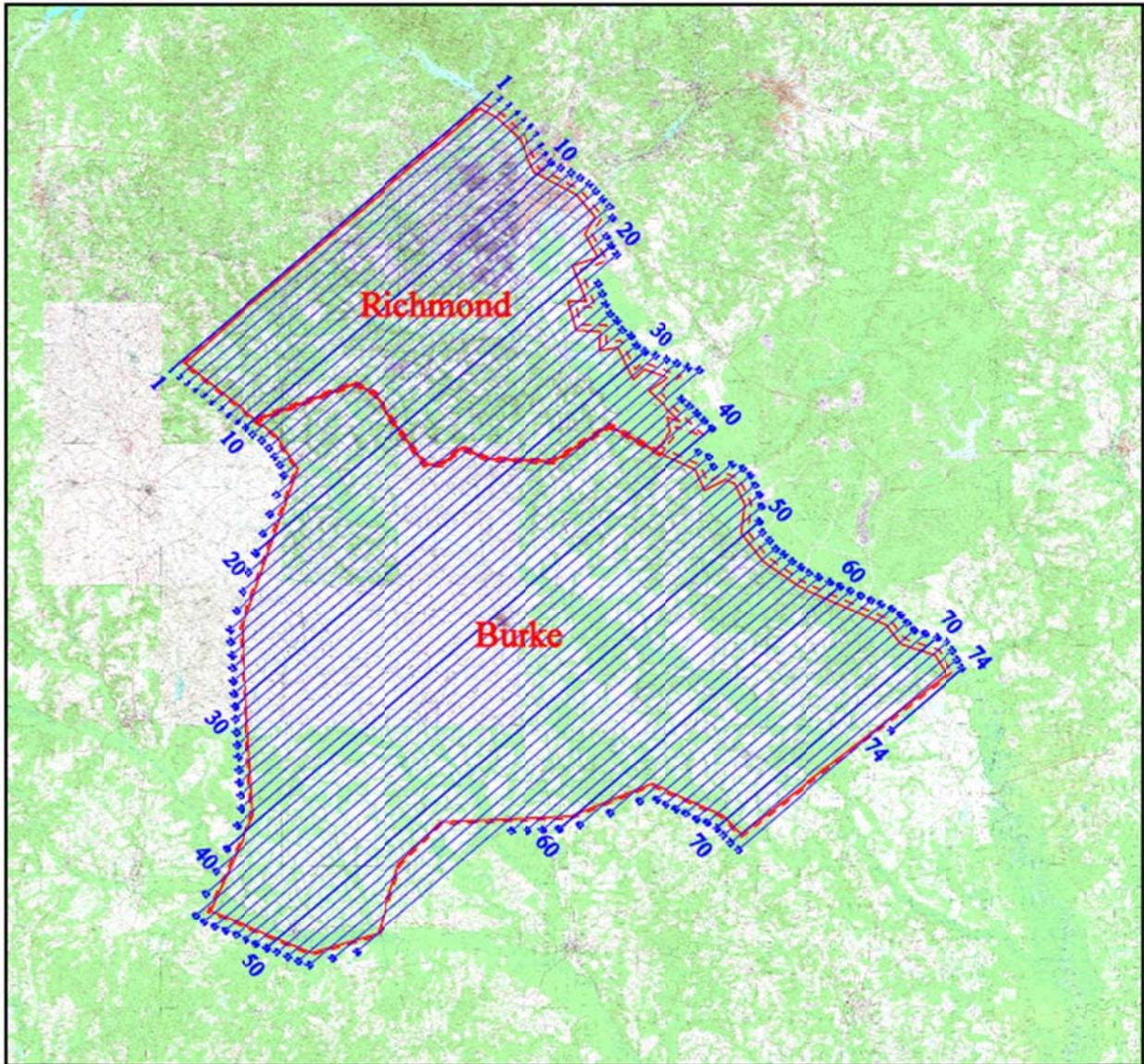


Figure 1.2: LiDAR Flight Diagram of Lincoln County, Georgia

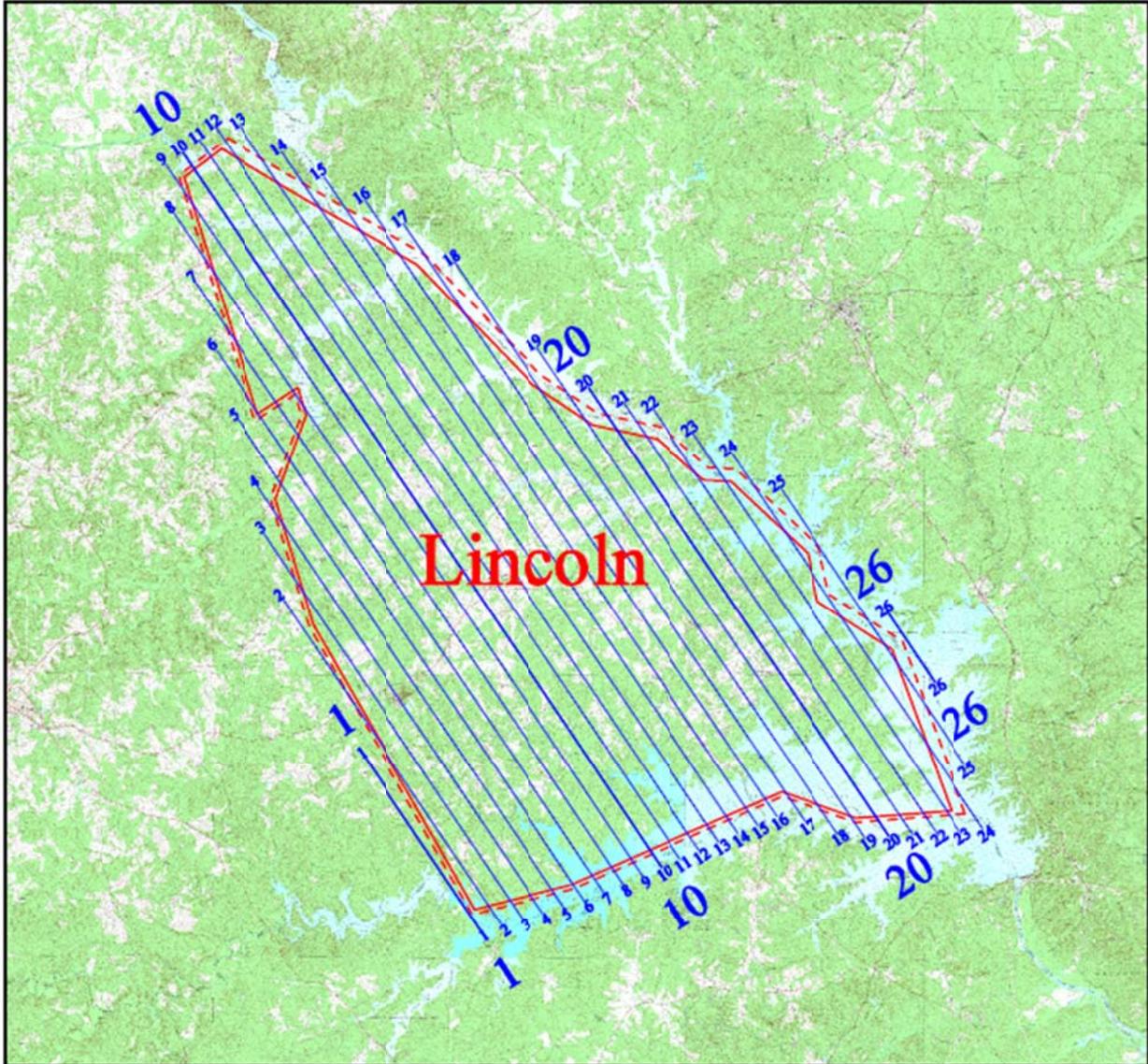
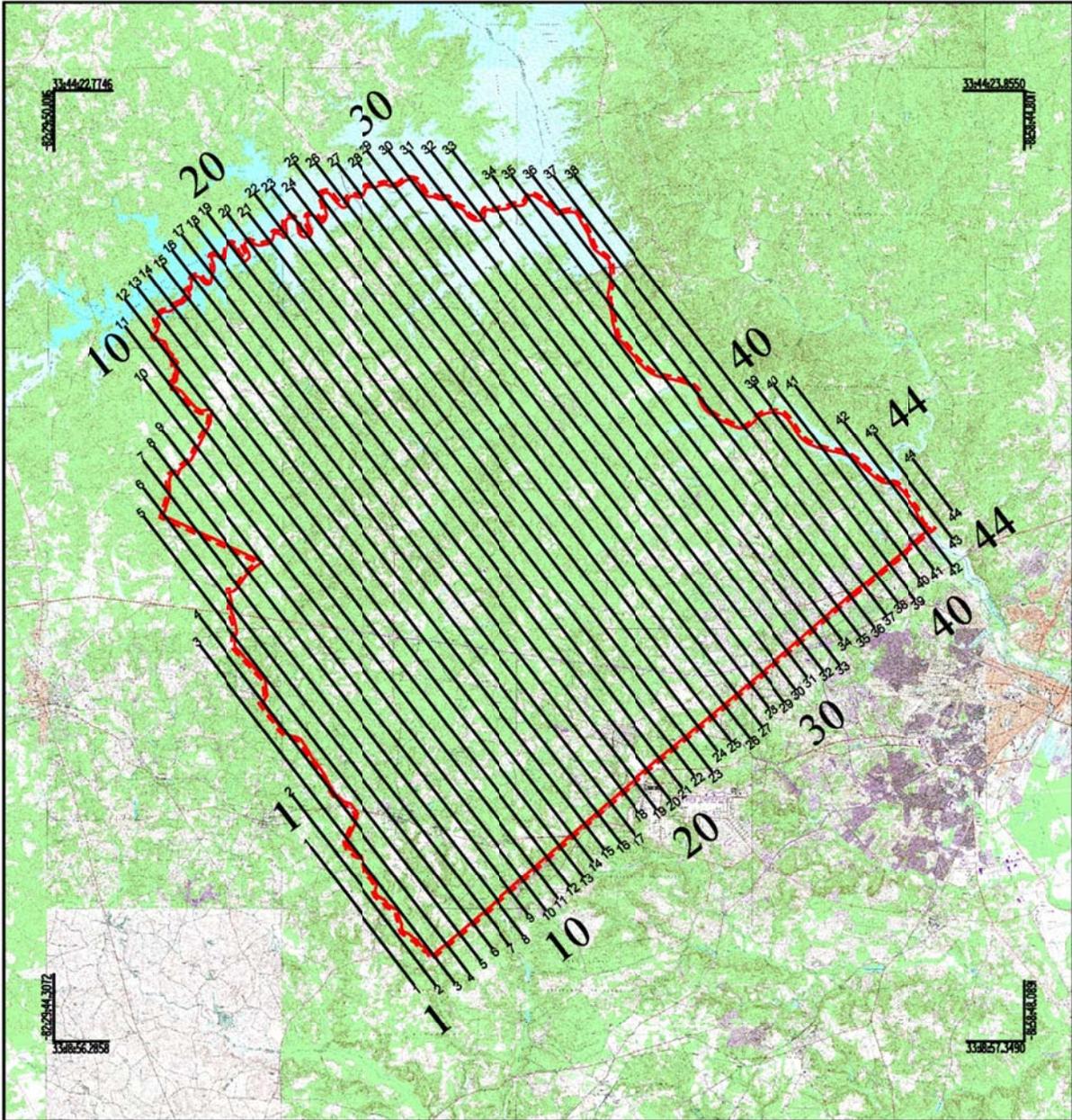


Figure 1.3: LiDAR Flight Diagram of Columbia County, Georgia



## SECTION 2: AERIAL PLATFORM / SENSOR INFORMATION

LiDAR data was collected utilizing an Optech Gemini 167 kHz, Leica ALS50-II 150 kHz and ALS60 200 kHz LiDAR sensors in Multi-Pulse mode. These sensors were aboard twin-engine Cessna 404's. These systems collect up to four returns (echo) per pulse, recording attributes such as time stamp and intensity data, for the first three returns. If a fourth return was captured, the system does not record an associated intensity value. The aerial LiDAR was collected at the following sensor specifications:

Post Spacing (Minimum):	3.28 ft / 1.0 m
AGL (Above Ground Level) average flying height:	6,500 ft / 1,981 m (Burke, Richmond, Lincoln) 5,700 ft / 1,737 m (Columbia)
MSL (Mean Sea Level) average flying height:	6,574 ft / 2,004 m (Burke & Richmond) 6,798 ft / 2,072 m (Lincoln) 5,900 ft / 1,798 m (Columbia)
Average Ground Speed:	130 knots / 149 mph
Field of View (full):	40 degrees
Pulse Rate:	115.6 kHz (Burke, Richmond, Lincoln) 100 kHz (Columbia)
Scan Rate:	41.8 Hz (Burke, Richmond, Lincoln) 29.5 Hz (Columbia)
Side Lap (Minimum):	25%

Table 2.1: LiDAR Acquisition Specifications

Project	Post Spacing	Number of Flight Lines	Number of Collection Days	Acquisition Dates
4 Georgia Counties of Elevation Data, Columbia County, GA	1.0-meter Average	44	1	February 26, 2011
4 Georgia Counties of Elevation Data, Burke and Richmond Co's, GA	1.0-meter Average	74	3	December 13, 2011 to December 17, 2011
4 Georgia Counties of Elevation Data, Lincoln County, GA	1.0-meter Average	26	1	December 18, 2011

Table 2.2: LiDAR Flight Summary. 1-Meter Nominal Post Spacing			
Date of Flying	Lines Flown	Time ON/Off Line (UTC)	Time On/Off Line (Local - EST)
Feb. 26, 2011 Optech 56108	Columbia 1 - 12	13:47 - 16:34	8:47 AM - 11:34 AM
Feb. 26, 2011 Optech 56108	Columbia 13 - 34	17:34 - 22:40	12:34 PM - 5:40 PM
Feb. 26, 2011 Optech 56108	Columbia 35 - 44	23:36 - 1:42	6:36 PM - 8:42 PM
Dec. 13, 2011 ALS50 077	Burke & Richmond 53 - 74	19:44 - 00:15	2:44 PM - 7:15 PM
Dec. 13, 2011 ALS60 6157	Burke & Richmond 1 - 20	20:00 - 00:29	3:00 PM - 7:29 PM
Dec. 14, 2011 ALS50 077	Burke & Richmond 38 - 52	19:10 - 00:03	2:10 PM - 7:03 PM
Dec. 14, 2011 ALS60 6157	Burke & Richmond 21 - 37	19:16 - 23:48	2:16 PM - 6:48 PM
Dec. 17, 2011 ALS60 6157	Burke & Richmond 51 - 53	21:52 - 22:34	4:52 PM - 5:34 PM
Dec. 18, 2011 ALS60 6157	Lincoln 1 - 26	15:46 - 20:31	10:46 AM - 03:31 PM

Table 2.3 lists the specifications and the requirements of the Leica ALS60, serial number SH6157

Table 2.3: ALS 60 System Specifications	
Specification	
Operating Altitude	200 - 6,000 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 - 100 Hz (variable based on scan angle)
Maximum Pulse Rate	200 kHz
Range Resolution	Better than 1 cm
Elevation Accuracy	8 - 24 cm single shot (one standard deviation)
Horizontal Accuracy	7 - 64 cm (one standard deviation)
Number of Returns per Pulse	4 (first, second, third, last)
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ $1/e^2$ (-0.15 mrad @ $1/e$ )
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 75 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium
Attitude Error after GNSS Processing	Roll: $\pm 0.005^\circ$ , Pitch: $\pm 0.005^\circ$ Heading: $\pm 0.023^\circ$

Table 2.4 lists the specifications and the requirements of the Leica ALS50-II, serial number 077.

Table 2.4 ALS 50-II LiDAR System Specifications	
Specification	
Operating Altitude	200 - 6,000 meters
Scan Angle	0 to 75° (variable)
Swath Width	0 to 1.5 X altitude (variable)
Scan Frequency	0 - 90 Hz (variable based on scan angle)
Maximum Pulse Rate	150 kHz
Range Resolution	Better than 1 cm
Elevation Accuracy	8 - 24 cm single shot (one standard deviation)
Horizontal Accuracy	7 - 64 cm (one standard deviation)
Number of Returns per Pulse	4 (first, second, third, last)
Number of Intensities	3 (first, second, third)
Intensity Digitization	8 bit intensity + 8 bit AGC (Automatic Gain Control) level
MPiA (Multiple Pulses in Air)	8 bits @ 1nsec interval @ 50kHz
Laser Beam Divergence	0.22 mrad @ 1/e <sup>2</sup> (-0.15 mrad @ 1/e)
Laser Classification	Class IV laser product (FDA CFR 21)
Eye Safe Range	400m single shot depending on laser repetition rate
Roll Stabilization	Automatic adaptive, range = 75 degrees minus current FOV
Power Requirements	28 VDC @ 25A
Operating Temperature	0-40°C
Humidity	0-95% non-condensing
Supported GNSS Receivers	Ashtech Z12, Trimble 7400, Novatel Millenium

Table 2.5 lists the specifications and the requirements of the Optech Gemini, serial number 56108.

Table 2.5 Optech Gemini 56108 Specifications			
Serial numbers	Sensor Head 09SEN258 Control Rack 09CON258		
Operating altitude	150 - 4000 m nominal		
General Enhanced Accuracy Specifications	Laser Repetition Rate	Horizontal Accuracy (m 1 δ)	Vertical Accuracy (m 1 δ) AGL
	33 kHz 50 kHz	1/5500 x altitude	< 5 cm up to 500 m < 10 cm up to 1 km < 15 cm up to 2 km < 20 cm up to 3 km < 25 cm up to 4 km
	70 kHz	1/5500 x altitude	< 5 cm up to 500 m < 10 cm up to 1 km < 15 cm up to 2 km
	100 kHz	1/5500 x altitude	< 10 cm up to 500 m < 15 cm up to 1 km < 20 cm up to 2 km
	125 kHz	1/5500 x altitude	< 10 cm up to 500 m < 15 cm up to 1km
	143 kHz	1/5500 x altitude	< 15 cm up to 500 m < 20 cm up to 1 km
	167 kHz	1/5500 x altitude	< 35 cm @ 750 m
Range capture	Up to 4 range measurements for each pulse including last		
Intensity capture	12 bit dynamic range for each measurement		
Scan frequency	Variable; maximum 70 Hz		
Scan angle	Variable from 0 to ± 25°, in increments of ±1°		
Scanner Product	Scan Angle x Scan Frequency ≤ 1000		
Roll compensation	5 Hz update rate (Scan angle + Roll Comp. Angle = FOV, i.e. ± 25° allows ± 5° compensation)		
Swath width	Variable; 0 to 0.93 x altitude m		
Position Orientation System	Applanix - Optech custom POS including internal 12 channel dual frequency 50 Hz GPS receiver		
Laser repetition rate	33 kHz (maximum AGL 4.0 km) 50 kHz (maximum AGL 3.0 km) 70 kHz (maximum AGL 2.5 km) 100 kHz (maximum AGL 2.0 km) 125 kHz (maximum AGL 1.6 km) 142 kHz (maximum AGL 1.4 km) 166 kHz (maximum AGL 1.2 km)		
Data storage hard drive	Ruggedized removable hard drive, (10hr continuous log time @ 100 KHz)		
Beam divergence	Dual 0.3 mrad (1/e) and 0.8 mrad (1/e)		
Eye safe range	<i>See eye safety table</i>		
Laser classification	Class IV (FDA CFR 21)		
Power requirements	28 V (continuous), 45 A (maximum)		
Operating temperature	Control rack: 10 to 35° C Sensor head: -10 to 35° C (assuming the use of thermal jacket)		
Storage Temperature	Control Rack: - 10 ° to 50° C Sensor Head: 0 ° to 50° C		
Humidity	0 - 95% non-condensing		
Control Rack Measurements	653mm x 591mm x 485mm, 55kg		
Sensor Head Measurements	298mm x 249mm x 437mm, 23kg		

Woolpert's Aerial Acquisition Team coordinated with the necessary Air Traffic Control personnel prior to flying to ensure access.

## Weather

No significant weather issues occurred during the flight mission.

## Ground Conditions

The project area was relatively flat terrain, so the project area was able to be flown at one flight altitude throughout each of the counties. No flooding or ponding occurred.

## SECTION 3: FILE INFORMATION

This section contains a listing of the final delivery files for Burke, Richmond, Lincoln, and Columbia Counties, GA.

- Arc Grid Files
- Hydro Line work Shape files
- LAS 1.2 files
- Geodata Base Hydro Breaklines
- Control Points Shape files
- Data Extent Shape files
- Tile Index Shape files
- Trajectories Shape files
- Border Shape files
- Metadata
- ASCII files

# SECTION 4: GPS/IMU COLLECTION AND QA/QC

## GPS Base Station Information

Table 4.1: GNSS Base Stations Used

Station Name	Latitude (DMS)	Longitude (DMS)	Ellipsoid Height (L1 Phase Center) Meters
DNL B (Columbia)	N 33° 28' 04.83107"	W 82° 02' 03.01776"	98.070
CORS GACC (Columbia)	N 33° 32' 44.70584"	W 82° 08' 01.70105"	100.004
KAGS BASE (Burke & Richmond)	N 33° 22' 16.61197"	W 81° 58' 28.07723"	12.954
THOMPORT (Lincoln)	N 33° 31' 45.84384"	W 82° 31' 07.05313"	111.159

Figure 4.1: GPS Base Station Location - Columbia County

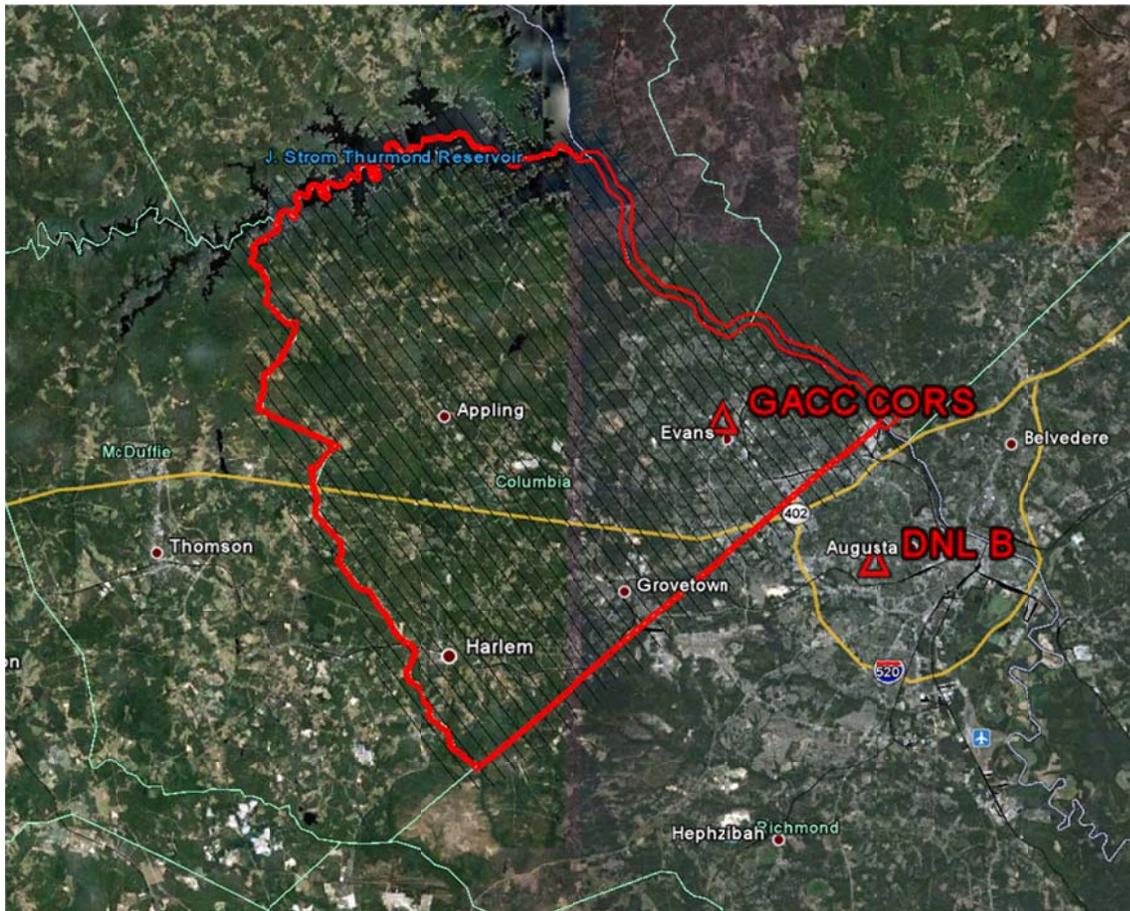


Figure 4.2: GPS Base Station Location - Burke and Richmond Counties

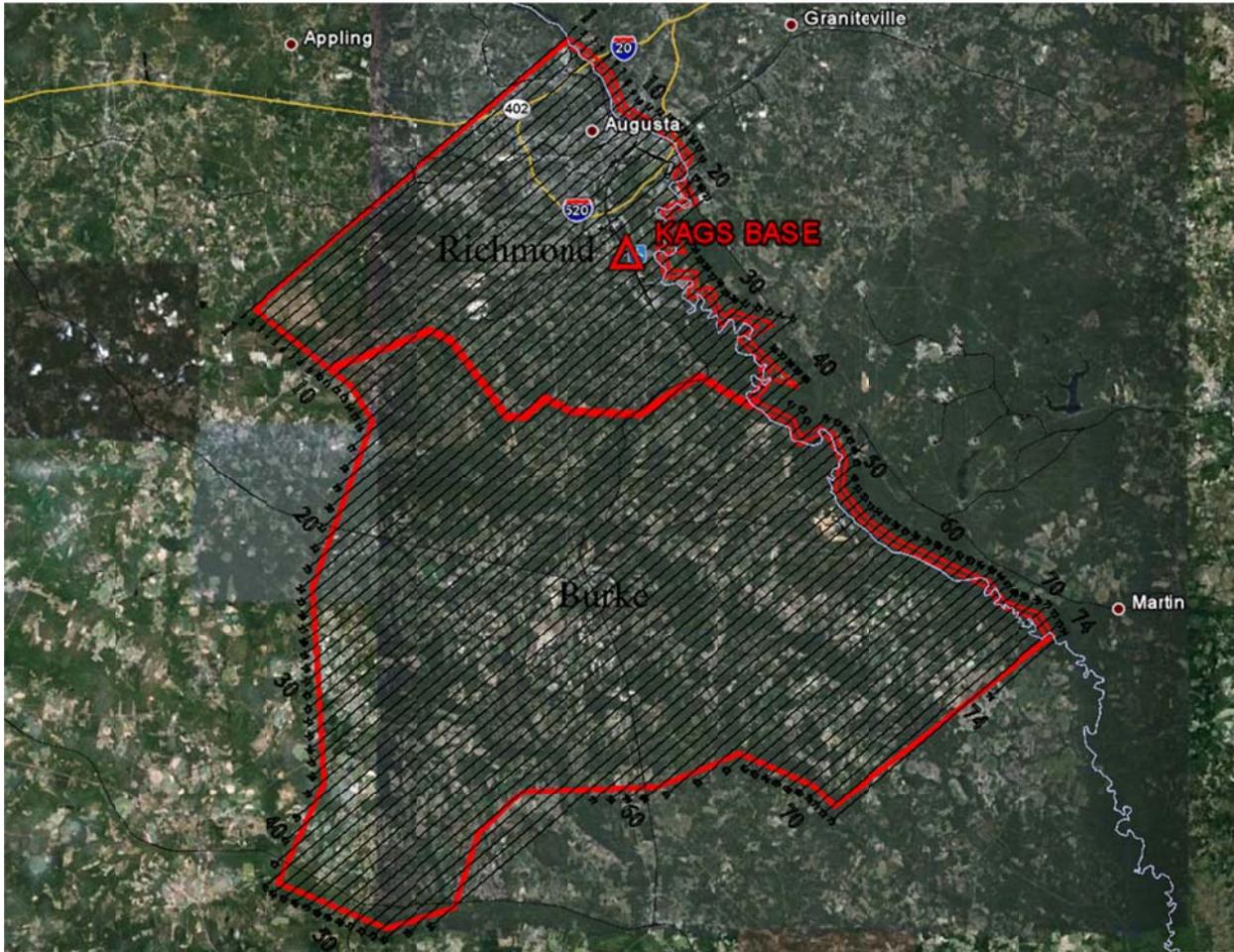
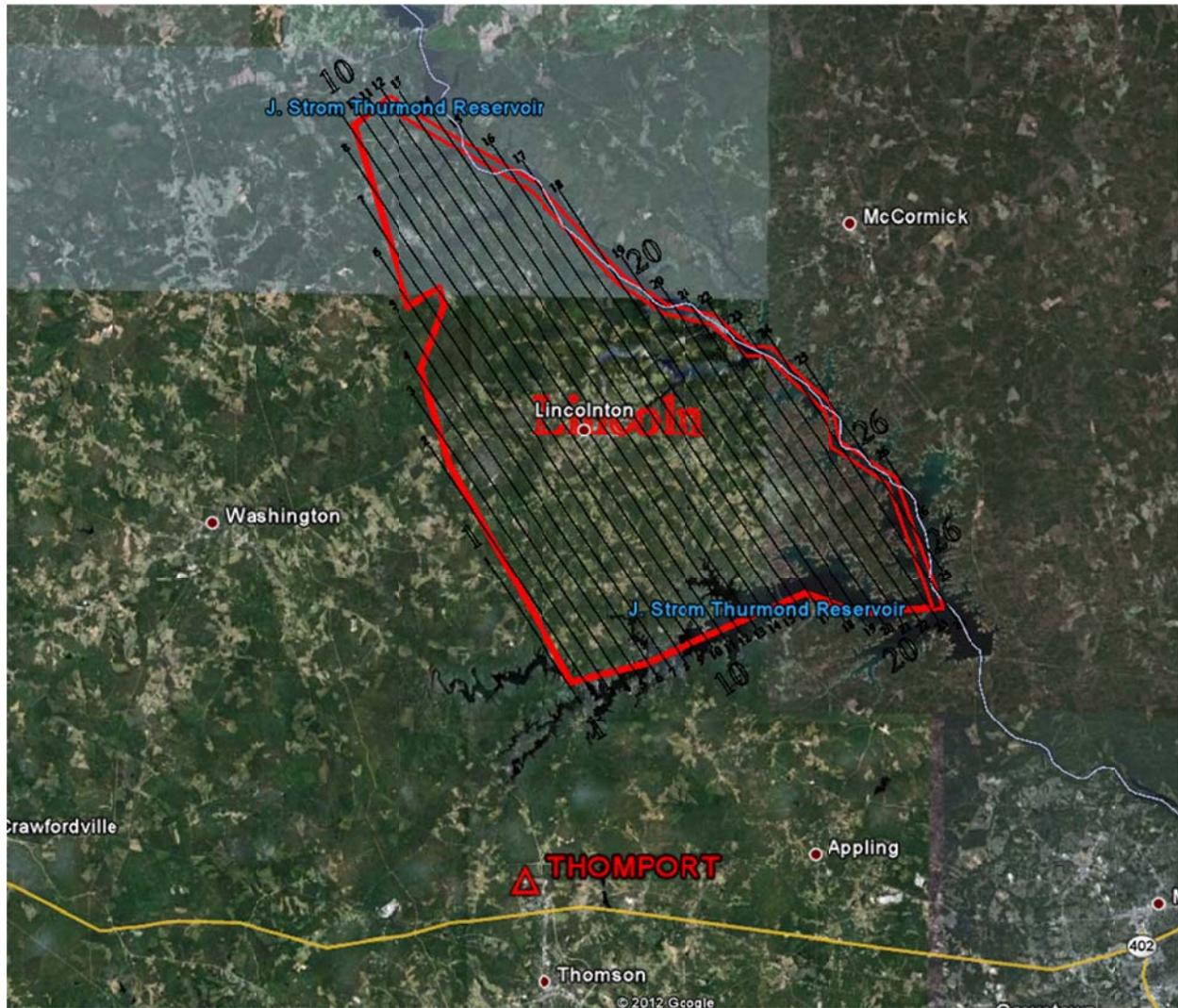


Figure 4.3: GPS Base Station Location - Lincoln County



## GPS/IMU Collection Parameters

Flight navigation is performed using IGI CCNS (Computer Controlled Navigation System). The pilots are thoroughly trained and highly skilled at maintaining their planned trajectory, while holding the aircraft steady and level. If atmospheric conditions are such that the trajectory, ground speed, roll, pitch and heading cannot be properly maintained, the mission is aborted until suitable conditions occur.

The aircraft are all configured with a NovAtel Millennium 12-channel, L1/L2 dual frequency GNSS receivers collecting at 2 Hz.

All Woolpert aerial sensors are equipped with Litton LN200 series IMU's operating at 200 Hz.

A base-station unit was mobilized for the imagery acquisition mission, and was operated by a member of the Woolpert survey and/or flight crew. Each base-station setup consisted of one (1) Trimble 5000 series dual frequency receiver, one (1) Trimble Zephyr Geodetic L1/L2 dual frequency antenna, one (1) 2-meter fixed-height tripod, and essential battery power and cabling. Ground planes were used on the base-station antennas. Data was collected at 1 or 2 Hz.

All GNSS base station data and point locations were tied together, along with the ground control.

## GPS/IMU Data QA/QC

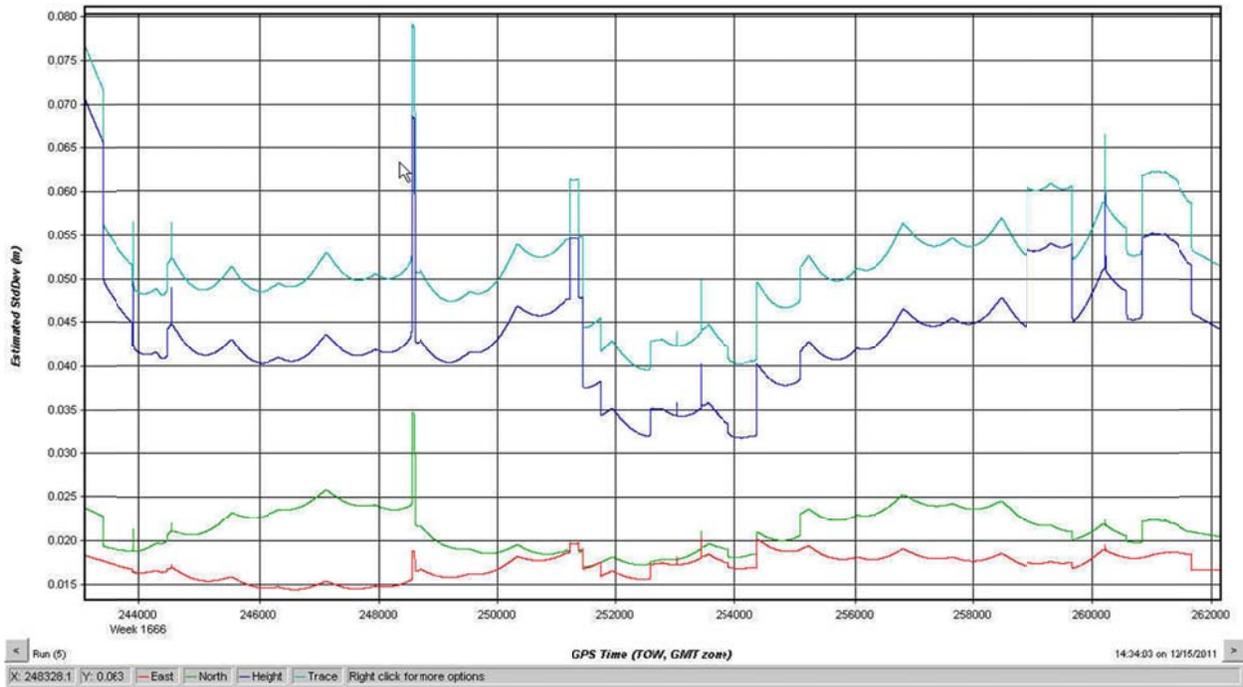
The collected data was shipped back to the Woolpert Dayton, Ohio office for processing and quality control. All data was downloaded into a standard Woolpert directory structure. The data was immediately checked for missing files, corrupt files, etc. Once verified, the GPS data was processed using Leica IPAS Pro 1.35 and PosGNSS 5.1 software packages, combining airborne GPS data with base ground data. The GPS quality control process includes checking the data to within specs in regards to positional accuracy (<10cm), PDOP (<3), etc. A Maximum Position Dilution of Precision (PDOP) of < 3.0 was achieved.

# Estimated Positional Accuracy

The Estimated Positional Accuracy plots the standard deviations of the east, north, and vertical directions along a time scale of the trajectory. It illustrates loss of satellite lock issues, as well as issues arising from long baselines, noise, and/or other atmospheric interference.

Woolpert's goal is to maintain an Estimated Positional Accuracy of less than ten (10) centimeters, often achieving results well below this threshold.

Figure 4.4: Sample Horizontal and Vertical Positional Accuracies from Day 347 (ALS60\_6157):



# Combined Separation

The Combined Separation is a measure of the difference between the forward run and the backward run solution of the trajectory. The Kalman filter is run in both directions to remove directional specific anomalies. The closer these two solutions match; in general, the better is the overall reliability of the solution. Woolpert's goal is to maintain a Combined Separation Difference of < 10cm, often achieving results well below this cap.

Figure 4.5: Sample GPS Combined Separation from Day 347 (ALS60\_6157):

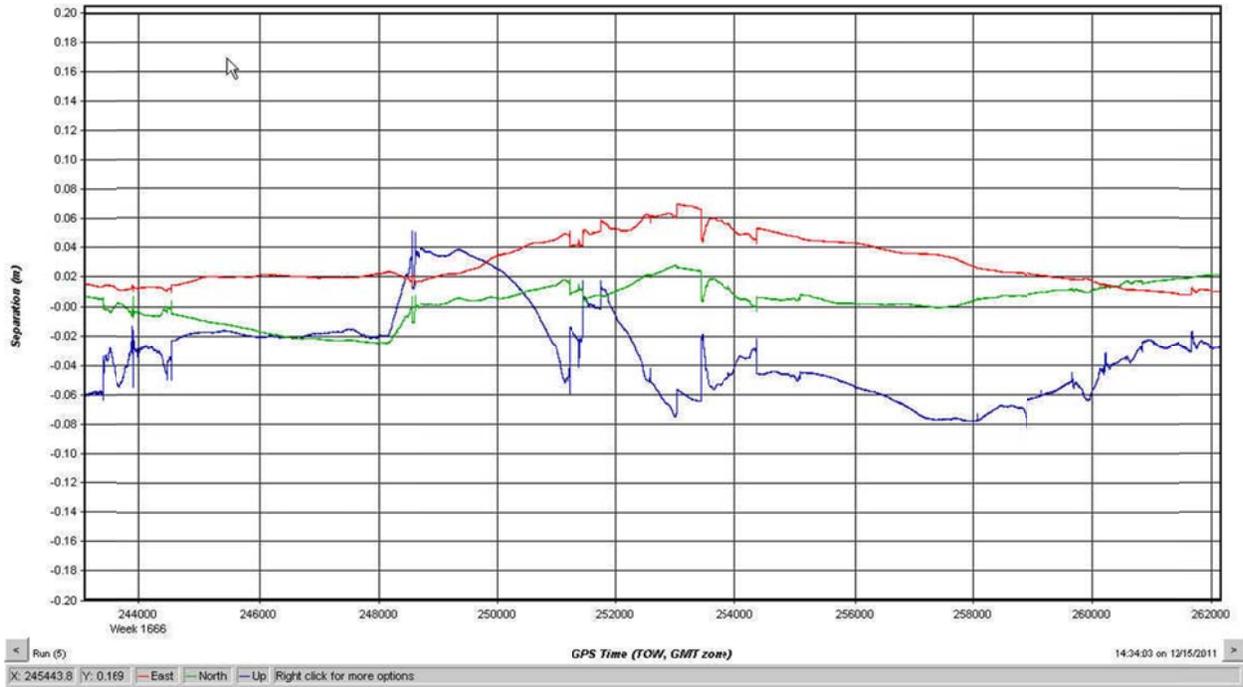


Figure 4.6: Sample GPS Altitude Plot from Day 347 (ALS60\_6157):

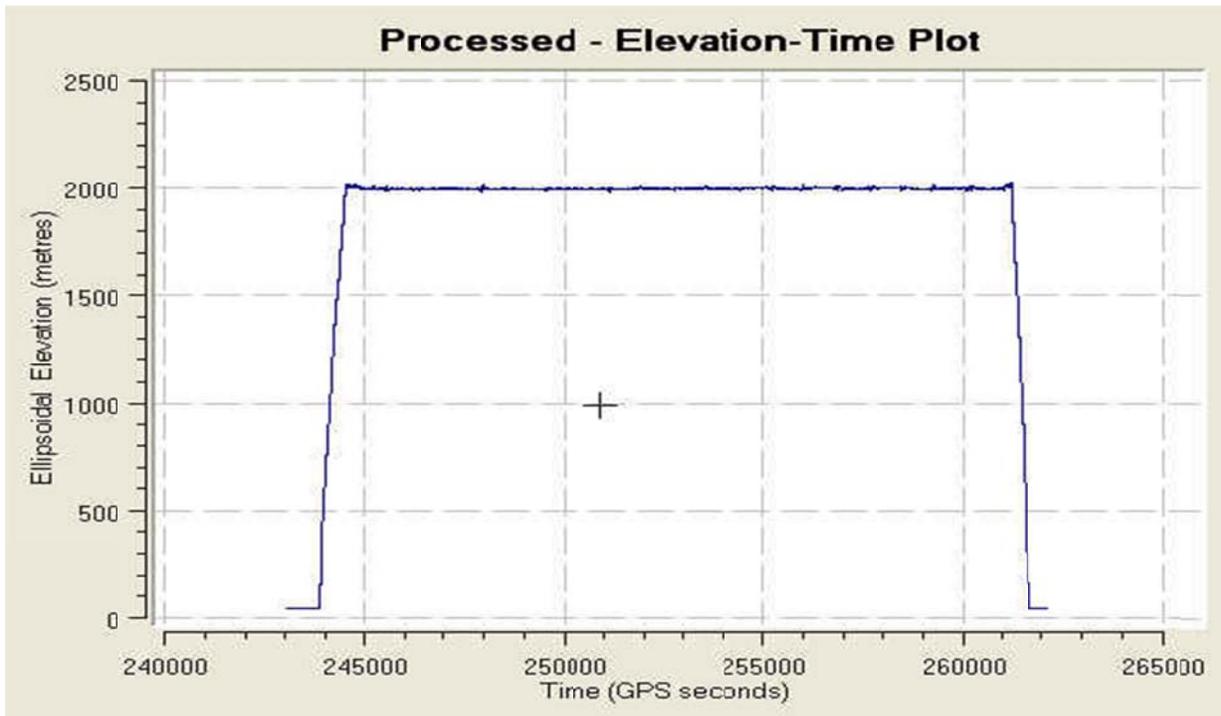


Figure 4.7: Sample horizontal GPS distance from base station from Day 347 (ALS60\_6157):

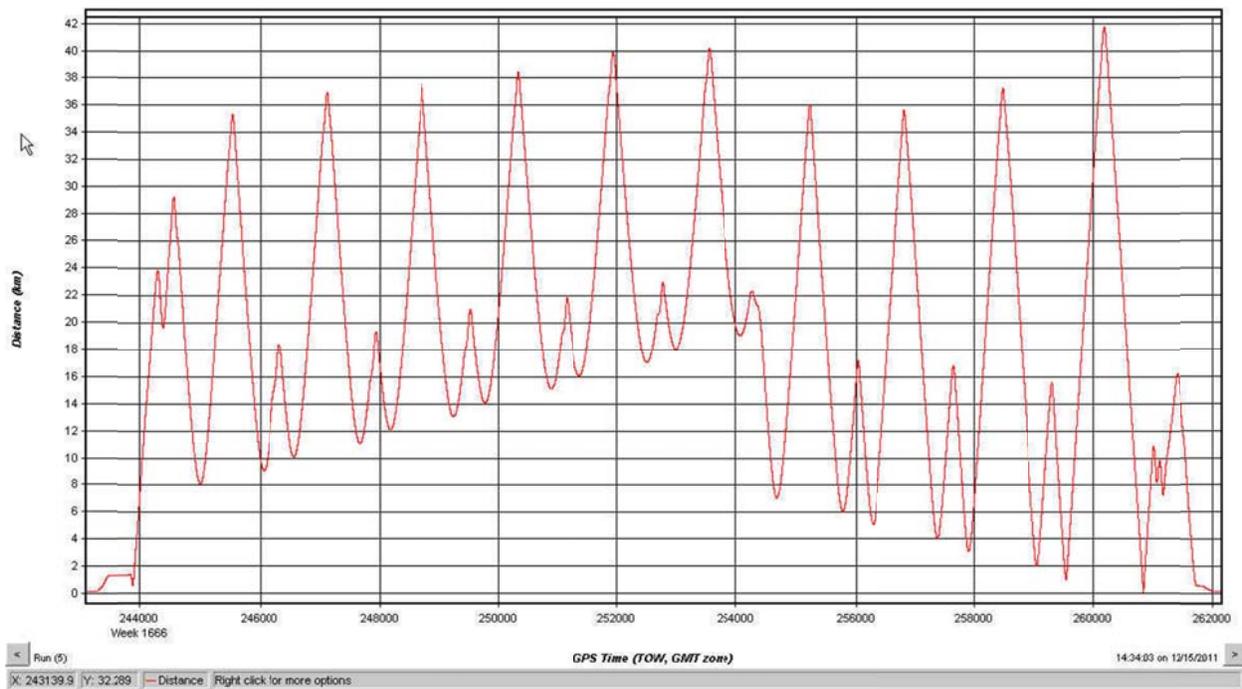


Figure 4.8: Sample PDOP Plot from Day 347 (ALS60\_6157):

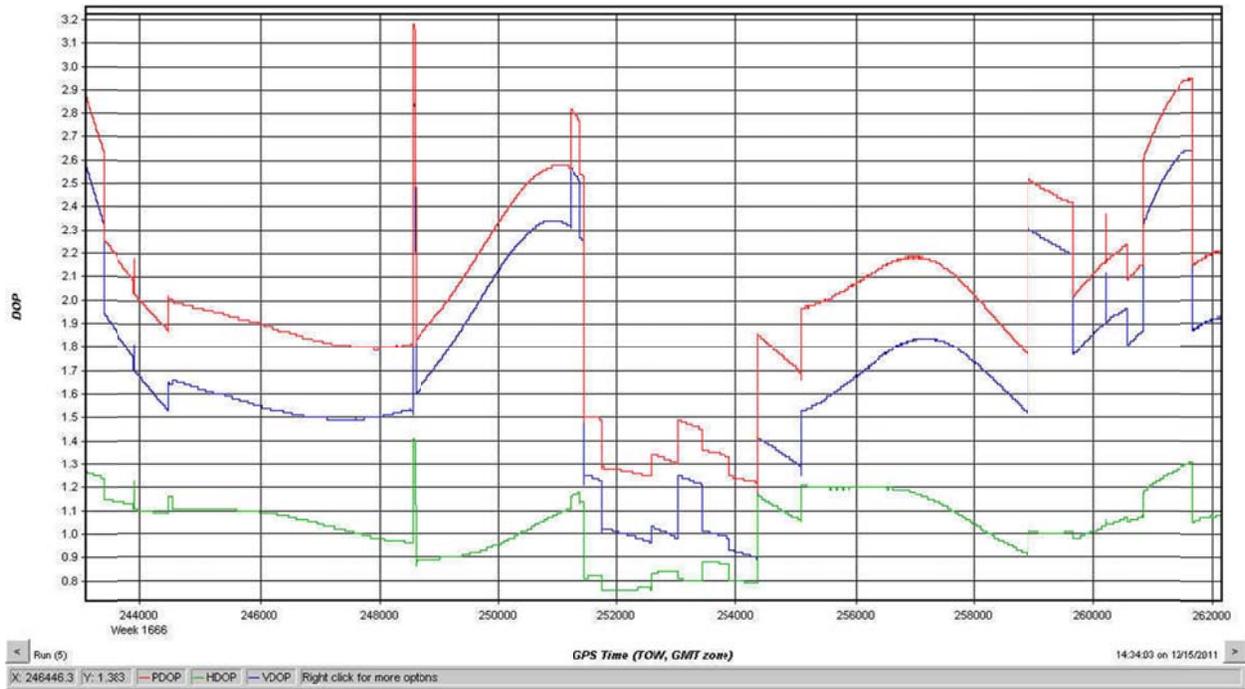
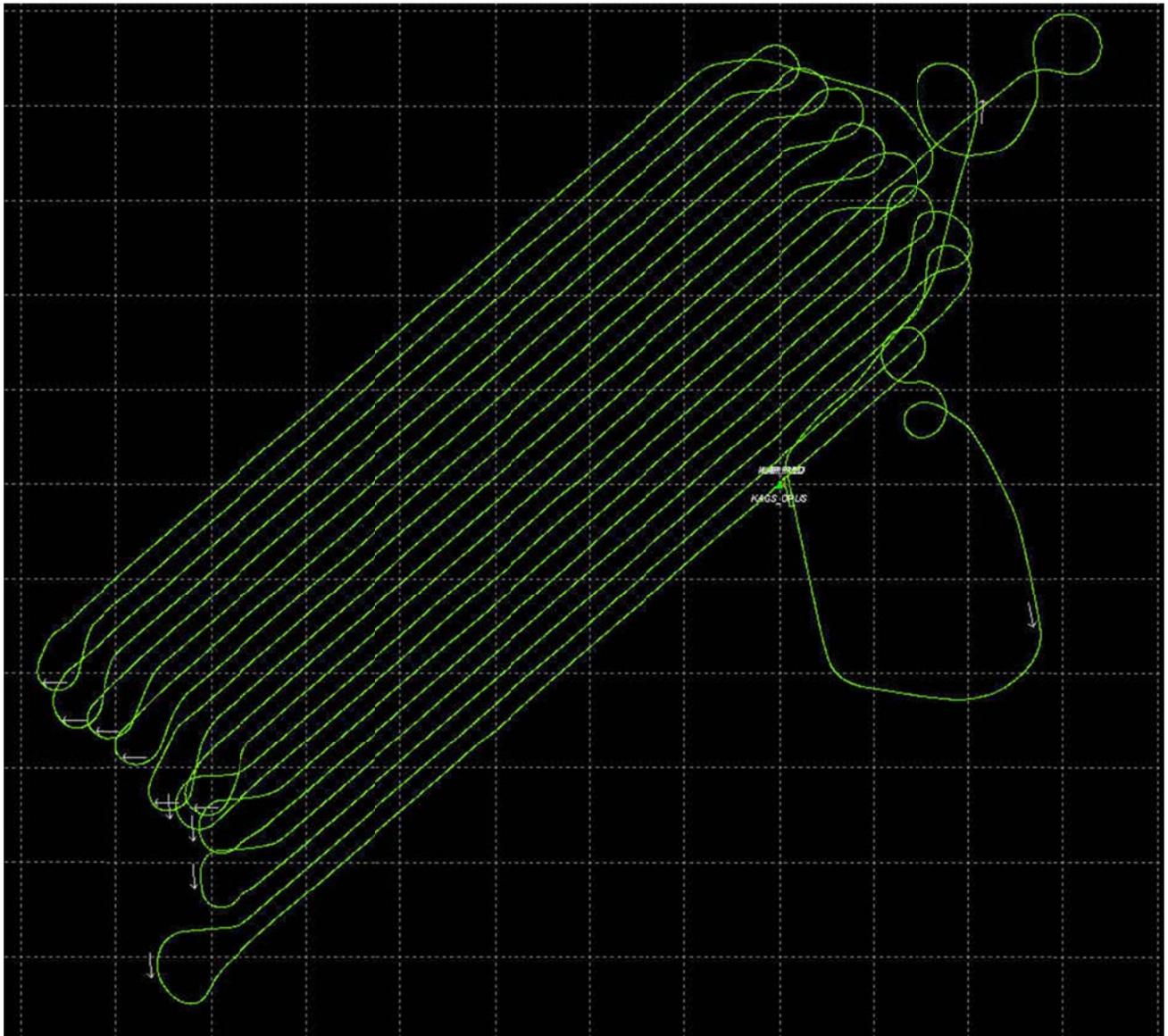


Figure 4.9: Flight Trajectory from Day 347 (ALS60\_6157):



**Table 4.2: Mission Specific Base Stations, Combined Separation, Estimated Positional Accuracy and PDOP**

Date Sensor Head	Base Station(s)	Combined Separation: Average Difference (Meters)	PDOP Average	Maximum Horizontal Positional Accuracy: (Meters)	Maximum Vertical Positional Accuracy: (Meters)
Feb. 26, 2011 56108	DNL B	0.01	1.8	0.03	0.07
Feb. 26, 2011 56108	CORS GACC	0.01	1.7	0.03	0.06
Dec. 13, 2011 ALS50 077	KAGS BASE	0.03	2.6	0.03	0.07
Dec. 13, 2011 ALS60 6157	KAGS BASE	0.03	2.3	0.03	0.08
Dec. 14, 2011 ALS50 077	KAGS BASE	0.04	2.6	0.03	0.09
Dec. 14, 2011 ALS60 6157	KAGS BASE	0.06	2.2	0.03	0.07
Dec. 17, 2011 ALS60 6157	KAGS BASE	0.02	1.6	0.03	0.06
Dec. 18, 2011 ALS60 6157	THOMPORT	0.03	2.2	0.03	0.08

## Projection / Datum Information

The LiDAR data was produced in Georgia State Plane East Zone, North American Datum of 1983 (NAD83). Coordinate positions were specified in units of US Survey Feet. The vertical datum used for the project was referenced to North American Vertical Datum of 1988 (NAVD88) in units of US Survey Feet.

## SECTION 5: LIDAR DATA PROCESSING AND QA/QC

### DATA PROCESSING AND DATA VERIFICATION

The LiDAR data was processed with DashMap v5.1061 software from Optech, and ALS Post Processor v2.74. The processed LiDAR data was immediately checked against the flight line layout via via MicroStation V8, using TerraScan. Each flight data was checked for spatial accuracy and completeness, data quality, any data voids, clarity of the intensity imagery, point spacing specs, etc.

The results of the data analysis were immediately provided back to the flight crew, and reflown as soon as weather conditions allowed.

Third party QA/QC of LiDAR data and hydro-enforced breaklines was provided by Dewberry. A report of their QA/QC analysis is attached.

DATE: 6/5/2012  
TO: Woolpert Inc.  
FROM: Dewberry  
SUBJECT: Burke, Richmond, and Lincoln County – Third Delivery Review

Dewberry has reviewed the third delivery dataset for Burke, Richmond, and Lincoln Counties. The most prominent issue discussed here is a complete alteration of the breaklines for Lincoln County. Additionally, a small amount of calls from the second delivery dataset need further corrections. A new field has been added to the existing QAQC Markers feature classes denoting which edit calls need to be addressed by Woolpert. Examples of these calls are discussed in the sections below.

This memo is divided into the following sections:

Burke and Richmond County Review .....	1
LiDAR Review .....	1
Breakline Review .....	1
DEM Review.....	2
Burke and Richmond County Recommendations Summary.....	3
Lincoln County Review.....	3
LiDAR Review.....	3
Breakline Review .....	4
DEM Review.....	4
Lincoln County Recommendations Summary.....	4
Columbia County Tie-In .....	4

## Burke and Richmond County Review

A full delivery of the Burke and Richmond County dataset was received from Woolpert including 1,485 LAS tiles, a geodatabase containing Islands, Lakes, and Stream Rivers feature classes, and 1,485 DEM files. Fewer tiles were delivered on for this review because the data set was clipped to match existing data in Columbia County. This was Dewberry's third review of the LAS and breakline datasets and second review of the DEM dataset.

### LiDAR Review

Seven (7) LiDAR calls requiring further corrections were identified during the second delivery review including one divot, one vegetation artifact, and 5 water classification issues. All calls LiDAR calls were corrected by Woolpert.

### Breakline Review

Fourteen (14) calls were identified as needing further corrections during the review of the second delivery breaklines. All breakline calls were addressed by Woolpert.

There is one very minor call placed where a geometry on geometry crossing error occurs where a stream breakline has been modified. Because this doesn't impact the usability of the breaklines, LiDAR, or DEMs this issue does not require correction unless requested by NOAA.

### DEM Review

Woolpert delivered 1,485 hydro enforced DEMs as part of the second delivery. The Burke and Richmond County DEMs are projected to NAD 1983 StatePlane Georgia East FIPS 1001, NRS2007. This was Dewberry's second review of the DEMs. Sixty-two (62) edit calls were placed during the first review. Most were adequately addressed by Woolpert including floating water, hydroflattening errors, and DEM tiling artifacts; however some calls are being recommended for additional corrections.

### DEM Clipping

The DEMs have been clipped to match the extents of the adjacent Columbia County DEMs. DEMs from both data sets were spot checked for consistency. Gaps and overlap were detected between Burke/Richmond DEM tile gae69501285 and Columbia DEM tile 695285 which should be corrected. Dewberry recommends Woolpert check all DEMs along the Burke/Richmond and Columbia border for gaps and or overlap.



Figure 2 – Gaps and an area of overlap between Delivery 3 Burke/Richmond DEM tile gae69501285 and Columbia DEM tile 695285. A red background is used to highlight gaps. Dewberry recommends Woolpert review all DEMs along the Burke/Richmond and Columbia border to ensure no other gaps or overlap exist.

### Hydroflattening Issues

Two (2) calls identifying areas where a stream is not flat from bank to bank should receive further corrections.

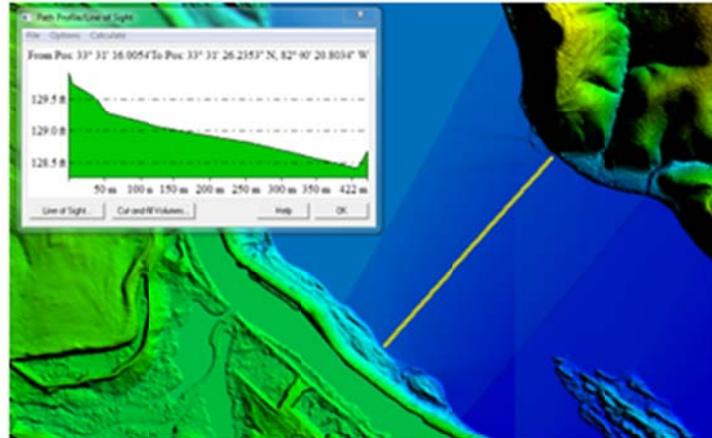


Figure 3 – One area resulting in two calls is recommended for further hydro flattening improvement. Here the stream varies in elevation from bank to bank by more than 1 foot.

### Burke and Richmond County Recommendations Summary

Dewberry recommends that the Burke and Richmond County data be returned to Woolpert for corrections. The following is a list of issues that need to be addressed by Woolpert:

#### LAS:

- Dewberry recommends accepting the Burke/Richmond LAS.

#### Breaklines:

- One geometry error should be corrected.

#### DEMs:

- All DEMs which adjoin DEMs from Columbia County should be reviewed to ensure no data gaps or overlap exists between the data sets.
- One area is recommended for further flattening corrections.

### Lincoln County Review

As part of the second delivery, Woolpert delivered 347 LAS tiles, a geodatabase containing Islands, Lakes, and Stream\_Rivers feature classes, and 347 DEM files. This was Dewberry's second review of the LAS and breakline datasets and first review of the DEM dataset.

### LiDAR Review

Woolpert has previously addressed all issues associated with the LiDAR edit calls.



### Breakline Review

Woolpert has made extensive changes to the entire Lincoln breakline database. The breaklines no longer reflect ground/water conditions at the time of LIDAR collection. The changes were extensive enough that breakline calls made by Dewberry on the second delivery no longer apply and could not be reviewed.

### DEM Review

Woolpert delivered 347 hydro enforced DEMs as part of the second delivery. The Lincoln County DEMs are projected to NAD 1983 StatePlane Georgia East FIPS 1001, NRS2007. This was Dewberry's second review of the DEMs. All issues that could be addressed including DEM tile edge gaps and an area of misclassification were corrected by Woolpert. Two ridge calls were not corrected because using the modified third delivery breaklines, the areas of ground which contained the ridges are now covered by water.

### Lincoln County Recommendations Summary

Dewberry recommends that the Burke, Richmond, and Lincoln County data be returned to Woolpert for corrections. The following is a list of issues that need to be addressed by Woolpert:

LAS:

- Recommended for acceptance.

Breaklines:

- The breaklines have been revised based on guidance provided by NOAA in order to better match the water elevations of the surrounding counties. After a secondary review these breaklines are recommended for acceptance.

DEMs:

- All issues have been addressed and the DEMs are recommended for acceptance.

### Columbia County Tie-In

The borders of Richmond and Lincoln County share a border with Columbia County. The Columbia County dataset has been previously reviewed and accepted by Dewberry; the borders were reviewed for consistency. As described in the Burke and Richmond County Review section, DEMs tiles along the border of Burke/Richmond Counties and Lincoln County should be reviewed by Woolpert and gaps or overlap should be corrected.

Overlap exists between Columbia County DEMs and Lincoln County DEMs, however it occurs within a water body. Dewberry feels this is acceptable.

Breaklines and DEMs for Richmond/ Burke Counties Lincoln County are now clipped to match the extent of the Columbia county breaklines and DEMs with no overlap. Elevation of all ponds and lakes are consistent across data sets. Elevations of streams may change between data sets however they do so monotonically which is acceptable.



# Vertical Accuracy

Average Error	0.002	Feet
Minimum Error	-0.424	Feet
Maximum Error	0.438	Feet
Root mean square	0.197	Feet
Std deviation	0.157	Feet

Average Error	0.298	Feet
Minimum Error	-0.303	Feet
Maximum Error	0.824	Feet
Root mean square	0.383	Feet
Std deviation	0.242	Feet

Average Error	0.120	Feet
Minimum Error	-0.424	Feet
Maximum Error	0.824	Feet
Root mean square	0.286	Feet
Std deviation	0.261	Feet

## Vertical Accuracy Conclusions - Burke, Richmond, and Lincoln Counties

- Fundamental Vertical Accuracy (FVA) tested 0.197 feet RMSE or 0.386 feet vertical accuracy at 95% percent confidence level.

Based on the analysis of the LiDAR data, the accuracy of the system meets the required specifications.

Table 5.4: Fundamental Vertical Accuracy Statistics for Columbia County		
Average Error	-0.006	Feet
Minimum Error	-0.354	Feet
Maximum Error	0.334	Feet
Root mean square	0.179	Feet
Std deviation	0.181	Feet

### Vertical Accuracy Conclusions - Columbia County

- Fundamental Vertical Accuracy (FVA) tested 0.179 feet RMSE or 0.351 feet vertical accuracy at 95% percent confidence level.

Based on the analysis of the LiDAR data, the accuracy of the system meets the required specifications.

#### Table 5.5 Approved By

Approved By:			
Title	Name	Signature	Date
LiDAR Specialist Certified Photogrammetrist #1281	Qian Xiao		June 27, 2012