GNSS Survey Report

New York Statewide
LiDAR Acquisition
Lot 17

2017 Southwest 17B (Fall) LiDAR
Ground Control and Check Point
Survey Report

AXIS Geospatial, LLC
28640 Mary's Court, Suite 200
Easton, Maryland 21601
Axis Project Number 13367-1710

Date: 02/19/2018

NY17-Southwest 17 B LiDAR Primary Gound Control Folder Explanation and Inventory

NY17 Southwest 17 B – GNSS Survey Report- This is the primary file forming the narrative of the survey report and contains descriptions of work areas, methodologies employed and contains a listing of final coordinate values and a coordinate analysis of our positioning vs. published NGS. Page three of the GNSS Survey Report is a table of contents breaking down the file structure of the work areas and listing report file names and equivalent deliverable features.

The deliverables are grouped into four subdirectories as follows:

Datasheets Folder-Contains three subdirectories

NGS Control Folder- Contains NGS datasheets for all terrestrial control points

RTN Datasheet Folder- Contains NYS Realtime Reference Network station datasheets

Datasheets Folder- Contains field observation datasheets of the LiDAR Primary Control points

Field Data Folder- Contains the field data files of the observations in Leica proprietary format

GNSS Reports Folder- Detailed reporting of GNSS Intervals, GNSS Observations Report, Points Report and a Coordinate System Report

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GNSS Survey Report Narrative

October 26, 2017

State of New York
Office of Information Technology Services,
GIS Program Office
10B Airline Drive
Albany, NY 12235

Attn : Francis M. Winters, Director of GIS Programs

Re: GNSS Survey Control Report-Primary Control
Axis Project # 13367-1710, Southwest 17B LiDAR Project Area, New York
NY Contract #C300036

Please find enclosed a series of reports, diagrams and other supporting information that forms the formal GNSS Survey Report for the referenced project. Additionally, we have included a narrative of the methodology, techniques and technical details about the equipment and technology utilized to execute the project.

Process Summary

AXIS GeoSpatial, LLC was authorized to collect airborne LiDAR data for the remaining area of Southwest 17 in the Fall of 2017. Based on mission planning by the project Certified Photogrammetrist, a map was provided to me for evaluation and GNSS Survey planning which contained the planned flightlines, the proposed ground control points and proposed check points. Based on available local control, the site's proximity to high order NYSNet CORS stations and the number and related geometry of surrounding Real-time Network base stations, as well as the numerous benefits of using a Real-time Network positioning solution, AXIS moved forward with mobilization for the project and configuration of my equipment to utilize The New York NYSNet Real-time GNSS Network. Based on the approximate locations of the ground control and check points needed for the dataset, I field selected a final location for each point based on a number of factors including safety concerns, visibility of the ground control point from the plane in its flight path, satellite obstructions, multipath sources and ground surface conditions. Positioning was conducted using a hybrid methodology, internally referred to as Real-time Static, which involves using a tripod or bipod mounted GNSS antenna/receiver to collect multiple sets of data at a one (1) second intervals, typically for one (1) minute per set, for each survey point. Traditional Real-time Kinematic survey practice is to take a single measurement of a point, using a rover pole. We have found that by collecting multiple sets of data on each point using a stabilized setup, accuracy and precision of the ground control points is optimized. As redundant check to all of the measurements, we measured all of the points, including the NGS control points and the survey points up to five times per occupation, with each observation being made after breaking the fixed solution and forcing re-resolution of the positioning ambiguities by the receiver. Per NYDOT specifications, all GNSS survey control points were re-occupied a minimum of twenty minutes later to confirm positioning quality with a different satellite constellation configuration. A report is attached showing the observation times, measurement statistics, and other pertinent information, including a spreadsheet detailing observed variances from published control. Results using multiple observations, and time offset re-occupations are exceptional, as borne out by the statistical analysis and aero-triangulation report.

Check Point Survey

Following USGS specifications (LiDAR Base Specification; Techniques and Methods, 11-B4, Page 8) citing the Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014, Table C.1 Recommended Number of Checkpoints Based on Area, Page A19) Axis determined the number of Quality Check (QC) points. For this project, seventy-seven (77) Non-vegetated Vertical Accuracy (NVA) points were surveyed and sixty-two (62) Vegetated Vertical Accuracy (VVA) points were surveyed. The QC surveys were conducted as separate, fully independent mobilizations. Axis proposed and received approval for the check point sites, distributed across the work area.

At each site, a GNSS control pair was set using the approved methodology for GNSS control points. Once the observation sequences were completed and satisfactory positions obtained, Axis personnel used a Leica MS-50 robotic instrument to make terrestrial measurements to the second control point as well as the desired QC points. Each QC point was located using a two face (direct/indirect) measurement sequence and then documented with two digital photographs, detailing ground and general site conditions. Positions were recorded for the NVA and VVA check points, with attention given to randomize locations across each site as much as reasonably possible. This combined GNSS/robotic approach has several benefits, the first being reduced numbers of time intensive GNSS observations. By setting only two inter-visible GNSS control points, and performing the actual QC observations with the robot, dozens of control points can be located quickly, with very little error in positioning, across the site, without being hampered by the lack of GNSS observability in wooded areas.

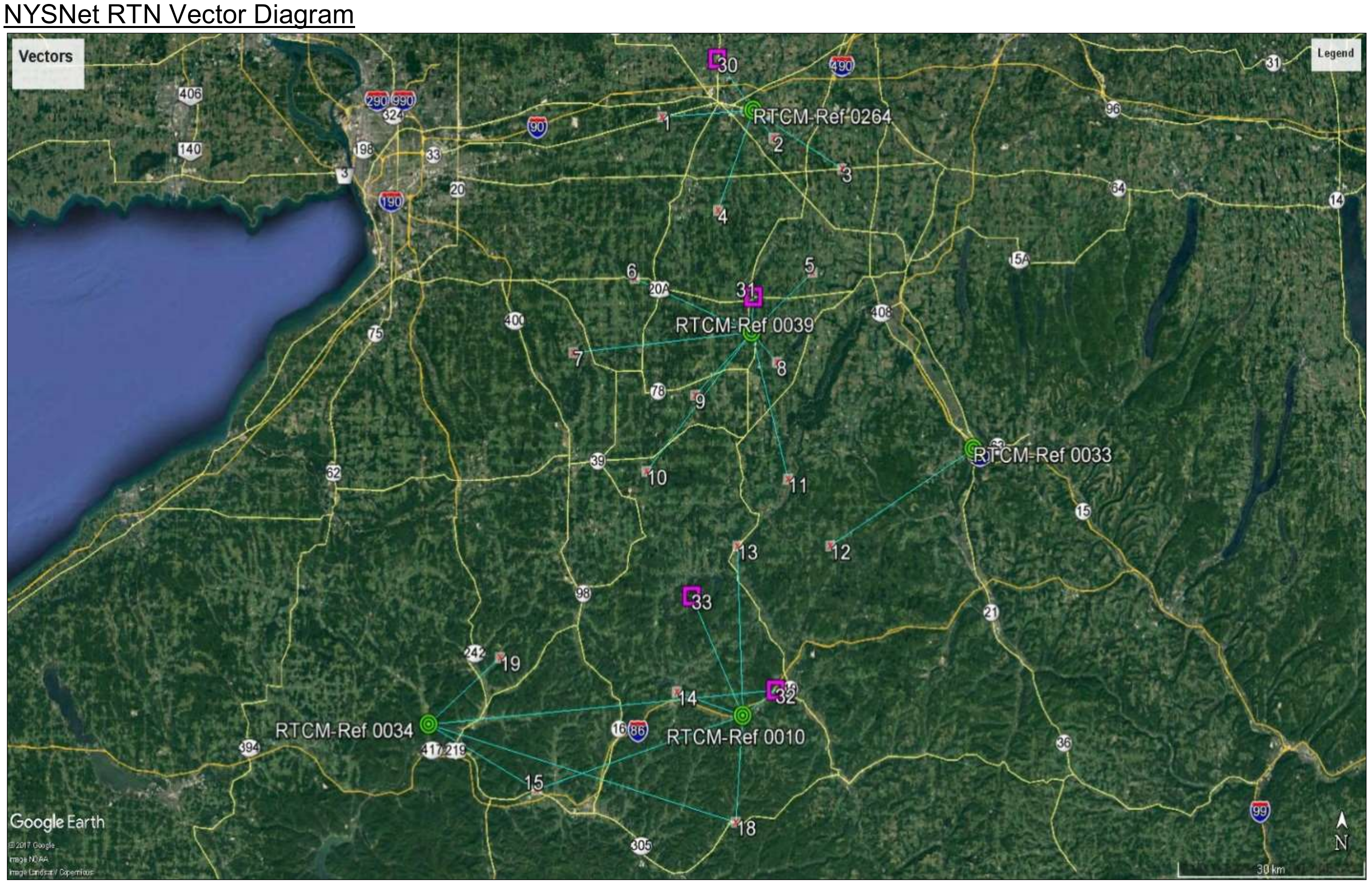
Real-time Network Positioning

UTM Zone 17 coordinates for this project were determined using the Real-time Network (RTN) NYSNet, verified with the measurements to monuments found in the National Geodetic Survey Control Point database. The use of an RTN for geodetic control involves the collection and correction of ionospheric, tropospheric, satellite clock errors and orbital errors from multiple permanent control points surrounding the observation site, resulting in high precision positional data, based on correction data from all the surrounding stations, and a positioning vector measurement from an optimized base station, generally the closest to the rover. The control points of this network are NY State Continuously Operating Reference Stations, NYSNet CORS Stations and National Geodetic Survey Continuously Operating Reference Stations or NGS CORS, and the resulting measurement vectors between the GNSS receiver and network station are direct measurements to existing, high order physical monuments, which have been vetted, documented and distributed by the State of New York and the National Geodetic Survey from their online control databases. Additional measurement data was also collected during the survey fieldwork to other high order, local national geodetic survey monuments as a supplemental verification of positioning quality.

A real-time reference frame based positioning system by its very nature will not always match published positions of ground control points, regardless of their adjustment status, due to their original measurement methodology and accuracy classification, time passage since original observation, exposure to the elements, forces of nature and the deliberate or accidental injury to their integrity by man.

The project area contains a fairly well distributed, GNSS observable NGS control point framework, and control check in was conducted to points within the immediate project area.

<u>NYSNet RTN Vector Diagram</u>



Primary RTN Control Stations:

NYSNet NYBT/RTCM REF 0264	BATAVIA CORS ARP (DI0444)
NYSNet NYFS/RTCM REF 0010	FRIENDSHIP CORS ARP (DI0454)
NYSNet NYSM/RTCM REF 0034	SALAMNACA CORS ARP (DI0620)
NYSNet NYDV/RTCM REF 0033	DANSVILLE CORS ARP (DI1870)
NYSNet NYWS/RTCM REF 0039	NOT A CORS STATION

NGS Control Stations:

ELBA 1	AE2166	RECOVERED AS DESCRIBED
RUSHFORD	NC0965	RECOVERED AS DESCRIBED
WARSAW 7	AE2172	RECOVERED AS DESCRIBED
Y 468	NC0820	RECOVERED AS DESCRIBED

Positional comparisons for both work areas are available for review, as well as detailed observations reports in the Static Mission Reports sections of this GNSS report.

Fieldwork Mobilization Dates: October 23, 2017 through October 27, 2017

RTN Field Equipment

GNSS receiver technical data: Leica GS-15- Geodetic GNSS receiver/antenna (GPS L1/L2/L2C/L5 and L1/L2 GLONASS frequencies), Serial #1505760 firmware v. 6.13
Leica CS-20- Serial #2490713 Controller firmware/Captivate v. 2.2

Leica GS-14- Geodetic GNSS receiver/antenna (GPS L1/L2/L2C and L1/L2 GLONASS frequencies), Serial # 2806875 firmware v. 6.13
Leica CS-35- Serial # 5GTSA86661 Controller firmware/Captivate v. 2.2

Field procedure/methodology: GNSS- Multiple, redundant, multi-set observations with offset occupation times and individual ambiguity resolutions, using NYSNet real-time network.

Field Equipment Adjustment/Calibration/Field Checks

Laser plummets were field checked at each setup, using the precise level plate level bubble and a two position check routine. Rotation of a laser plummet will immediately reveal any defect in the internal structure or alignment of the laser.

Instrument heights were measured using a device called a height hook, which makes a direct, vertical reading of the instrument height without concern for slant height or other problems. The height hook reading is made in millimeters, which offers an exact, high precision measurement.

No change or adjustment to any field equipment was necessary throughout the duration of this project.

Office Software

The GNSS receiver and its controller hardware interface via field software called Leica SmartWorx, which provides a user interface and workflows for collecting data, analyzing datasets, selecting results and performing other calculations, including QA/QC analysis, exporting of data and reports and organizing project data. Office software used is the full suite of Leica Geo Office, Version 8.4 (current) and Leica Infinity Version 2.3 (current), which provide an interface for downloading data, generating reports and performing calculations, analyzing data, and organizing and printing project reports. Additional analysis was performed using Microsoft Excel 2010, AutoCAD Civil 3D 2016, AutoCAD Map 2016 and the Google Earth extension of Leica Infinity.

RTN Observation Methodology

Every point established during this project has a final position based on a number of individual observations at different times, each with a fresh ambiguity resolution. The total number of observations on a point is based on the observer's analysis of the quality of those observations, known network geometry and the consistency of the results as a group. Positioning points using a number of observations helps to identify fluctuations in positioning due to base to rover vector length, varying satellite geometry due to observation window obstructions, and network cell station geometry/spacing and availability. The individual observation dates and times can be reviewed in the GNSS Observations Report of this report, and the actual detailed observation vectors, geodetic positions, Dilution of Precision values, observation inclusion and exclusion, and related averaging information can be reviewed in the Field Book Report section of this report. Averaging of the individual observations to obtain the final position for a point is weighted by the software, based on the positional quality of each observation.

Survey point numbers were matched to the Photo ID point numbering scheme, allowing a reviewer to follow the progress of the observations as they were made on both photo control points and to document the sequencing of check in observations to NGS and local survey control points. The correlation between survey point number and the actual Photo ID number is documented in the tabulation of the Final Project Control values on page 13.

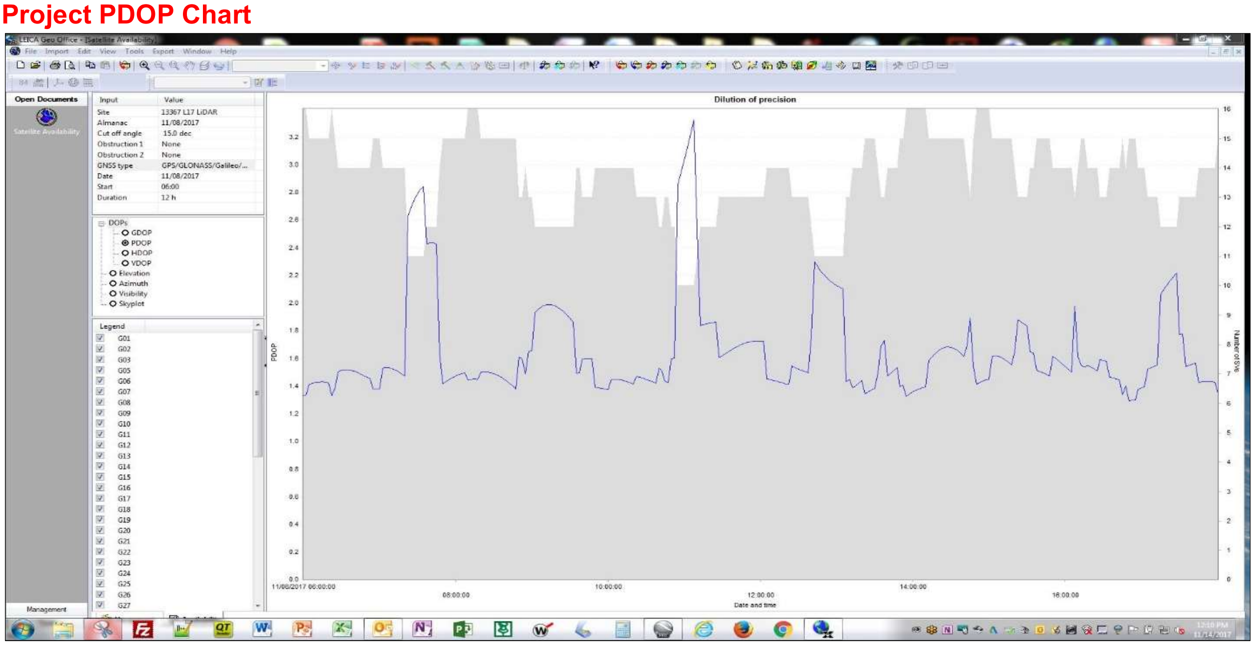
QA Testing of RTN Observations
Quality Assurance testing of the RTN data was accomplished via statistical analysis of the observations on each point, as well as using two instrument heights during observations to confirm height hook readings. A table comparing redundant observations on primary control points and NGS control points is available in the Control Analysis section of the report.

Statistical Analysis & Quality Reporting
A table showing the statistical analysis and positional quality of the NGS control points is available in the Control Analysis Table starting on page 12 of this report.

Satellite Geometry and Observation Planning
The following charts were used to schedule and manage the point observation schedule during the fieldwork. Point locations were selected in the field to optimize satellite visibility, avoid multipath sources and provide the most accurate control network for the digital aero-triangulation process. The observation planning site for this project was
based on the approximate centroid of the work area, as final visibility of the satellite constellation is dictated by the individual site conditions and obstructions. Since the constellation changes daily, with satellites arriving approximately four (4) minutes earlier each successive day, the observation planning was revisited every two weeks to maintain a current status on the timing of spikes in DOP values. The chart is used in real time during the work day to optimize observations and avoid DOP spikes. The planning chart windows were restricted to working hours to enhance detail.

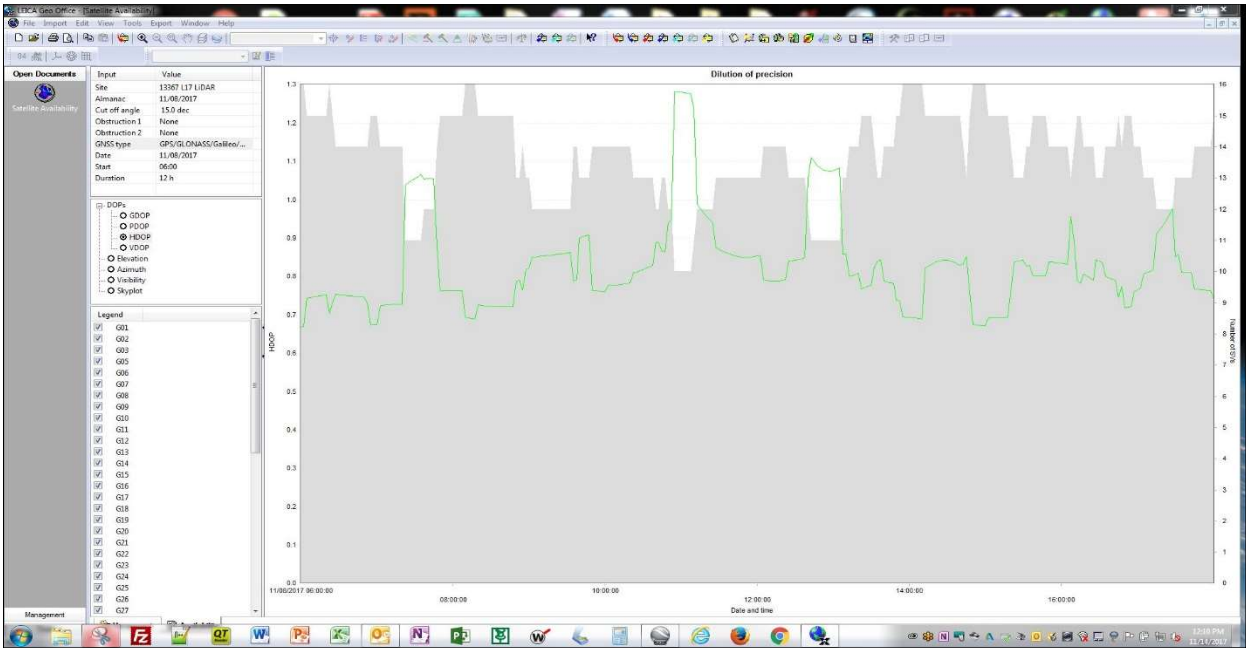
Samples of the planning charts for the project are presented on the following page.

Project PDOP Chart



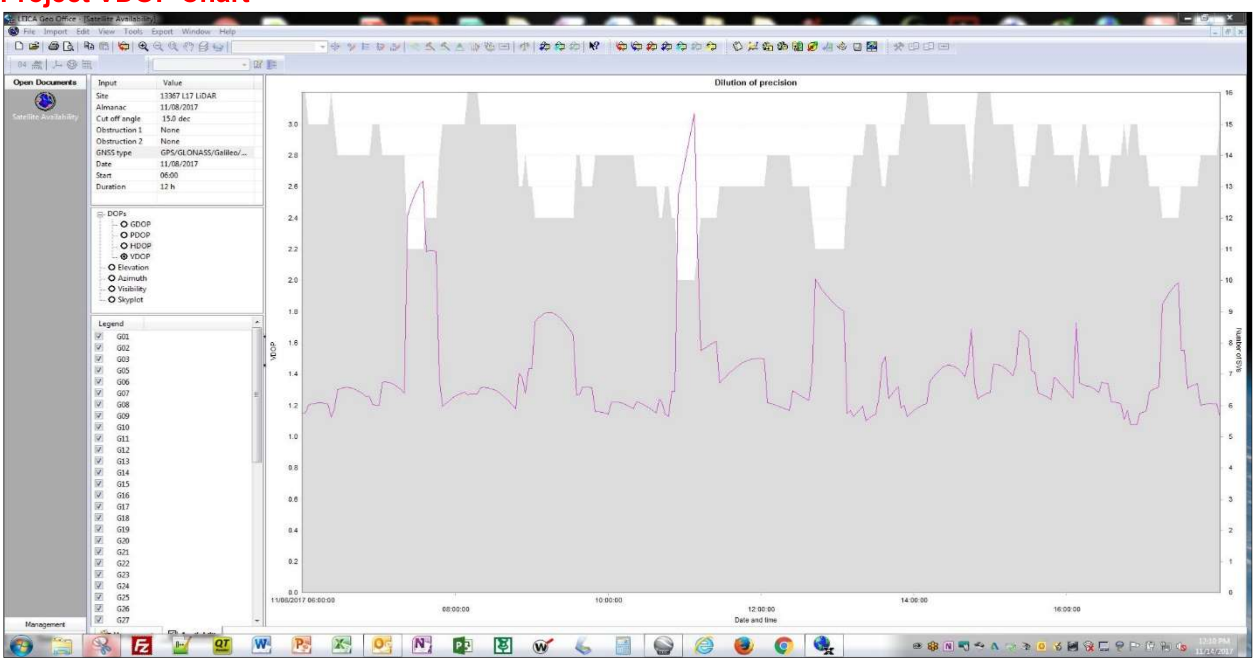
The Positional Dilution of Precision is a numerical gauging of the quality of positions yielded by GPS and GLONASS satellites at a particular time, without consideration of ground conditions. Actual PDOP will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project HDOP Chart



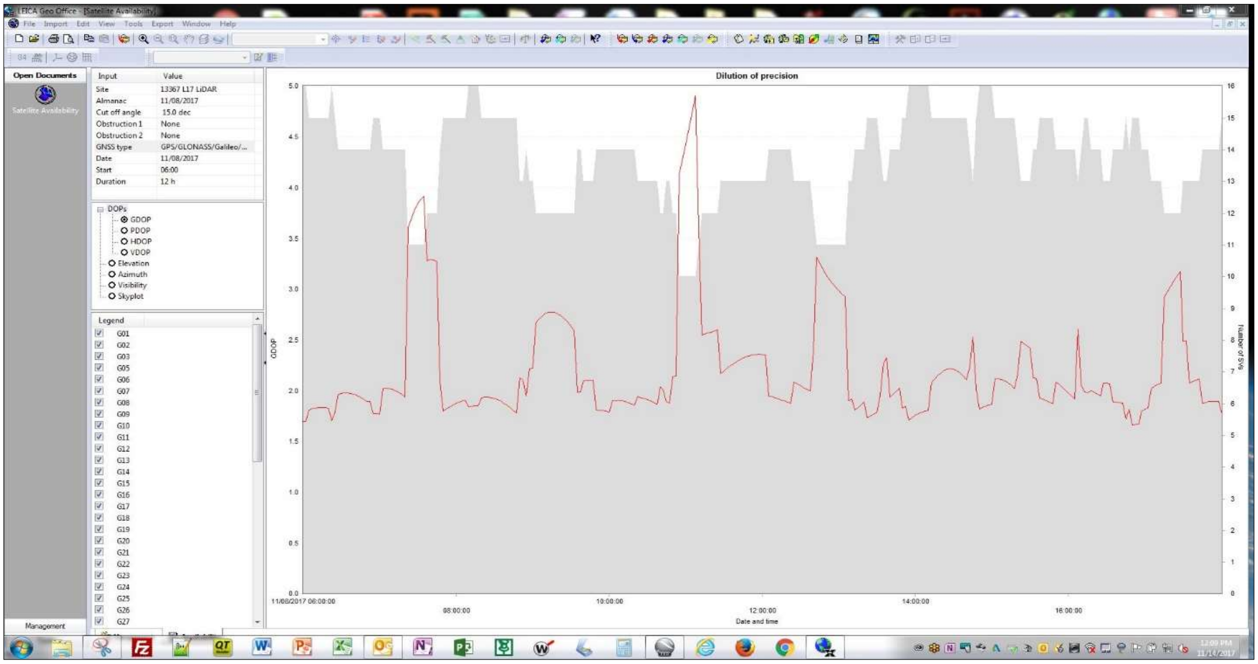
The Horizontal Dilution of Precision (HDOP) value is a numerical gauging of the quality of 2-D horizontal position yielded by GPS and GLONASS satellites at a particular time, without consideration of ground conditions. Actual HDOP will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project VDOP Chart



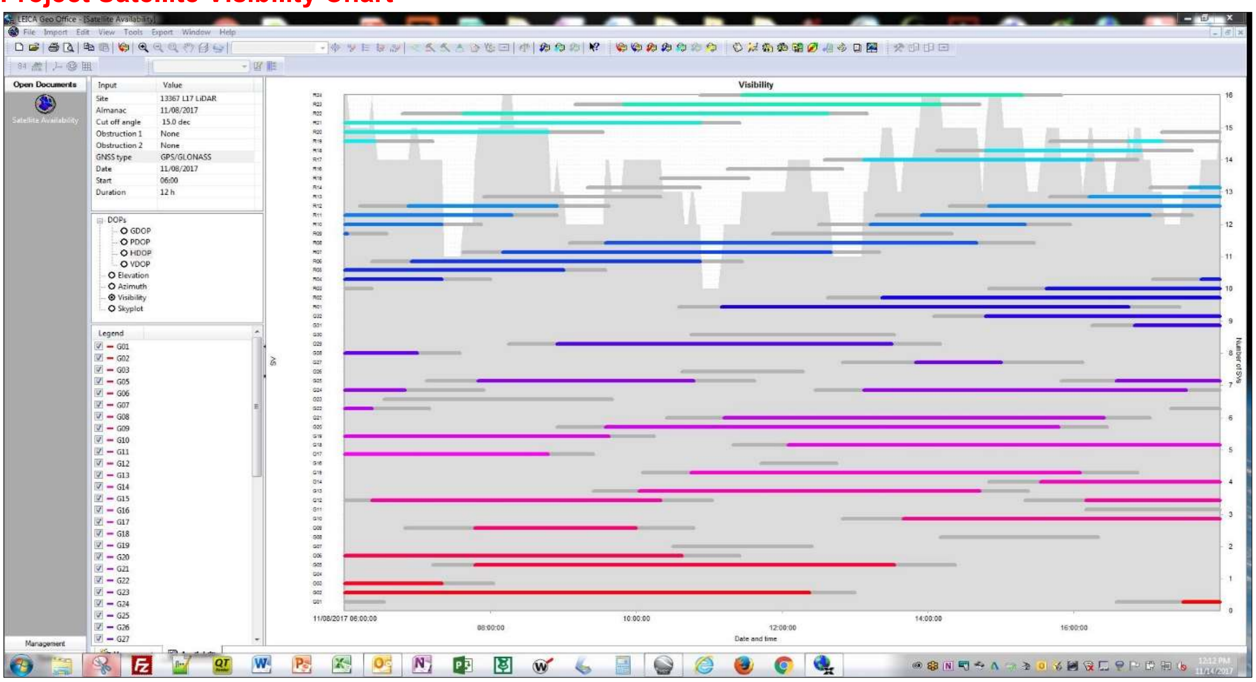
The Vertical Dilution of Precision (VDOP) value is a numerical gauging of the quality of 1-D vertical position yielded by GPS and GLONASS satellites at a particular time, without consideration of ground conditions. Actual VDOP will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project GDOP Chart



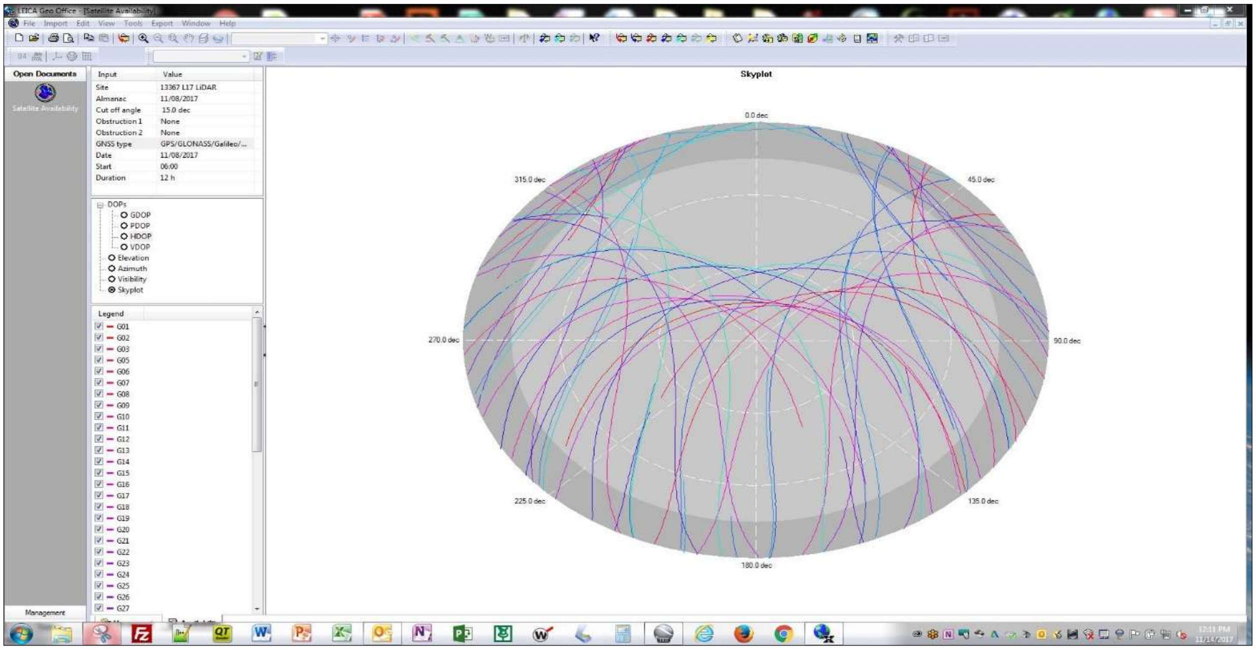
The Geometric Dilution of Precision (GDOP) value is a numerical gauging of the satellite geometry yielded by GPS and GLONASS satellites at a particular time, without consideration of ground conditions. Actual GDOP will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project Satellite Visibility Chart



The Satellite Visibility Chart is a graphical representation of the time that individual satellites are available for observation, allowing planning for observations based on satellite constellation density and common time. The satellite visibility will vary from the planned values based on field conditions, such as obstructions by buildings, trees and terrain.

Project Sky Plot Chart



The skyplot chart is used in mission planning to assess satellite location and trajectory during a particular window in time that will be used to observe GNSS satellites. The chart shows day long trajectories of available satellites. During actual planning, the planned start and stop times of the observation are used to restrict the plotted trajectories to only their path during the observation. Satellite observability is further restricted by site obstructions.

Responsible Charge

All of the field work and GNSS computations for this project was conducted under my supervision, a Professional Land Surveyor, following NYDOT Photogrammetric Control Procedures, National Geodetic Survey Guidelines for GNSS Surveying using Real Time Kinematic and Real Time Networks and FGDC Guidelines for GPS Positioning.

Date: 11-14-2017

William T. Derry, Prof. LS
Delaware Professional Land Surveyor # 652
Pennsylvania Professional Land Surveyor # SU-052920-E
Maryland Professional Land Surveyor # 0021745
North Carolina Professional Land Surveyor # L-5120

Southwest 17 B; NGS QA Control Analysis				
Horizontal Datum:	UTM 17			
Vertical Datum:	North American Vertical Datum of 1988 derived using Geoid 12B			
Units:	Meters			
Axis Geospatial Survey Points- RTN				
Pt#	Northing	Easting	Ortho Ht.	Code
30	4770748.075	728649.358	239.49	DISK ELBA1
31	4736695.509	735482.483	404.717	DISK WARSAW
32	4680298.283	740855.569	429.036	ROD Y 468
33	4693382.735	727116.487	645.3	DISK RUSHFORD
NGS Datasheet Values				
PID	Northing	Easting	Ortho Ht.	Name
AE 2166	4770748.083	728649.366	239.52	DISK ELBA1
AE 2172	4736695.512	735482.486	404.681	DISK WARSAW
NC0820	4680298.288	740855.566	429.039	ROD Y 468
NC0965	4693382.704	727116.507	645.3	DISK RUSHFORD
Comparison Matrix (RTN Dataset vs. NGS Published Data)				
	▲ Northing	▲ Easting	▲ Height	
30 VS. AE 2166	-0.008	-0.008	-0.034	
31 VS. AE 2172	-0.003	0.003	-0.016	
32 VS. NC0820	-0.005	0.003	-0.003	
33 VS. NC0965	0.031	-0.020	0.008	
	0.016	**0.010**	**0.016**	Std. Dev.
	0.031	**0.003**	**0.008**	Max.
	-0.008	**-0.020**	**-0.034**	Min.
	0.004	**-0.006**	**-0.011**	Average

Southwest 17 B LiDAR
UTM Zone 17, meters
Primary Control Values

Point Id	Northing	Easting	Ortho. Height	CQ 3D	CQ 2D	CQ 1D	SD North	SD East	SD Ortho. Height	Description
MAGS GC 01	4762101.487	720146.094	271.982	0.003	0.002	0.002	0.002	0.001	0.002	Mag nail set in asphalt
MAGS GC 02	4759630.454	737937.588	282.041	0.005	0.005	0.002	0.004	0.002	0.002	Mag nail set in asphalt
MAGS GC 03	4755589.299	748967.967	280.668	0.003	0.003	0.002	0.001	0.002	0.002	Mag nail set cor of stop bar
MAGS GC 04	4748944.521	729472.539	466.507	0.005	0.001	0.004	0.001	0.000	0.004	Mag nail set end of paint line
MAGS GC 05	4740529.623	744748.685	426.865	0.003	0.001	0.002	0.001	0.000	0.002	Mag nail set end of paint line
MAGS GC 06	4738738.906	716595.319	504.009	0.004	0.003	0.003	0.003	0.002	0.003	Mag nail set in asphalt
NS GC 7	4727728.019	707216.602	420.368	0.004	0.003	0.003	0.002	0.002	0.003	Nail set in gravel parking lot
MAGS GC 08	4727420.866	739532.119	430.830	0.002	0.002	0.001	0.002	0.001	0.001	Mag nail set end of paint line
MAGS GC 09	4722253.921	726732.050	584.322	0.002	0.001	0.001	0.001	0.001	0.001	Mag nail set in asphalt
MAGS GC 10	4711067.514	719377.622	608.174	0.003	0.002	0.002	0.001	0.001	0.002	Mag nail set in asphalt
MAGS GC 11	4710692.537	741853.139	352.311	0.002	0.001	0.001	0.001	0.001	0.001	Mag nail set in asphalt
MAGS GC 12	4701294.097	748856.533	508.649	0.003	0.002	0.002	0.002	0.000	0.002	Mag nail set in asphalt
MAGS GC 13	4700797.448	734127.360	365.637	0.002	0.001	0.001	0.001	0.001	0.001	Mag nail set end of paint line
INK X GC 14	4679520.892	725232.522	454.620	0.003	0.001	0.003	0.001	0.001	0.003	Ink X at corner of paint lines
MAGS GC 15	4664724.020	703374.711	429.179	0.008	0.005	0.005	0.005	0.002	0.005	Mag nail set end of paint line
MAGS GC 18	4661068.101	735186.829	501.093	0.004	0.002	0.003	0.002	0.001	0.003	Mag nail set cor of blue paint
MAGS GC 19	4683543.665	697012.268	502.948	0.002	0.001	0.002	0.001	0.001	0.002	Mag nail set in asphalt
DISK ELBA 1	4770748.080	728649.360	239.490	0.011	0.005	0.010	0.004	0.003	0.010	NYS DoT Disk
DISK WARSAW	4736695.510	735482.480	404.720	0.001	0.001	0.001	0.001	0.000	0.001	NYS DoT Disk; survey marker
ROD Y 468	4680298.280	740855.570	429.040	0.002	0.001	0.001	0.001	0.000	0.001	USC&GS Disk
DISK RUSHFORD	4693382.740	727116.490	645.310	0.003	0.002	0.002	0.002	0.000	0.002	USC&GS Disk