IL_LaSalle Expansion Counties QL2
Lidar 2017 Final Report

Report Produced for U.S. Geological Survey

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Overview

The primary purpose of this project was to develop a consistent and accurate surface elevation dataset derived from high-accuracy Light Detection and Ranging (LiDAR) technology for the USGS Il_LaSalle Expansion Counties QL2 Lidar 2017 project Area. Grundy, Kendall, and DeKalb Counties, Illinois will be referred to as Expansion Counties and are the focus of this report as one area of interest (AOI) from a lidar survey that was collected over two (2) areas of interest in Illinois identified as LaSalle and Expansion Counties. Expansion counties consisted of Grundy, Kendall, and DeKalb County, Illinois, covering approximately 1,388 square miles. Grundy, Kendall, and DeKalb County Counties are a QL2 project and the second AOI for this lidar survey. Acquisition of LiDAR was planned for and executed as a combined collection. LaSalle and Expansion Counties cover a total of approximately 2,563 square miles.

The LiDAR data was processed and classified according to project specifications. Detailed breaklines, bare earth Digital Elevation Models (DEMs), and Intensity Images were produced for the project area. Data was formatted according to tiles with each tile covering an area of 2,000 feet by 2000 feet. A total of 10097 LAS tiles, 10097 DEMs, and 10097 Intensity Images were produced for the project encompassing an area of approximately 1,338 square miles. Thirty LAS tiles in the LaSalle County Block 1 AOI contain flagged withheld points due to an isolated anomaly found in the lidar data. A Low Confidence polygon was use to circumscribe an area where lidar was reflected by particulates in smoke stack emission. Photons were unable to penetrate through the emissions for collection of ground surface within the polygon. The emission cloud obscures approximately 3.72 acres of ground surface. Tiles in which the emission cloud occurred are listed in Appendix B.

PROJECT TEAM

Aerial Services, Inc. (ASI) served as the prime contractor for the project. In addition to project management ASI was responsible for LiDAR acquisition and calibration, LAS classification, LiDAR products, Digital Elevation Model (DEM) production, Intensity Image production, and quality assurance. Subcontractor: GRW Aerial Surveys, Inc. Preformed; lidar classification, manually reviewed bare earth surface, and undertook hydro collection and hydro-flattened for DeKalb County lidar data. Subcontractor: Woolpert Preformed; lidar classification, manually reviewed bare earth surface, and undertook hydro collection and hydro-flattened for Kendall and Grundy County lidar data. All follow-on processing was completed by the prime.

GRW Aerial Surveys, Inc. completed ground surveying for the project and delivered surveyed checkpoints. GRW was to acquire surveyed checkpoints for the project to use in independent testing of the vertical accuracy of the LiDAR-derived surface model. Please see SURVEY REPORT to view the separate Survey Report that was created for this portion of the project.

SURVEY AREA

The project area addressed by this report falls within Grundy, Kendall, and DeKalb Counties, Illinois.

DATE OF SURVEY

LiDAR acquisition was conducted from November 19, 2017 to November 23, 2017, with one re-flight conducted April 12, 2018.

COORDINATE REFERENCE SYSTEM

Data produced for the project was delivered in the following reference system.

Horizontal Datum: The horizontal datum for the project is North American Datum of 1983 with the 2011 Adjustment (NAD 83 (2011)).

Vertical Datum: The Vertical datum for the project is North American Vertical Datum of 1988 (NAVD88).

Coordinate System: Illinois East State Plane (FIPS 1201)

Units: Horizontal units are in US Survey Feet, Vertical units are in US Survey feet.

Geoid Model: Geoid12B

LIDAR VERTICAL ACCURACY

For the IL_LaSalle QL2+ and Expansion Counties QL2 project, the tested RMSEz of the classified LiDAR data for checkpoints in non-vegetated terrain equaled 5.26 cm (0.173 ft), compared with the 10 cm (0.33 ft) specification: and the NVA of the classified LiDAR data computed using RMSEz x 1.96 was equal to 10.31 cm (0.338 ft), compared with the 19.6 cm (0.64 ft) specification.

For the IL_LaSalle QL2+ and Expansion Counties project, the tested VVA of the classified LiDAR data computed using the 95th percentile was equal to 27.21 cm (0.893 ft), compared with the 29.4 cm (0.96 ft) specification.

Additional accuracy information and statistics for the classified LiDAR data, raw swath data, and bare earth DEM data can be found in following sections of this report.

PROJECT DELIVERABLES

The deliverables for the project are listed below.

1. Raw Point Cloud Data (Swaths)
2. Classified Point Cloud Data (Tiled)
3. Bare Earth Surface (Raster DEM – IMG format)
4. Intensity Images (8-bit gray scale, tiled, GeoTIFF format)
5. Breakline Data (File DGB)
6. Independent Survey Checkpoint Data
7. Calibration Points
8. Metadata
9. Project Report (Acquisition, Processing, QC)
10. Project Extent (Included in DGB)

PROJECT TILING FOOTPRINT

Ten thousand ninety seven (10097) LAS tiles, Ten thousand ninety seven (10097) DEM tiles, and Ten thousand ninety seven (10097) Intensity Image tiles were delivered for the project 2 tiles contain a Low Confidence polygon. Each tile's extent is 2,000 feet by 2000 feet. (See Appendix A for a complete listing of delivered tiles and Appendix B for a list of tiles containing Low Confidence polygon.)

IL_LaSalle Expansion Counties QL2 LiDAR

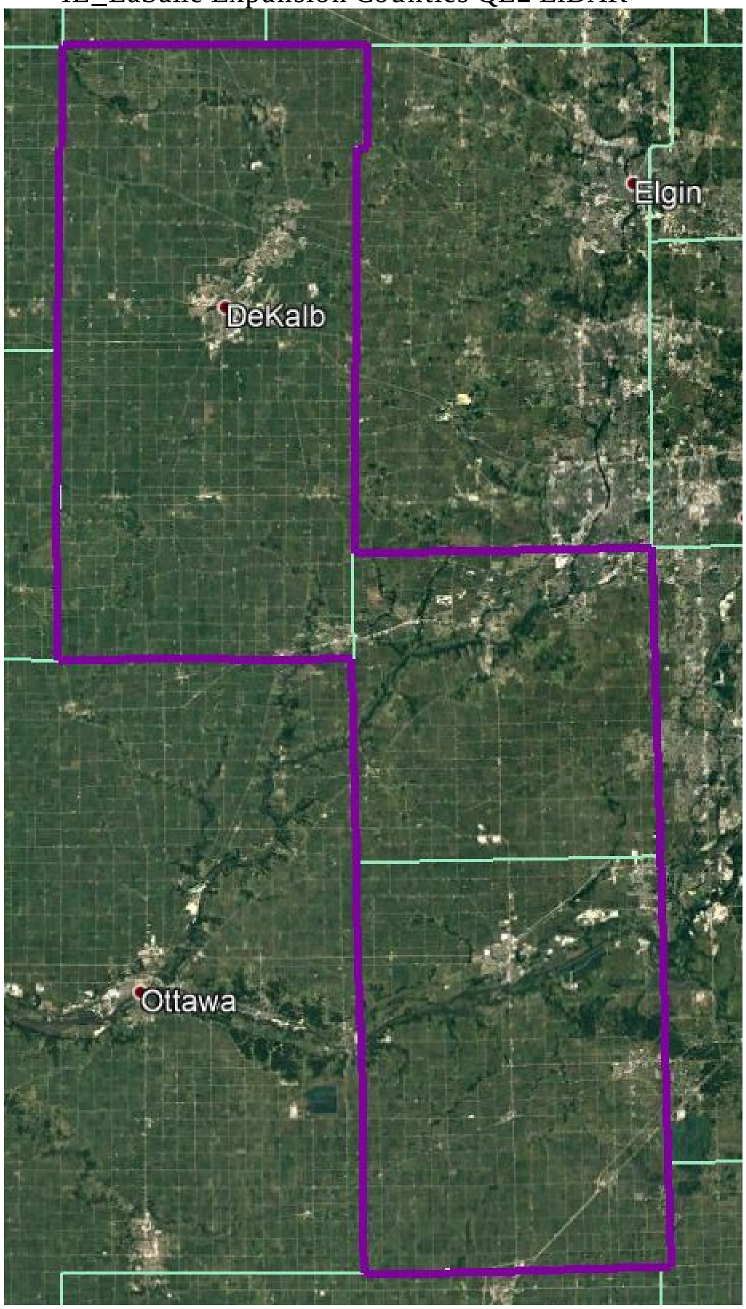

Figure 1 – Area of Interest

Lidar Acquisition Details

Aerial Services, Inc. served as prime contractor for the Il_LaSalle QL2+ and expansion counties QL2 project and preformed the LiDAR Acquisition and Calibration.

Aerial Services, Inc. planned 145 passes for the project area (70 lines for block 2), as well a series of cross flightlines for the purposes of quality control. The flight plan included zigzag flight line collection as a result of the inherent IMU drift associated with all IMU systems. In order to reduce any margin for error in the flight plan, Aerial Services, Inc. followed FEMA's Appendix A "guidelines" for flight planning and, at a minimum, includes the following criteria:

- A digital flight line layout using LEICA MISSION PRO flight design software for direct integration into the aircraft flight navigation system.
- Planned flight lines; flight line numbers; and coverage area.
- Lidar coverage extended by a predetermined margin beyond all project borders to ensure necessary over-edge coverage appropriate for specific task order deliverables.
- Local restrictions related to air space and any controlled areas have been investigated so that required permissions can be obtained in a timely manner with respect to schedule. Additionally, Aerial Services, Inc. will file our flight plans as required by local Air Traffic Control (ATC) prior to each mission.

Aerial Services, Inc. monitored weather and atmospheric conditions and conducted lidar missions only when no conditions exist below the sensor that will affect the collection of data. These conditions include leaf-off for hardwoods, no snow, rain, fog, smoke, mist and low clouds. Lidar systems are active sensors, not requiring light, thus missions may be conducted during night hours when weather restrictions do not prevent collection. Aerial Services, Inc. accesses reliable weather sites and indicators (webcams) to establish the highest probability for successful collection in order to position our sensor to maximize successful data acquisition.

Within 72-hours prior to the planned day(s) of acquisition, Aerial Services, Inc. closely monitored the weather, checking all sources for forecasts at least twice daily. As soon as weather conditions were conducive to acquisition, our aircraft mobilized to the project site to begin data collection. Once on site, the acquisition team took responsibility for weather analysis.

Aerial Services, Inc. lidar sensors are calibrated at a designated site located at the Waverly Municipal Airport in Waverly, Iowa and are periodically checked and adjusted to minimize corrections at project sites.

LIDAR SYSTEM PARAMETERS

Aerial Services, Inc. operated a Piper Navajo PA-31 (Tail # N35AS) outfitted with a LEICA ALS70-HP lidar system during the collection of the study area. Table 1 illustrates Aerial Services, Inc. system parameters for lidar acquisition on this project.

Item	Parameter
System	Leica ALS-70 HP
Maximum Number of Returns per Pulse	4
Nominal Pulse Spacing (single swath), (m)	0.5
Nominal Pulse Density (single swath) (ppsm), (m)	4
Aggregate NPS (m) (if ANPS was designed to be met through single coverage, ANPS and NPS will be equal)	0.5
Aggregate NPD (m) (if ANPD was designed to be met through single coverage, ANPD and NPD will be equal)	4
Altitude (AGL meters)	1100
Approx. Flight Speed (knots)	150
Total Sensor Scan Angle (degree)	50
Scan Frequency (hz)	47
Scanner Pulse Rate (kHz)	240
Did the Sensor Operate with Multiple Pulses in The Air? (yes/no)	Yes
Nominal Swath Width on the Ground (m)	1025
Swath Overlap (%)	30
Max. Point Spacing Along Track (m)	1.64
Max. Point Spacing Across Track (m)	0.56

Table 1: Aerial Services, Inc. Lidar System Parameters

ACQUISITION STATUS REPORT AND FLIGHTLINES

Upon notification to proceed, the flight crew loaded the flight plans and validated the flight parameters. The Acquisition Manager contacted air traffic control and coordinated flight pattern requirements. Lidar acquisition began immediately upon notification that control base stations were in place. During flight operations, the flight crew monitored weather and atmospheric conditions. Lidar missions were flown only when no condition existed below the sensor that would affect the collection of data. The pilot constantly monitored the aircraft course, position, pitch, roll, and yaw of the aircraft. The sensor operator monitored the sensor, the status of PDOPs, and performed the first Q/C review during acquisition. The flight crew constantly reviewed weather and cloud locations. Any flight lines impacted by unfavorable conditions were marked as invalid and re-flown immediately or at an optimal time.

Figure 2 shows the combined trajectory of the flightlines.

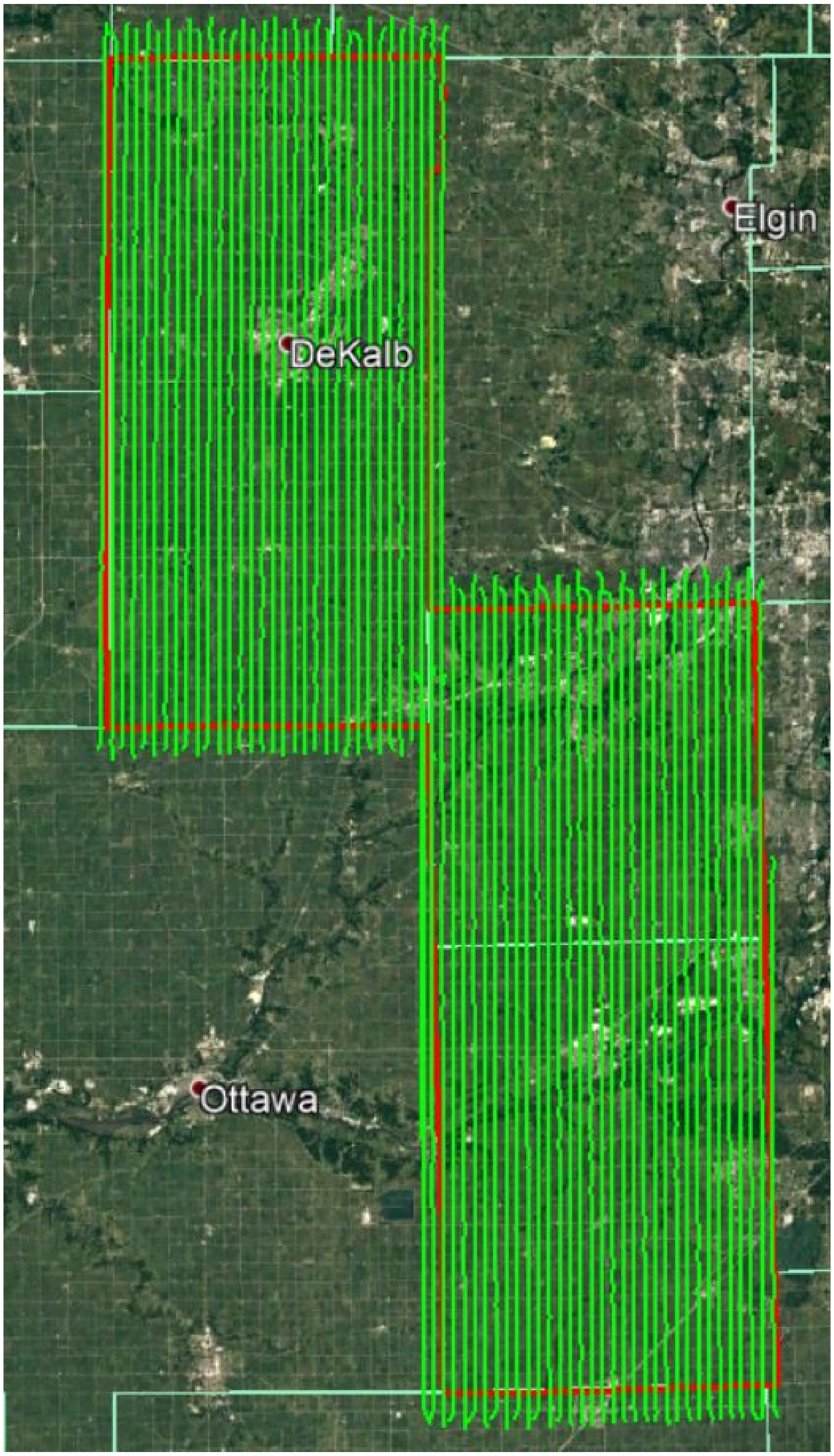

Figure 2: Trajectories as flown by Aerial Services, Inc.

ACQUISITION CONTROL

Aerial Services, Inc. conducted the survey which provided the established base stations used to control the lidar acquisition for the IL_LaSalle Expansion Counties project area. The coordinates of the base stations are provided in the table below.

Name	NAD83(2011) UTM 16		Ellipsoid Ht (WGS84, m)
	Easting X (m)	Northing Y (m)	
MF1786_Kalbport	415548.837	-884300.856	243.667
MF1801_Morport AZ MK	412530.444	-882517.270	140.283

Table 2 – Base station used to control lidar acquisition for the Project.

AIRBORNE GPS KINEMATIC

Airborne GPS data was processed using Waypoint's Inertial Explorer version 8.60 software suite. All flights were flown with PDOP less than or equal to 3.0 and with at least 6 satellites in common view of both a stationary reference receiver and the airborne GPS. Distances from base station to aircraft were kept to a maximum of 50 km.

For all flights, the GPS data can be classified as excellent, with GPS residuals no larger than 10 cm being recorded.

GPS processing reports for each mission are included in Appendix C.

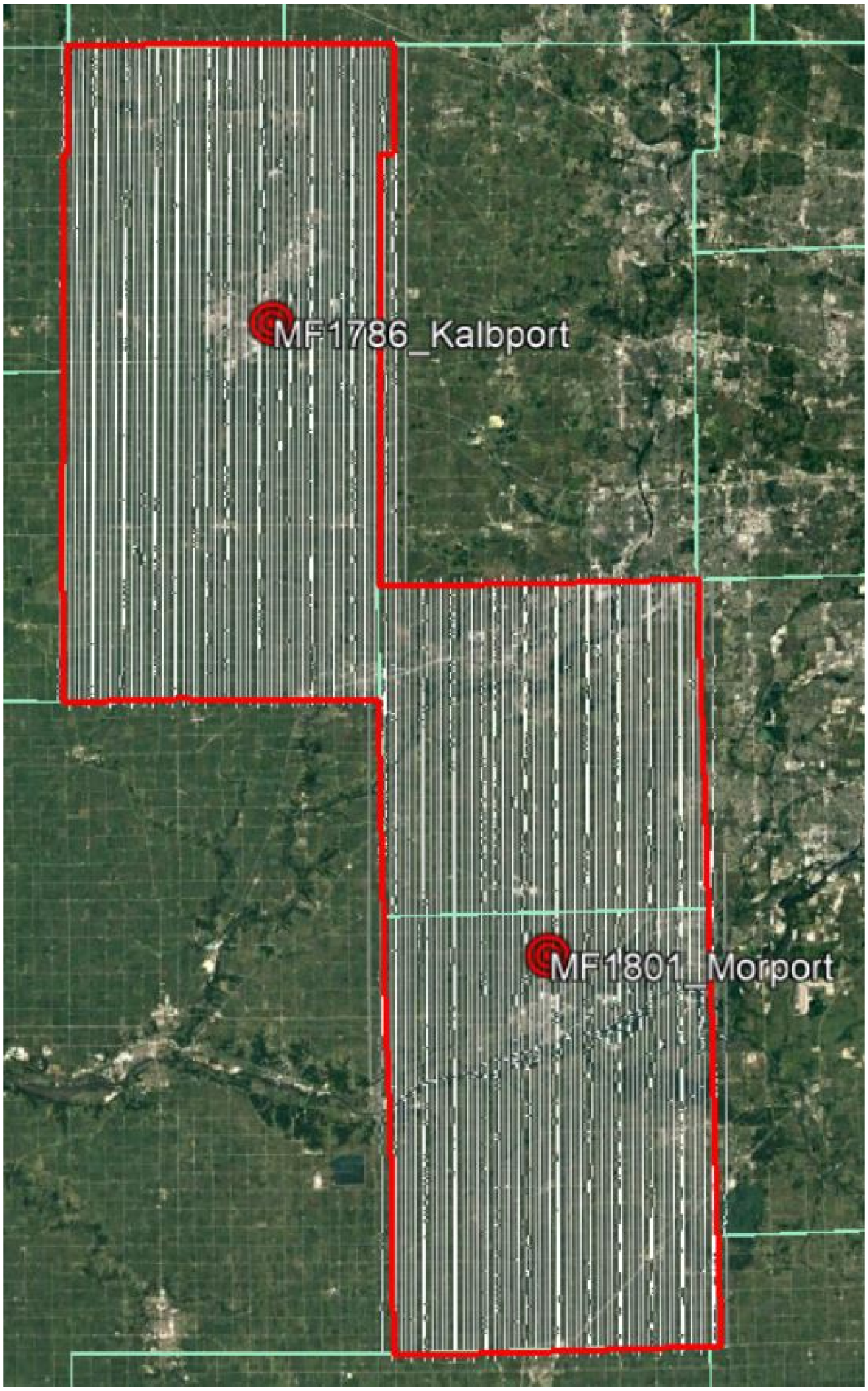

FIGURE 3 – IL_LASALLE EXPANSION COUNTIES PROJECT BASESTATIONS AND SWATHS

Generation and Calibration of Laser Points (raw data)

After processing the GNSS/GPS and IMU data in Inertial Explorer, the data is then exported to raw LAS files using Leica's CloudPro software. CloudPro combines the raw data collected with the ALS 70 HP sensor, combines it with the airborne trajectory data, applies the sensor's calculated boresite correction angles, and then outputs the point cloud to the specified coordinate reference system and file format.

The initial step of calibration is to verify the complete coverage of the AOI with the 100 meter buffer with no internal voids present, as well as ensuring that minimum point density of 2.0 ppsm has been achieved.

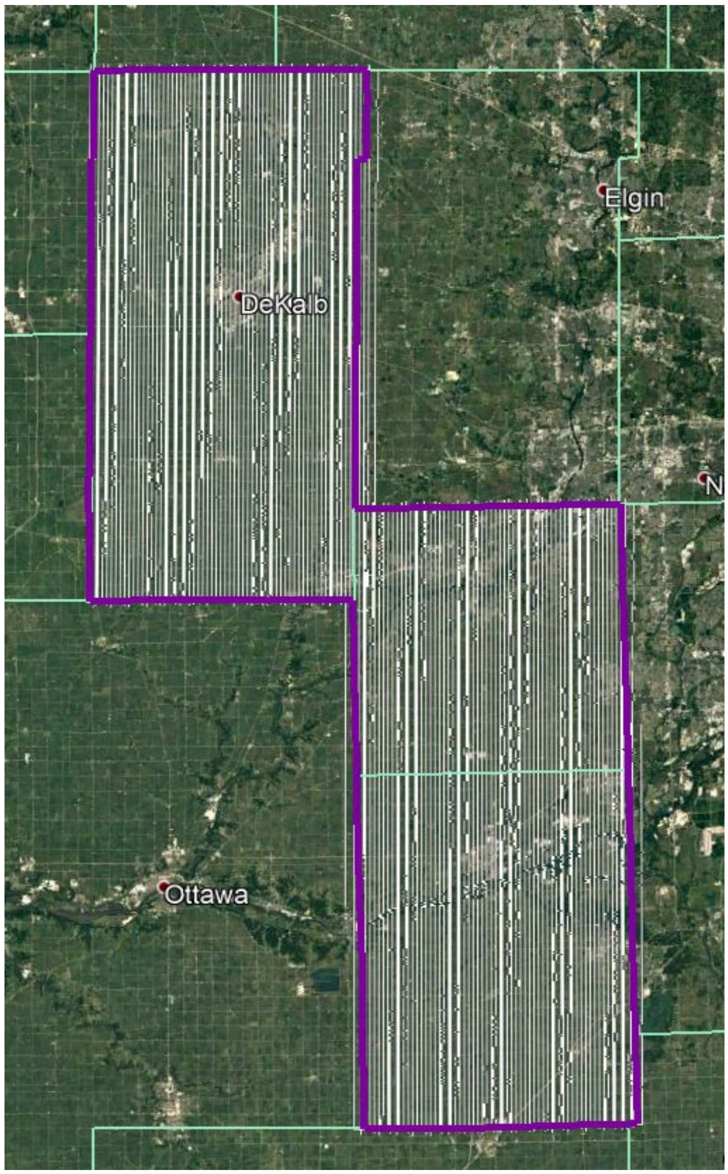

Figure 4 – Lidar swath coverage over Block 1.

Boresight and Relative accuracy

Subsequently, the project's data is then loaded into Microstation/TerraScan for viewing and post-processing of calibration errors. Roll, pitch, and heading corrections are calculated to produce the best relative accuracy that can be achieved, and at minimum 8 cm RMSDz with a 16 cm maximum difference. Tested interswath RMSDz was 4.511 cm.

The relative accuracy of every swath is checked and QC'd at 3 different points along its length. Cross sections are visually inspected across each block to validate point to point, flight line to flight line and mission to mission agreement to verify that the project meet the specifications.

For this project the specifications used are as follow
Relative accuracy <= 6 cm maximum differences within individual swaths and <=8 cm RMSDz between adjacent and overlapping swaths.

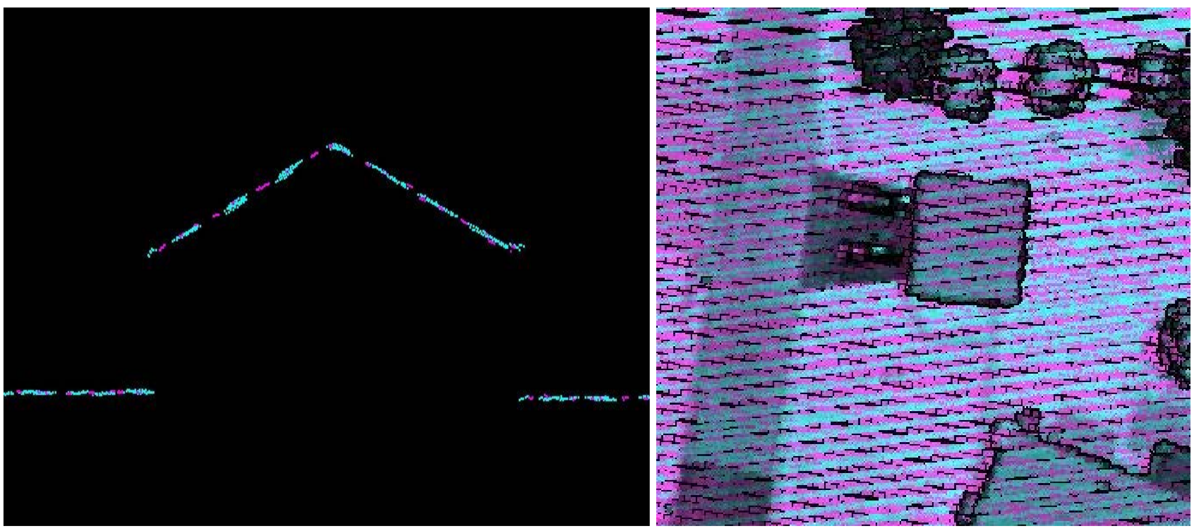

Figure 5 – Profile and top views showing proper interswath calibration.

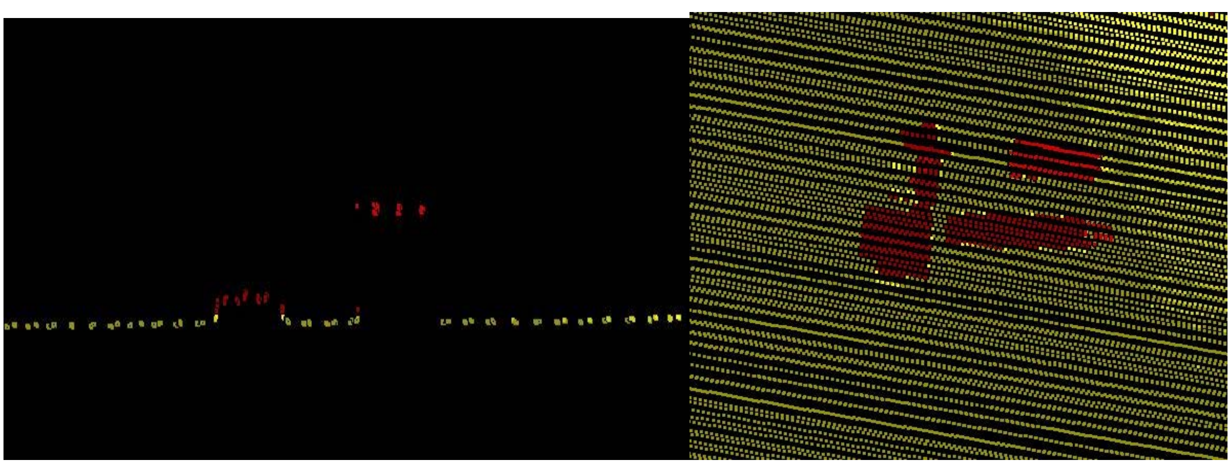

Figure 6 – Top view showing a parking lot with a car and raised feature on a single swath demonstrating intraswath accuracy. Yellow color is scaled to a range of 6 cm in elevation. Points are within 6 cm of variation until the raised curb and car. Also shown is a profile view showing low variability of ranges within the swath.

Final Calibration Verification

GRW Aerial Surveys, Inc. conducted the survey for 53 ground control points (GCPs) which 50 were used to test the accuracy of the calibrated swath data. These 50 GCPs were available to use as control in case the swath data exhibited any biases which would need to be adjusted or removed. The coordinates of all GCPs are provided in table 3 and the accuracy results from testing the calibrated swath data against the GCPs is provided in table 4; no further adjustments to the swath data were required based on the accuracy results of the GCPs. Accuracy of the raw point cloud against GCP: 0.187 ft (5.71 cm) with a 95% confidence value of 0.368 ft (11.21 cm).

Point ID	NAD83 (2011 adj) Illinois East State Plane		NAVD88 (Geoid 12B)		
	Easting X (USft)	Northing Y (USft)	Z-Survey (USft)	Z-LiDAR (USft)	Dz
ASI-01	757730.212	1807820.903	846.397	846.420	+0.023
ASI-02	771270.016	1703616.174	617.140	617.400	+0.260
ASI-03	760852.184	1622517.018	650.284	650.440	+0.156
ASI-04	782013.266	1749628.284	649.924	650.070	+0.146
ASI-05	796053.875	1711608.620	615.042	615.140	+0.098
ASI-06	824809.747	1712642.272	628.614	628.480	-0.134
ASI-07	792955.388	1600032.641	681.177	681.220	+0.043
ASI-08	814497.844	1563048.613	669.315	669.510	+0.195
ASI-09	819396.568	1653359.599	613.428	613.320	-0.108
ASI-10	803090.503	1788880.333	707.821	707.920	+0.099
ASI-11	843211.602	1632054.680	627.437	627.610	+0.173
ASI-12	835147.699	1752535.984	653.722	653.840	+0.118
ASI-13	820129.834	1807415.883	722.042	722.260	+0.218
ASI-14	856867.368	1808564.379	703.906	704.130	+0.224
ASI-15	885186.762	1808485.169	684.171	684.320	+0.149
ASI-16	902684.988	1808496.457	665.718	665.860	+0.142
ASI-17	870014.355	1776555.722	628.321	628.350	+0.029
ASI-18	911943.262	1755476.757	699.127	699.090	-0.037
ASI-19	892093.494	1738438.937	728.826	728.760	-0.066
ASI-20	781321.912	1672967.002	661.067	661.130	+0.063
ASI-21	867732.054	1722232.031	614.324	614.350	+0.026
ASI-22	898507.662	1693798.314	520.782	520.880	+0.098
ASI-23	860671.749	1675594.493	622.297	622.500	+0.203
ASI-24	882543.658	1643914.910	701.472	701.220	-0.252
ASI-25	914467.287	1617765.495	688.966	688.950	-0.016
ASI-26	822508.813	1993365.171	755.595	755.55	0.045
ASI-27	849440.35	1955347.391	885.394	885.28	0.114
ASI-28	886032.679	1998758.012	868.506	868.28	0.226
ASI-29	914996.932	1992877.372	836.251	836.23	0.021
ASI-30	840002.732	1917460.035	915.717	915.65	0.067
ASI-31	869991.298	1917267.368	878.308	878	0.308
ASI-32	900752.045	1908993.269	875.019	874.88	0.139
ASI-33	824467.265	1855978.083	925.275	925.12	0.155
ASI-34	881946.537	1858821.025	758.28	758.11	0.17

ASI-35	912078.465	1838603.761	720.277	720.16	0.117
ASI-36	891685.427	1948509.917	862.242	862.07	0.172
ASI-37	855237.782	1887821.903	865.654	866.32	-0.666
ASI-38	935534.993	1838706.566	679.713	679.41	0.303
ASI-39	956524.544	1824205.842	636.826	636.66	0.166
ASI-40	980458.368	1838663.502	636.074	636.17	-0.096
ASI-42	929794.218	1779428.264	739.37	739.34	0.03
ASI-43	965752.317	1764350.718	598.793	598.52	0.273
ASI-44	986786.093	1798969.71	640.781	640.85	-0.069
ASI-45	998452.996	1734697.582	617.653	617.33	0.323
ASI-46	941588.969	1707997.558	523.881	523.69	0.191
ASI-47	914260.898	1666768.744	669.775	669.940	+0.165
ASI-48	977244.603	1683300.093	552.447	552.43	0.017
ASI-49	1001676.039	1624962.652	601.363	601.14	0.223
ASI-50	962019.264	1623713	619.812	619.5	0.312
ASI-51	950101.111	1665672.877	600.688	600.51	0.178

Table 3 – IL_LaSalle and Expansion Counties Project surveyed ground control points (GCPs).

This project must meet Non-vegetated Vertical Accuracy (NVA) ≤ 0.64 ft (19.6 cm) at the 95% confidence level based on $RMSE_z$ ≤ 0.33 ft (10 cm) x 1.9600.

100 % of Totals	# of Points	RMSEz NVA (m)	NVA- Non-vegetated Vertical Accuracy ((RMSEz x 1.9600) m	Mean (m)	Median (m)	Skew	Std Dev (m)	Min (m)	Max (m)	Kurtosis
GCP	50	0.057	0.112	0.028	-0.036	-0.632	0.050	-0.203	0.098	2.399

Table 4 - Ground control points (GCPs) vertical accuracy results.

DATA CLASSIFICATION AND EDITING

Once the calibration, absolute swath vertical accuracy, and relative accuracy of the data were confirmed, ASI utilized TerraScan software for data processing. The acquired 3D laser point clouds, in LAS binary format, were imported into the project and tiled according to the project tile grid. Once tiled, the laser points were classified using a proprietary routine in TerraScan. This routine classifies any obvious low outliers in the dataset to class 7 and high outliers in the dataset to class 18. After points that could negatively affect the ground are removed from class 1, the ground layer is extracted from this remaining point cloud. The ground extraction process encompassed in this routine takes place by building an iterative surface model. This surface model is generated using three main parameters: building size, iteration angle and iteration distance. The initial model is based on low points being selected by a "roaming window" with the assumption that these are the ground points. The size of this roaming window is determined by the building size parameter. The low points are triangulated and the remaining points are evaluated and subsequently added to the model if they meet the iteration angle and distance constraints. This process is repeated until no additional points are added within iterations. A second critical parameter is the maximum terrain angle constraint, which determines the maximum terrain angle allowed within the classification model. Once the ground surface had been deduced through the filtering process the LAS are ready editing

In TerraScan surface models for each tile was created to examine the ground classification. ASI analysts visually reviewed the ground surface model for artifacts left in the ground classification. Theses artifacts consist of vegetation, buildings, and bridges that were still present in the ground after initial processing. ASI analysts employ 3D visualization techniques to view the point cloud at multiple angles and in profile to ensure that errant points are removed from the ground classification. Bridge decks are manually classified to class 17. After the ground classification and corrections are completed, the dataset was processed through a water classification routine that utilizes breaklines, compiled by subcontractors GRW and Woolpert, to automatically classify class code 2 ground points within hydro features to class code 9 water. The water classification routine selects ground points within the breakline polygons and automatically classifies them as class 9, water. During this water classification routine, ground points that are within 2x NPS or less of the hydrographic features are moved to class 10 ignored ground, due to breakline proximity. Overage points are then identified in TerraScan and used to set the overlap bit for those points. The withheld points identified during the classification routine are used to set the withheld bit. The LiDAR tiles were classified to the following classification schema:

- Class 1 – Default, Processed, but unclassified
- Class 2 – Ground, Bare-earth
- Class 7 – Low Noise (low and manually identified)
- Class 9 – Water
- Class 10 – Ignored Ground (Breakline Proximity)
- Class 17 – Bridge Decks
- Class 18 – High Noise (high, manually identified)

After manual classification, the LAS tiles were peer reviewed and then underwent a final QA/QC. After the final QA/QC and corrections, the LAS files were then converted from LAS v1.2 to LAS v1.4 using TerraScan software to flag the overlap bit and withheld bit. LP360 64bit was used to deduce the Well Known Text (WKT) and a ASI proprietary software was used to format the LAS to the final LAS v1.4 Format 6 version. LP360 and ASI's proprietary software was used to perform final analysis of point classes, densities, and LAS header information checks.

LiDAR Qualitative Assessment

ASI's qualitative assessment utilizes a combination of statistical analysis and interpretative methodology or visualization to assess the quality of the data for a bare-earth digital terrain model (DTM). This includes creating pseudo image products such as LiDAR orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-

dimensional models as well as reviewing the actual point cloud data. Bare earth DEMs for this area of interest were produced by ASI. During DEM production ASI looks for anomalies in the data; such areas where man-made structures or vegetation points may not have been classified properly to produce a clean bare-earth model, or other ground classification errors. This report will present representative examples where the LiDAR and post processing had issues as well as examples of where the LiDAR performed well.

VISUAL REVIEW

The following sections describe common types of issues identified in LiDAR data and the results of the visual review for IL_LaSalle Expansion Counties project.

Data Voids

Acceptable voids (areas with no LiDAR returns in the LAS files) that are present in the majority of LiDAR projects include voids caused by bodies of water. No unacceptable voids are present in the IL_LaSalle Expansion Counties project. A Low Confidence polygon was use to circumscribe an area where lidar was reflected by particulates in smoke stack emission. Photons were unable to penetrate through the emissions for collection of ground surface within the polygon. The emission cloud obscures approximately 3.72 acres of ground surface. Tiles in which the emission cloud occurred are listed in Appendix B. Below is an example of an emission cloud found in the lidar data.

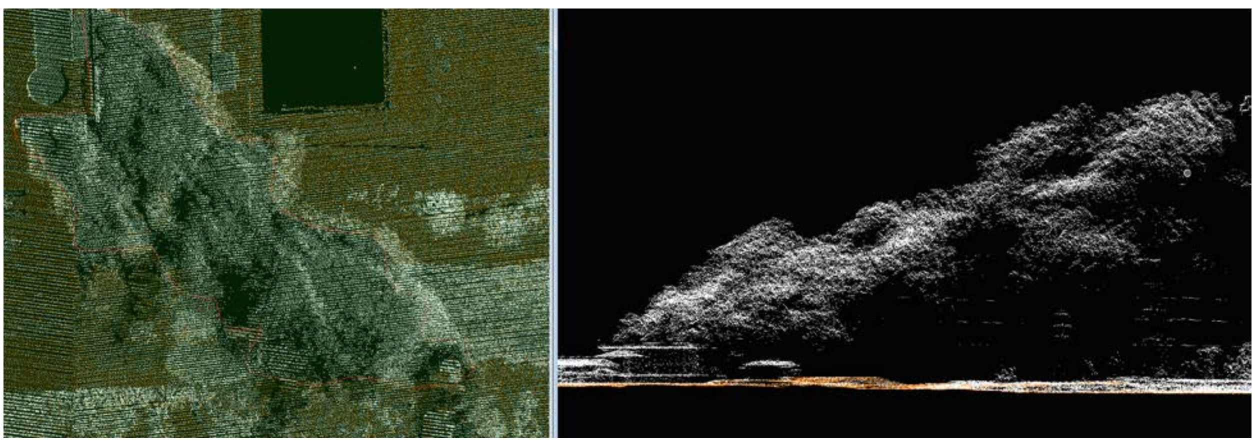

Figure 7: Left image is a Top view of emission cloud. Right image is a Profile view of emission cloud that obscures underling ground surface.

Bridge Removal Artifacts

The DEM surface models are created from TINs or Terrains. TIN and Terrain models create continuous surfaces from the inputs. Because a continuous surface is being created, the TIN or Terrain will use interpolation to continue the surface beneath the bridge where no LiDAR data was acquired. Locations where bridges were removed will generally contain less detail in the bare-earth surface because these areas are interpolated. The DEM in the bottom view shows an area where a bridge has been removed from ground. The surface model must make a continuous model and in order to do so, points are connected through interpolation. This results in less detail where the surface must be interpolated. The profile in the top view shows the LiDAR points of this particular feature colored by class. All bridge points have been removed from ground (orange) and are bridge deck (blue).

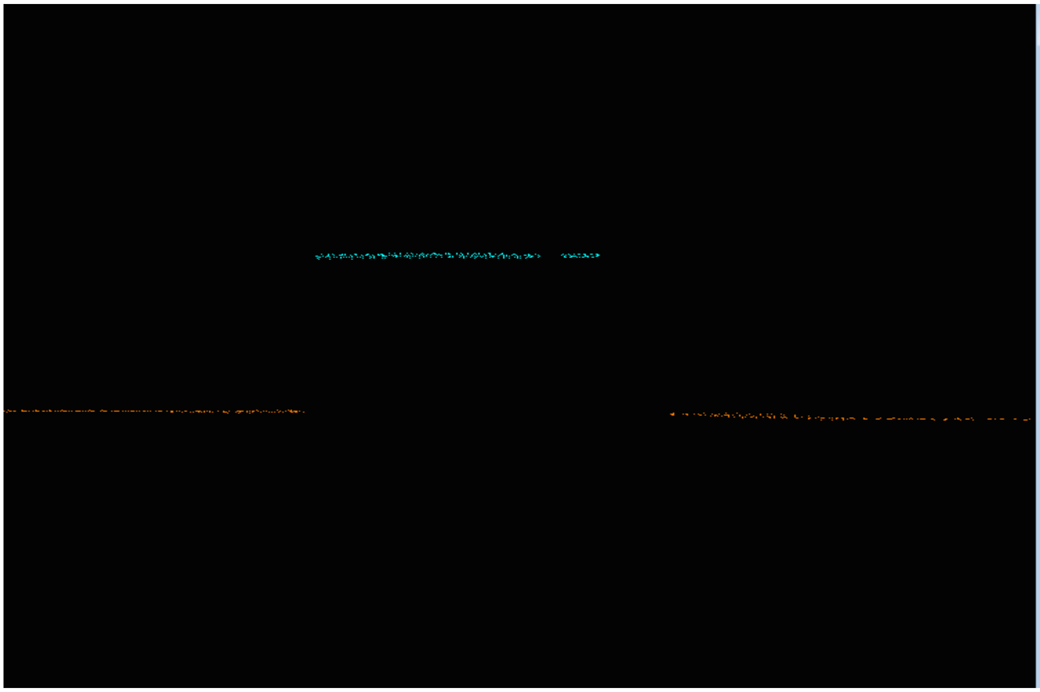

Figure 8: Profile view of a classified bridge deck (blue) and ground (orange).

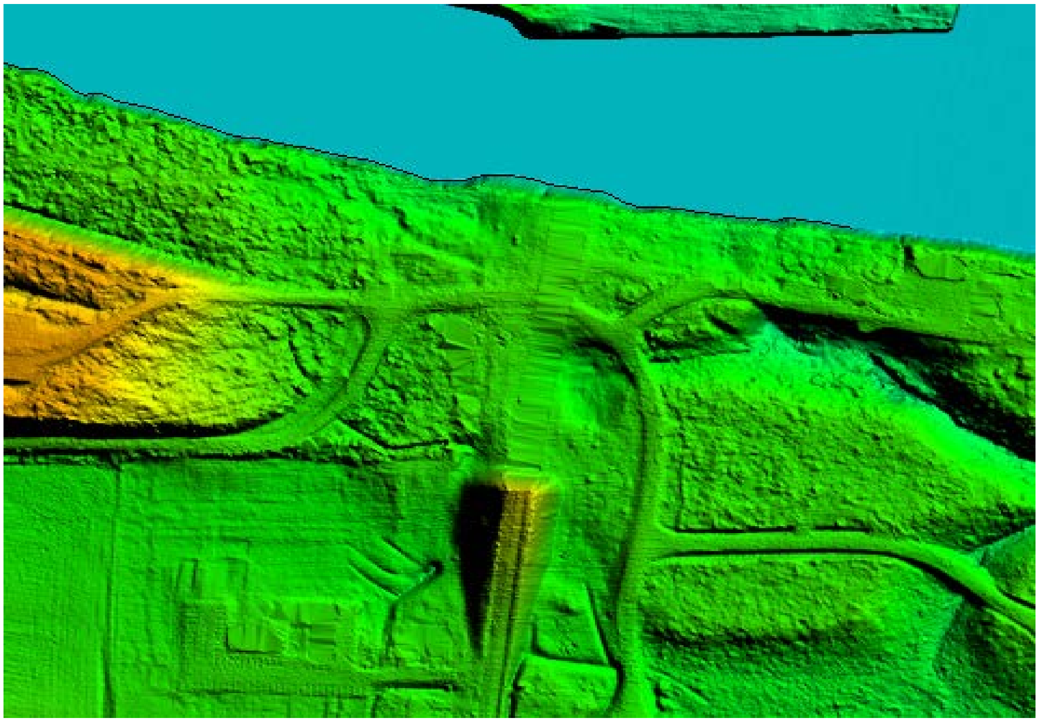

Figure 9: DEM with bridge removed from surface model.

Culverts

Bridges have been removed from the bare earth surface while culverts remain in the bare earth surface. In instances where it is difficult to determine if the feature is a culvert or bridge, such as with some small bridges, ASI erred on assuming they would be culverts especially if they are on secondary or tertiary roads. Below is an example of a culvert that has been left in the ground surface.

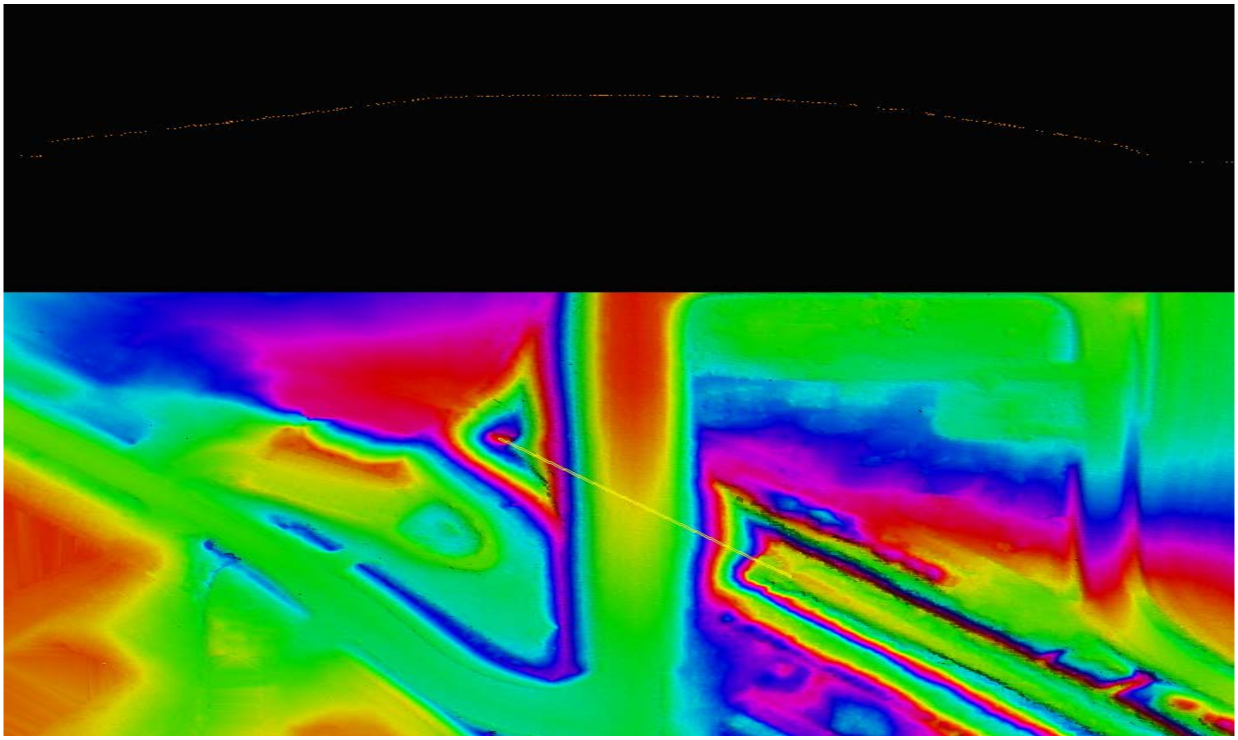

Figure 10: Profile with points colored by class (class 1=white, class 2=orange, model key point=red) is shown in the top view and the DEM is shown in the bottom view. This culvert remains in the bare earth surface. Bridges have been removed from the bare earth surface and classified to class 17.

Dirt Mounds

Irregularities in the natural ground exist and may be misinterpreted as artifacts that should be removed. Hills and dirt mounds are present throughout the project area. These features are correctly included in the ground.

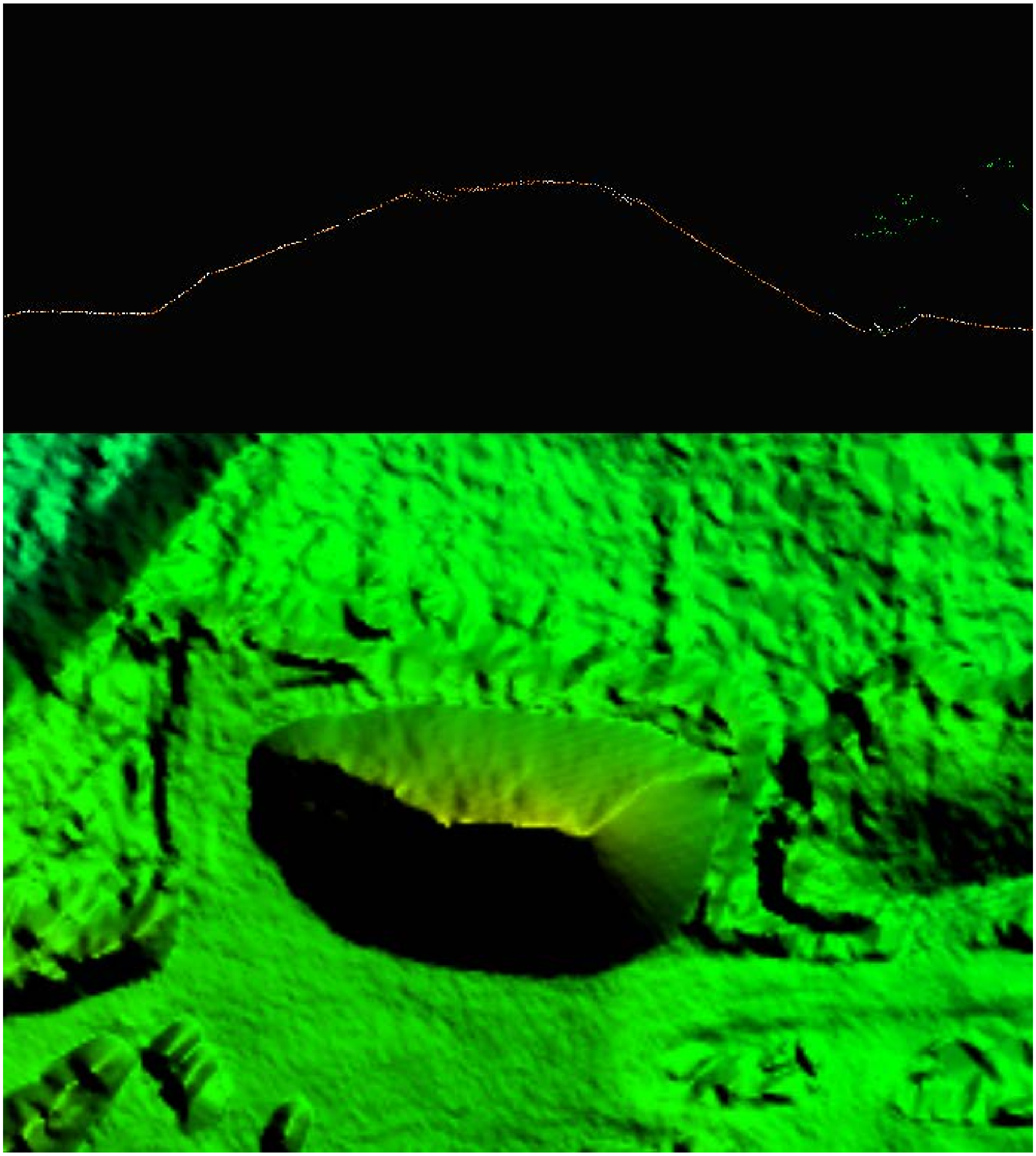

Figure 11 - Profile with the points colored by class (unclassified points are white, ground points are orange) is shown on the right and a DEM of the surface is shown to the left. These features are correctly included in the ground classification.

Flightline Ridges

Ridges occur when there is a difference between the elevations of adjoining flight lines or swaths. Some flightline ridges are visible in the final DEMs but they do not exceed the project specifications and the overall relative accuracy requirements for the project area have been met. An example of a visible flightline ridge that is within tolerance is shown below.

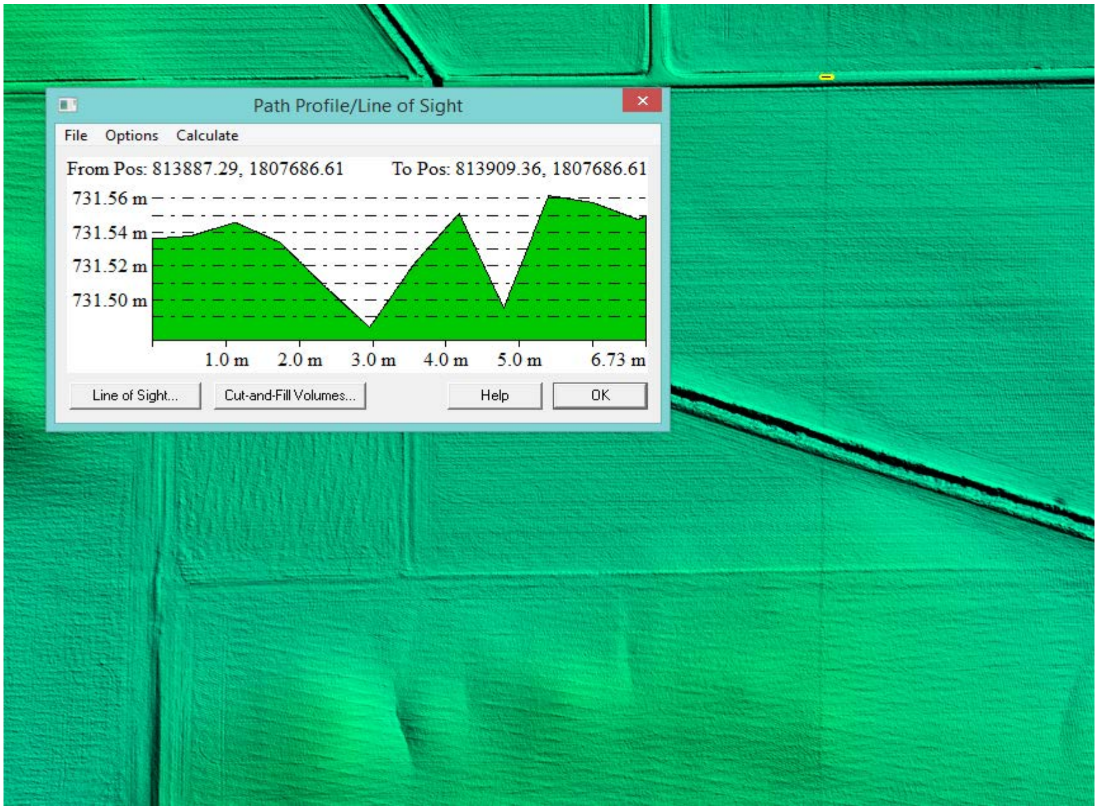

Figure 12 – The flight line ridge is less than 8 cm. Overall, the IL_LaSalle Expansion Counties project data meets the project specifications for 8 cm RMSDz relative accuracy requirement.

Dam and Lock system

Irregularities in the natural water flow exist in sections of river affected by Lock and Dam systems. Series of locks enable vessels to "step" up or down a river or canal from one water level to another. There is a Dam and Lock systems in the IL LaSalle Expansion Counties Lidar project area.

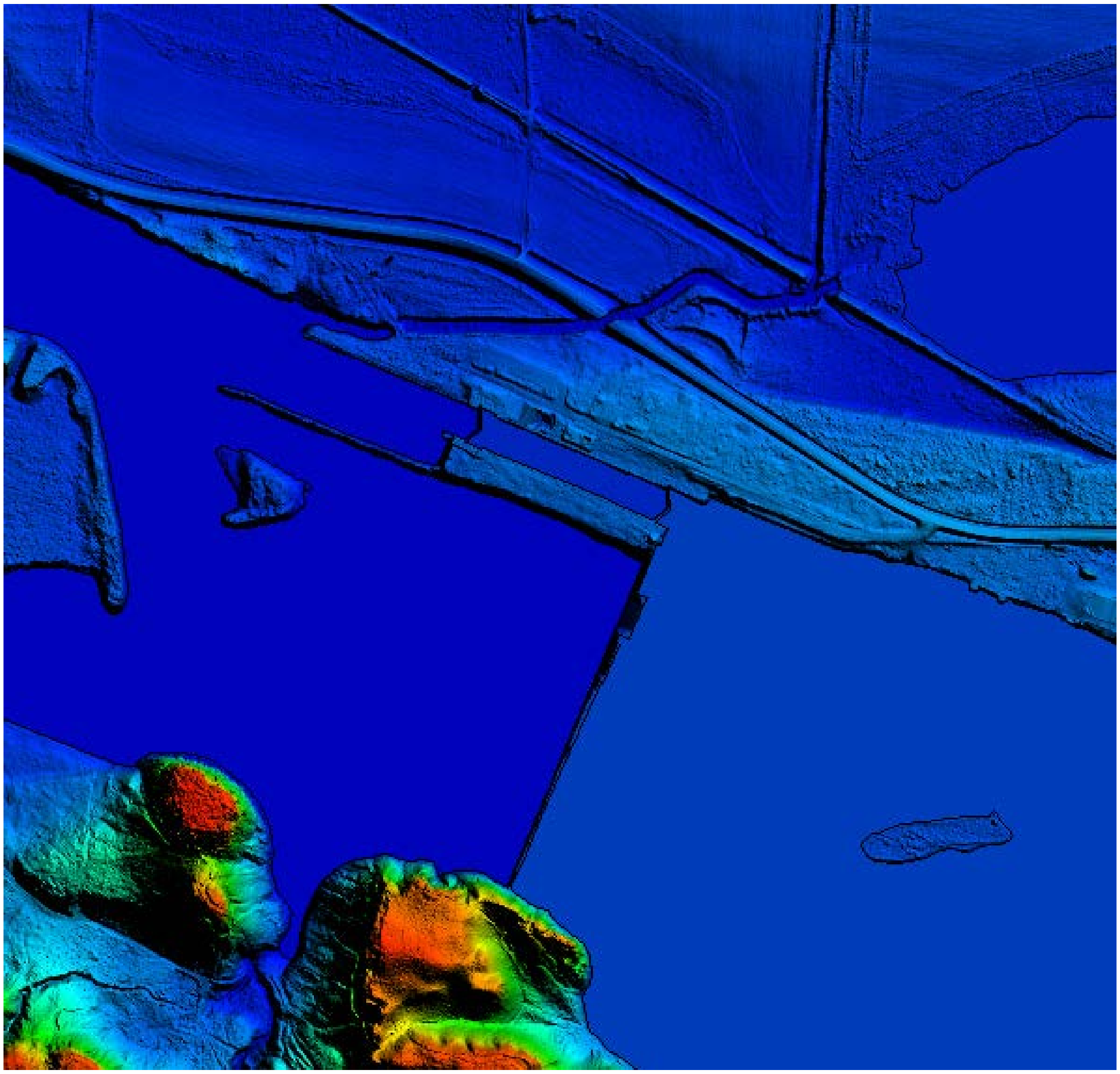

Figure 13 – DEM shows Large Dam structure that disrupts natural monotonic river flow, coupled with a lock system.

FORMATTING

After the final QA/QC is performed and all corrections have been applied to the dataset, all LiDAR files are updated to the final format requirements and the final formatting, header information, point data records, and variable length records are verified using ASI proprietary tools. ASI routinely reviews for: proper LAS versions, Coordinate Reference System, Global Encoder Bit, Time Stamp, System ID, Multiple Returns, Intensity, Classification, Overlap and Withheld Points, Scan angle, XYZ Coordinates.

LiDAR Positional Accuracy

BACKGROUND

ASI quantitatively tested the dataset by testing the vertical accuracy of the LiDAR. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest LiDAR points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the LiDAR data is actually tested. However there is an increased level of confidence with LiDAR data due to the relative accuracy. This relative accuracy in turn is based on how well one LiDAR point "fits" in comparison to the next contiguous LiDAR measurement, and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. ASI also tests the horizontal accuracy of LiDAR datasets when checkpoints are photo-identifiable in the intensity imagery. Photo-identifiable checkpoints in intensity imagery typically include checkpoints located at the ends of paint stripes on concrete or asphalt surfaces or checkpoints located at 90 degree corners of different reflectivity, e.g. a sidewalk corner adjoining a grass surface. The XY coordinates of checkpoints, as defined in the intensity imagery, are compared to surveyed XY coordinates for each photo-identifiable checkpoint. These differences are used to compute the tested horizontal accuracy of the LiDAR. As not all projects contain photo-identifiable checkpoints, the horizontal accuracy of the LiDAR cannot always be tested.

SURVEY VERTICAL ACCURACY CHECKPOINTS

For the vertical accuracy assessment of IL_LaSalle and Expansion Counties project, one hundred fifty seven check points were surveyed. Eighty nine of those check points are located within bare earth/open terrain (89 NVA points). Sixty eight check points are located within grass/weeds/crops, brush/low trees, and forested/fully grown land cover categories (68 VVA points). Please see provided survey report which details and validates how the survey was completed for this project. Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the “dispersed method” of placement. All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table.

Point ID	NAD83 (2011) State Plane IL East	NAD83 (2011) State Plane IL East	NAVD88 (Geoid12B)
	Easting (USft)	Northing (USft)	Elevation (USft)
NVA_1001	840236.350	1996834.296	784.200
NVA_1002	863101.811	1983890.357	823.531
NVA_1003	899179.112	1993415.028	843.475
NVA_1004	905740.596	1966970.333	877.569
NVA_1005	883287.669	1949241.763	845.418
NVA_1006	844824.851	1958067.933	887.183
NVA_1007	825592.751	1940731.975	887.392
NVA_1008	864650.620	1930717.275	878.556
NVA_1009	895775.825	1929746.196	842.207
NVA_1010	884973.220	1912524.936	903.681
NVA_1011	839390.326	1915623.258	916.882
NVA_1012	823023.544	1892652.938	947.756
NVA_1013	862813.458	1887886.877	887.643
NVA_1014	897937.295	1893312.358	826.770
NVA_1015	849328.586	1872908.420	886.223
NVA_1016	884486.365	1876065.054	787.400
NVA_1017	822663.719	1850754.931	936.752
NVA_1018	902977.014	1851023.398	732.034
NVA_1019	864397.451	1840130.654	735.153
NVA_1020	830462.803	1817644.276	730.287
NVA_1021	889404.339	1820039.382	695.228
NVA_1022	924321.518	1823858.206	661.758
NVA_1023	954747.826	1835995.232	661.245
NVA_1024	1000298.781	1832294.652	730.812
NVA_1025	761423.742	1805500.263	887.602
NVA_1026	814888.231	1797109.657	711.795
NVA_1027	863622.535	1797852.941	684.081
NVA_1028	913346.389	1800457.644	643.801
NVA_1029	948883.688	1799455.822	792.943
NVA_1030	982780.918	1810411.041	753.897
NVA_1031	995979.698	1788966.480	621.208
NVA_1032	966831.276	1777605.602	627.201
NVA_1033	934148.819	1774147.616	726.689
NVA_1034	890397.924	1776948.092	584.222
NVA_1035	845150.619	1770614.982	666.449

NVA_1036	803328.746	1770927.634	689.179
NVA_1037	765713.788	1766066.429	713.850
NVA_1038	789318.627	1750182.887	665.106
NVA_1039	828087.764	1749762.577	650.741
NVA_1040	887448.607	1747618.683	610.141
NVA_1041	922440.255	1750322.181	693.176
NVA_1042	956832.974	1753406.325	635.457
NVA_1043	999923.715	1754134.940	639.580
NVA_1044	766985.955	1728972.881	663.109
NVA_1045	805940.340	1728627.218	621.945
NVA_1046	859375.259	1723904.213	605.631
NVA_1047	901955.070	1723322.464	698.768
NVA_1048	943877.345	1729222.597	582.448
NVA_1049	985533.404	1730233.390	531.345
NVA_1050	776233.423	1708736.228	620.482
NVA_1051	814539.569	1707451.812	618.700
NVA_1052	856946.347	1703218.934	483.010
NVA_1053	882633.389	1703407.374	690.437
NVA_1054	923128.969	1704198.118	607.089
NVA_1055	959602.899	1701838.117	511.675
NVA_1056	1001515.285	1703040.927	530.686
NVA_1057	759695.114	1682535.888	656.701
NVA_1058	798450.787	1686248.259	640.339
NVA_1059	846925.139	1685446.009	603.429
NVA_1060	909851.885	1684555.932	602.057
NVA_1061	943206.107	1681489.507	615.195
NVA_1062	993743.394	1680239.863	566.207
NVA_1063	1004586.580	1660918.976	582.059
NVA_1064	966027.301	1658505.732	582.412
NVA_1065	937754.728	1657526.100	633.013
NVA_1066	877172.208	1669370.104	678.105
NVA_1067	816774.066	1667849.759	661.926
NVA_1068	779718.858	1665024.011	671.332
NVA_1069	761092.842	1643658.114	733.827
NVA_1070	806883.092	1643812.261	665.020
NVA_1071	850860.294	1654477.991	674.308
NVA_1072	903780.479	1646101.938	679.719
NVA_1073	940869.481	1634905.156	636.629
NVA_1074	1001525.468	1630242.065	596.002
NVA_1075	783813.562	1630553.559	706.139
NVA_1076	838409.130	1625651.179	626.511

NVA_1077	881823.382	1622493.246	715.932
NVA_1078	914542.290	1622294.818	659.791
NVA_1079	812379.231	1609610.070	666.758
NVA_1080	786179.251	1595701.533	688.731
NVA_1081	814136.681	1583981.956	661.254
NVA_1082	797830.876	1562870.073	694.289
NVA_1083	962514.637	1619968.884	626.449
NVA_1084	862055.364	1819081.330	735.684
NVA_1085	863732.667	1912575.455	876.599
NVA_1086	909928.949	1908113.081	855.545
NVA_1087	867633.755	1859907.585	800.543
NVA_1088	834654.245	1711659.987	610.770
NVA_1089	822279.238	1980118.695	777.893
VA_2001	838562.327	1977358.018	773.710
VA_2002	905809.582	1969606.163	875.979
VA_2003	825577.832	1939164.454	893.301
VA_2004	877264.296	1934169.436	829.985
VA_2005	853909.470	1910648.209	885.570
VA_2006	892257.095	1898911.981	875.480
VA_2007	844152.053	1888190.538	875.995
VA_2008	875212.315	1880790.005	847.629
VA_2009	838502.636	1855853.977	891.158
VA_2010	897159.097	1857618.694	738.699
VA_2011	840896.877	1823417.156	724.429
VA_2012	901200.452	1830396.006	709.175
VA_2013	923660.983	1829580.411	662.497
VA_2014	956168.756	1821864.779	629.293
VA_2015	989404.592	1831205.685	653.933
VA_2016	769377.356	1794658.868	843.783
VA_2017	821380.752	1791882.244	695.910
VA_2018	887769.697	1791631.526	654.493
VA_2019	947847.942	1797977.893	788.599
VA_2020	1002188.483	1798530.044	625.305
VA_2021	785261.358	1766096.361	689.689
VA_2022	858922.953	1764615.659	642.128
VA_2023	893171.570	1763175.920	619.103
VA_2024	952234.494	1769214.382	669.312
VA_2025	992344.829	1759583.867	572.904
VA_2026	773373.673	1734365.536	659.229
VA_2027	830746.201	1741722.262	627.961
VA_2028	877214.043	1736588.205	588.170

VA_2029	931934.198	1747656.374	653.748
VA_2030	985481.179	1735582.084	552.274
VA_2031	764100.035	1705160.408	637.683
VA_2032	816687.758	1707290.703	620.804
VA_2033	883582.825	1704226.072	680.784
VA_2034	943253.735	1697381.487	528.546
VA_2035	1002677.675	1716470.295	507.302
VA_2036	993518.816	1692758.004	554.442
VA_2037	784727.927	1685173.388	633.379
VA_2038	836682.430	1691410.101	593.843
VA_2039	895342.231	1680645.694	684.701
VA_2040	952382.488	1678353.078	572.086
VA_2041	976572.221	1677291.401	551.952
VA_2042	764012.442	1673275.943	659.483
VA_2043	815454.657	1655566.236	623.742
VA_2044	871861.800	1671512.591	641.929
VA_2045	891939.008	1654554.774	718.182
VA_2046	937686.436	1665487.466	621.777
VA_2047	997357.158	1656676.018	568.967
VA_2048	779570.797	1649145.671	675.151
VA_2049	852146.705	1638456.920	628.247
VA_2050	903801.256	1638936.976	667.439
VA_2051	961035.684	1652522.786	583.321
VA_2052	1002740.287	1633026.745	591.304
VA_2053	835248.954	1627365.949	610.293
VA_2054	946223.811	1623117.692	627.475
VA_2055	778596.720	1627711.572	676.713
VA_2056	814080.170	1600155.324	652.129
VA_2057	788715.293	1598558.656	686.431
VA_2058	796798.163	1584078.856	677.188
VA_2059	814121.820	1578179.247	649.782
VA_2060	789291.172	1562646.051	727.613
VA_2061	803857.391	1552331.926	693.469
VA_2062	875306.190	1982512.570	798.410
VA_2063	862027.007	1952148.897	873.192
VA_2064	862040.355	1993094.759	846.292
VA_2065	899150.787	1924362.318	840.250
VA_2066	845024.517	1932795.483	874.523
VA_2067	864158.776	1846333.808	772.855
VA_2068	856907.349	1805487.127	688.370

Table 5 – LaSalle and Expansion Counties project LiDAR Checkpoints.

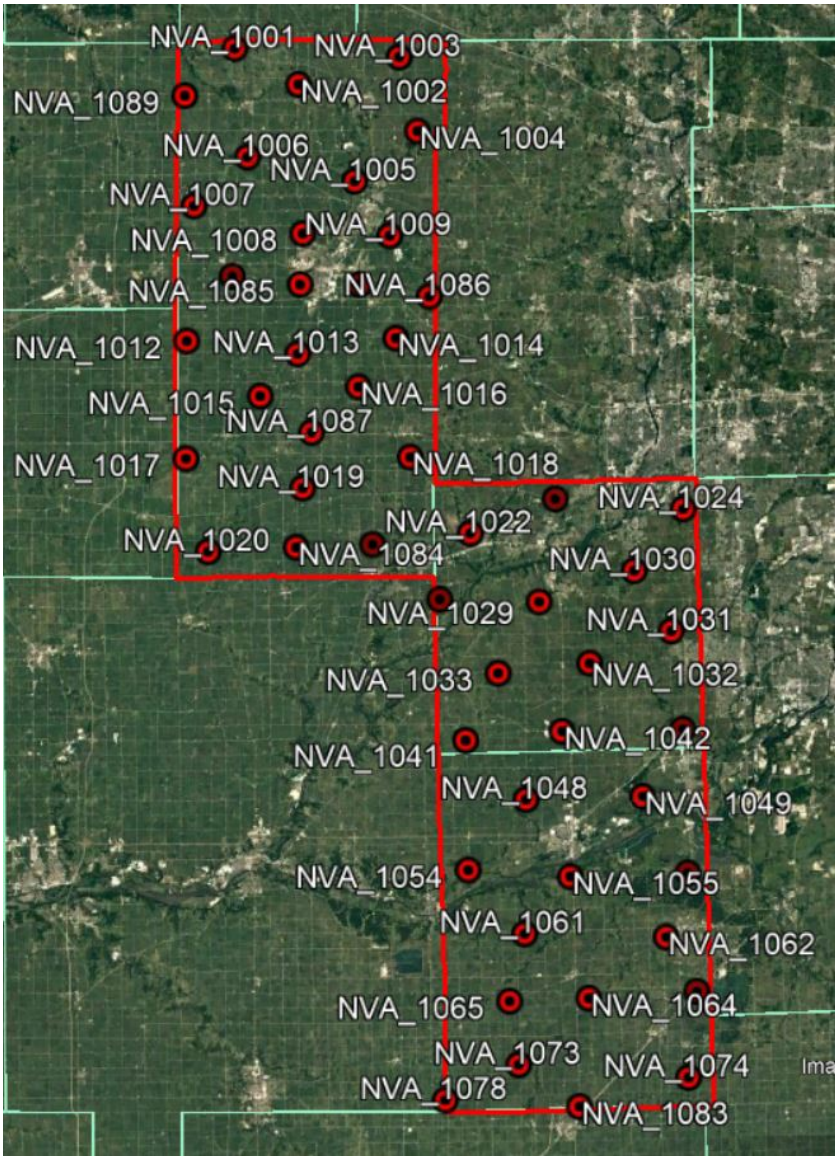

Figure 14a – Location of Expansion Counties NVA Checkpoints

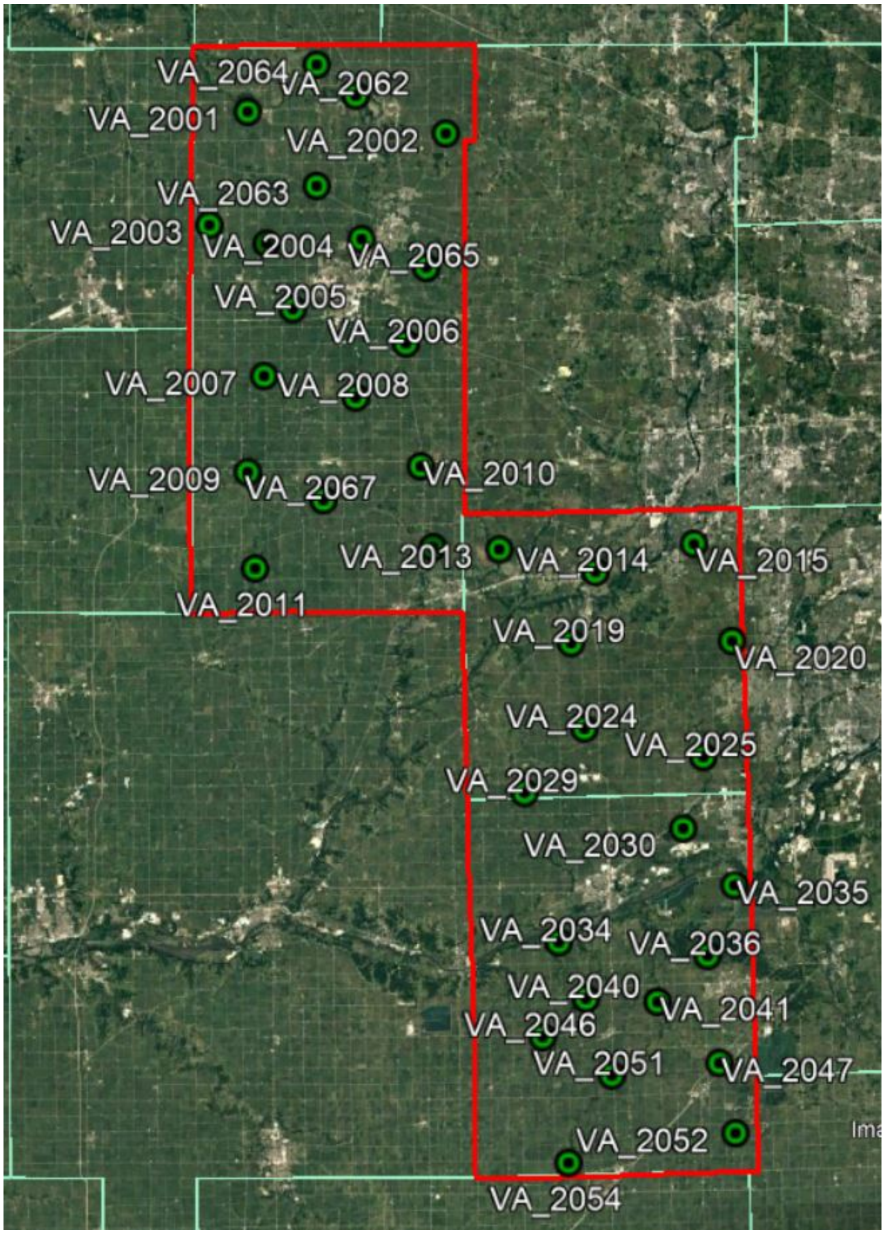

Figure 14b – Location of Expansion Counties VVA Checkpoints

VERTICAL ACCURACY TEST PROCEDURES

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in nonvegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the LiDAR sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated LiDAR sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error (RMSEz) of the checkpoints x 1.9600. For the IL_LaSalle and Expansion Counties project, vertical accuracy must be 0.64 ft (19.6 cm) or less based on an RMSEz of 0.33 ft (10 cm) x 1.9600. VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the LiDAR sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The LaSalle and Expansion Counties LiDAR project VVA standard is 0.96 ft (29.4 cm) based on the 95th percentile.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using RMSEz *1.96	19.6 cm (based on RMSEz (10 cm)*1.96)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined and at the 95th Percentile error	29.4 cm (based on combined 95th percentile)

Table 6 – Acceptance Criteria.

The primary QA/QC vertical accuracy testing steps used by ASI are summarized as follows:

1. GRW surveyed QA/QC vertical checkpoints in accordance with the project's specifications.

2. Next, ASI interpolated the bare-earth LiDAR DTM to provide the z-value for every checkpoint.

3. ASI then computed the associated z-value differences between the interpolated z-value from the LiDAR data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.

4. The data were analyzed by ASI to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

VERTICAL ACCURACY RESULTS

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified LiDAR LAS files.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (95% confidence)Spec = 0.196 m	VVA – Vegetated Vertical Accuracy (95th Percentile) spec = 0.294 m
NVA	89	0.103	
VVA	68		0.272

Table 7 – Tested NVA and VVA.

HORIZONTAL ACCURACY TEST PROCEDURES

Horizontal accuracy testing requires well-defined checkpoints that can be identified in the dataset. Elevation datasets, including LiDAR datasets, do not always contain well-defined checkpoints suitable for horizontal accuracy assessment. However, the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) recommends at least half of the NVA vertical check points should be located at the ends of paint stripes or other point features visible on the LiDAR intensity image, allowing them to double as horizontal check points. ASI reviews all NVA checkpoints to determine which, if any, of these checkpoints are located on photo-identifiable features in the intensity imagery. Photo-identifiable checkpoints are a subset of NVA checkpoints and are used for horizontal accuracy testing.

The primary QA/QC horizontal accuracy testing steps used by ASI are summarized as follows:

1. GRW surveyed QA/QC vertical checkpoints in accordance with the project's specifications and tried to locate half of the NVA checkpoints on features photo-identifiable in the intensity imagery.

2. Next, ASI identified the well-defined features in the intensity imagery.

3. ASI then computed the associated xy-value differences between the coordinates of the well-defined feature in the LiDAR intensity imagery and the ground truth survey checkpoints.

4. The data were analyzed by ASI to assess the accuracy of the data. Horizontal accuracy was assessed using NSSDA methodology where horizontal accuracy is calculated at the 95% confidence level. This report provides the results of the horizontal accuracy testing.

HORIZONTAL ACCURACY RESULTS

Eighteen checkpoints were determined to be photo-identifiable in the intensity imagery and were used to test the horizontal accuracy of the LiDAR dataset. As only eighteen (18) checkpoints were photo-identifiable, the results are not statistically significant enough to report as a final tested value, but the results of the testing are still shown in the table below. Using NSSDA methodology (endorsed by the ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014)), horizontal accuracy at the 95% confidence level (called ACCURACYr) is computed by the formula RMSEr * 1.7308 or RMSExy * 2.448. No horizontal accuracy requirements or thresholds were provided for this project. However, LiDAR datasets are generally calibrated by methods designed to ensure a horizontal accuracy of 1 meter or less.

# of Points	RMSEx (ft)	RMSEy (ft)	RMSEr (ft)	ACCURACYr (RMSEr x 1.7308) (ft)
18	0.129	0.183	0.382	0.658

Table 8– Tested horizontal accuracy at the 95% confidence level.

Actual positional accuracy of this dataset was found to be RMSEx = 0.129 ft (3.931 cm) and RMSEy = 0.183 (5.578 cm) which equates to +/- 0.658 ft (20.056 cm) at 95% confidence level.

BREAKLINE PRODUCTION METHODOLOGY

MicroStation, in conjunction with TerraSolid's TerraScan and TerraModeler was utilized for the collection of hydrologic breaklines, which occurred independently of manual edit. Collection was done using 2D information in the LAS format, intensity format, and ground surface. Breaklines are developed to the limit of the project boundary. Breaklines are in the same coordinate reference system and unit as the LiDAR point delivery. Hydrologic water-surface edges are set at or below the immediately surrounding terrain. Breaklines are developed to the limit of the project boundary.

BREAKLINE QUALITATIVE ASSESSMENT

Completeness and horizontal placement is verified through visual review against LiDAR intensity imagery, and bare earth surface. Breakline features are check for connectivity of features, enforced monotonicity on linear hydrographic breaklines, and flatness on water bodies.

After all corrections and edits to the breakline features, the breaklines are imported into the final GDB and verified for correct formatting.

FEATURE DEFINITION

Inland Streams and Rivers

Streams and Rivers with a nominal width of 30-m (100 feet), were collected to best fit the shoreline by using information in the LAS format; intensity format, ground surface TIN, and sometimes "quick guide" contours. Streams and rivers do not break at bridges, but they are closed ended breaks at culvert locations. Steams and Rivers breaklines have been delivered in PolylineZ format in the final GDB.

Inland Ponds and Lakes

Inland ponds and lakes of 2 acres (86,111 square feet/ ~350' diameter for a round pond) or greater were collected. Inland pond and Lakes were collected to best fit the shoreline by using information in the LAS format; intensity format, ground surface TIN, and sometimes "quick guide" contours. Inland pond and Lakes Breaklines have been delivered in PolygonZ format in the final GDB.

Islands

Permanent island 4000m² (1 acre) or larger shall be delineated within all water bodies. Breaklines have been delivered in PolygonZ format in the final GDB

Bridge Breaklines

Breaklines were placed across the bottom of the bridge embankment when triangulation occurred due to bridge deck classification. Breaklines have been delivered in PolylineZ format in the final GDB.

INTENSITY IMAGERY PRODUCTION & QUALITATIVE ASSESSMENT

INTENSITY PRODUCTION METHODOLOGY

ASI utilized MicroStation in conjunction with TerraSolid's TerraScan for Intensity production. Global Mapper was used to QC the products. ArcGIS was used finalize the Intensity's projection.

Intensity Images are created for each tile in the tiling schema. The Intensities are reviewed for any issues requiring corrections. Tiles are verified for final formatting and loaded into Global Mapper to ensure there are no missing, or corrupt tiles, and to check for seamlessness across tile boundaries.

INTENSITY QUALITATIVE ASSESSMENT

ASI performed a qualitative assessment of the Intensity deliverables to ensure that all tiled Intensity products were delivered with the proper extents, and contained proper referencing information.

The image below show an example of an Intensity Image

Figure 15 – Intensity Image example.

DEM PRODUCTION & QUALITATIVE ASSESSMENT

DEM PRODUCTION METHODOLOGY

ASI utilized MicroStation in conjunction with TerraSolid's TerraScan and TerraModeler for DEM production. Global Mapper was used to format and QC the products. ArcGIS was used finalize the DEMs projection.

The final bare earth LiDAR points are used to create a terrain. The final 3D breaklines collected for the project are enforced in the terrain. The terrain is then converted to raster format using linear interpolation. DEMs are created for each tile in the tiling schema. The DEMs are reviewed for any issues requiring corrections, including remaining LiDAR mis-classifications, erroneous breakline elevations, poor hydro flattening, and processing artifacts. Tiles are verified for final formatting and loaded into Global Mapper to ensure there are no missing, or corrupt tiles, and to check for seamlessness across tile boundaries.

DEM QUALITATIVE ASSESSMENT

ASI performed a qualitative assessment of the bare earth DEM deliverables to ensure that all tiled DEM products were delivered with the proper extents, were free of processing artifacts, and contained proper referencing information. This process was performed using a scrip ASI developed to verify that the raster extents match those of the tile grid and contain the correct projection information.

The image below shows an example of a bare earth DEM.

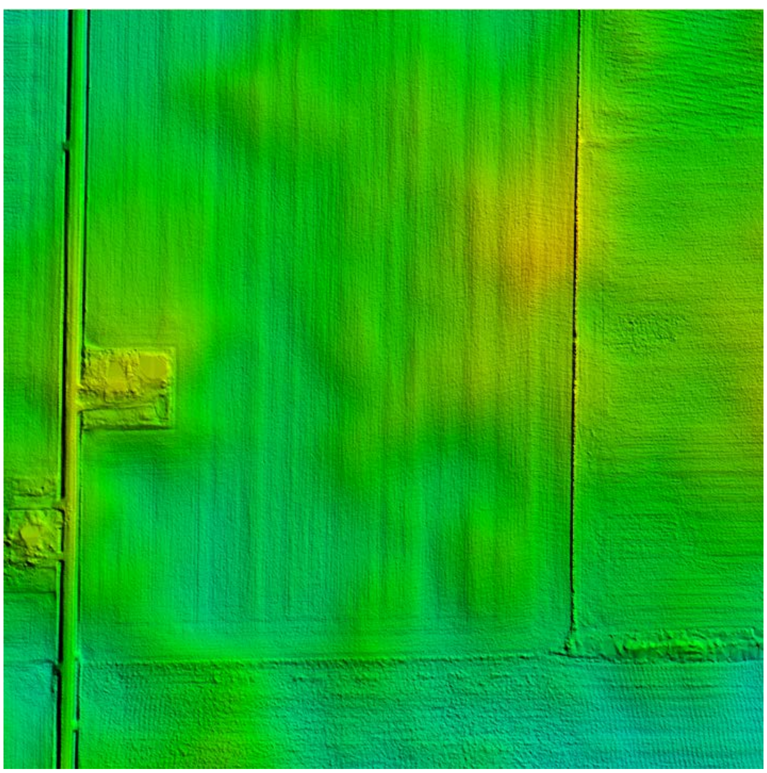

Figure 16 – IL_LaSalle Expansion Counties project bare earth DEM

DEM VERTICAL ACCURACY RESULTS

The same 89 checkpoints that were used to test the vertical accuracy of the LIDAR were used to validate the vertical accuracy of the final DEM products as well. Accuracy results may vary between the source LiDAR and final DEM deliverable. DEMs are created by averaging several LiDAR points within each pixel which may result in slightly different elevation values at each survey checkpoint when compared to the source LAS. The DEM pixel does not average several LiDAR point's together, it interpolates (linearly) between two or three points to derive an elevation value. The vertical accuracy of the DEM is tested by extracting the elevation of the pixel that contains the x/y coordinates of the checkpoint and comparing these DEM elevations to the survey elevations.

Table 9; summarizes the tested vertical accuracy result from a comparison of surveyed checkpoint to the elevation values present within the final DEM dataset.

Land Cover Category	# of Points	NVA – Non-vegetated Vertical Accuracy (95% confidence)	VVA – Vegetated Vertical Accuracy (95th percentile)
DEM NVA	89	0.096	
DEM VVA	68		0.267

Table 9 – DEM vertical accuracy summary

DEM datasets were tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 0.33 ft (10 cm) RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 0.161 ft (0.049 m) with a 0.315 ft (0.096 m) accuracy at 95 % confidence level. Actual VVA accuracy was found to be RMSEz = 0.397 ft (0.121 m) with a 0.876 ft (0.267 m) accuracy at the 95th percentile. Validation point NVA_1078 was omitted from the DEM report as it was located on a bridge deck that is removed from the DEM surface. Validation point NVA_1078 was omitted from the DEM report as it was located on a bridge deck that is removed from the DEM surface.

Based on the vertical accuracy testing conducted by ASI, the DEM dataset for the IL_LaSalle and Expansion Counties project satisfies the project's pre-defined vertical accuracy criteria.

Appendix A: List of Delivered LAS Files

10011619
10011621
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Appendix B: List of Low Confidence Tiles

A Low Confidence polygon was use to circumscribe an area where lidar was reflected by particulates in smoke stack emission. Photons were unable to penetrate through the emissions for collection of ground surface within the polygon. The emission cloud obscures approximately 3.72 acres of ground surface. Tiles in which the emission cloud occurred:

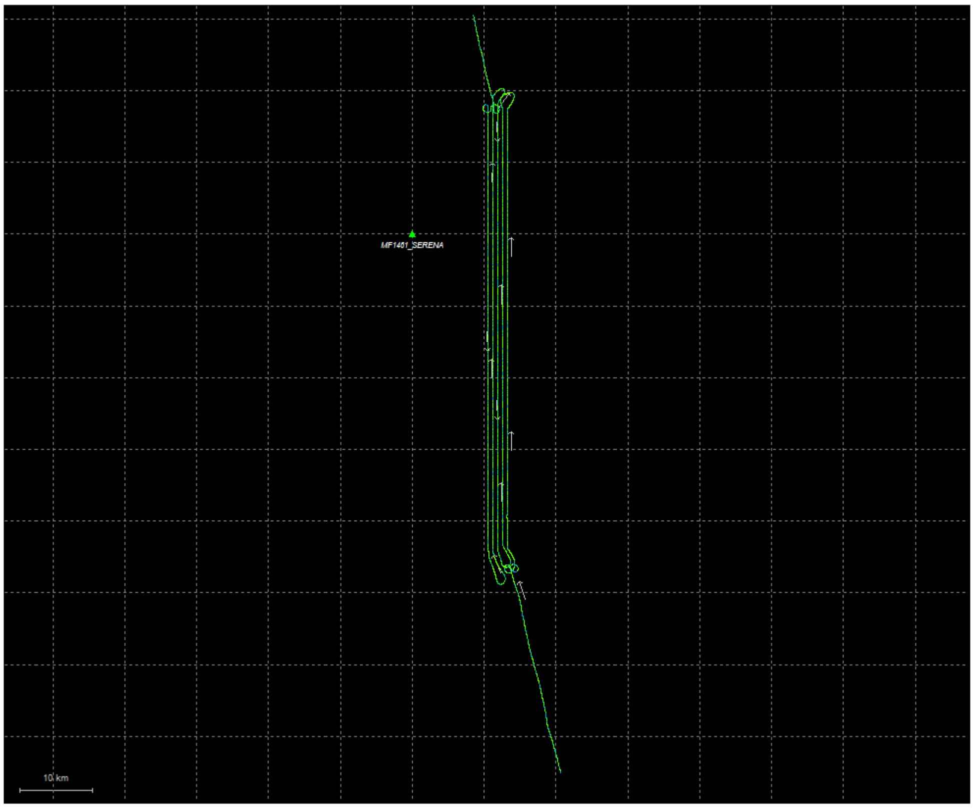
99101727
99301727

Appendix C: Mission GPS and IMU Processing Report

Output Results for 3DEP_LaSalle_20171119_201531

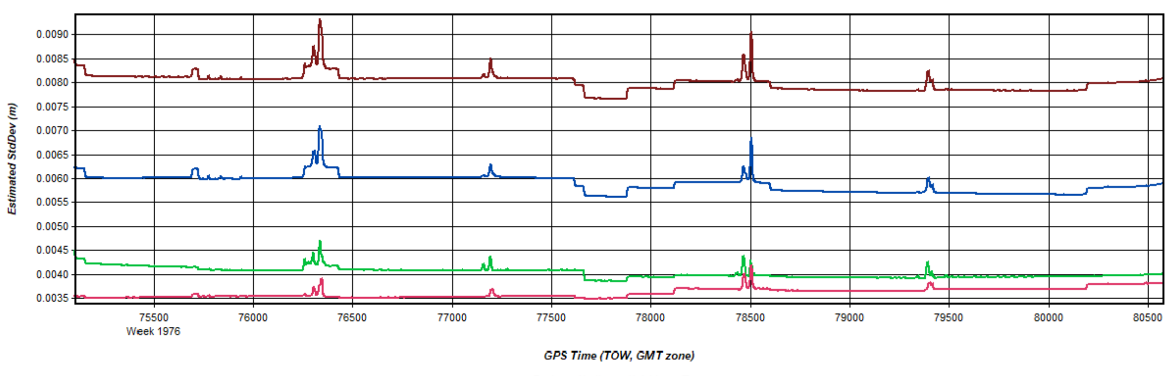
Inertial Explorer Version 8.60.6717
06/07/2018

Figure 1: Smoothed TC Combined - Map



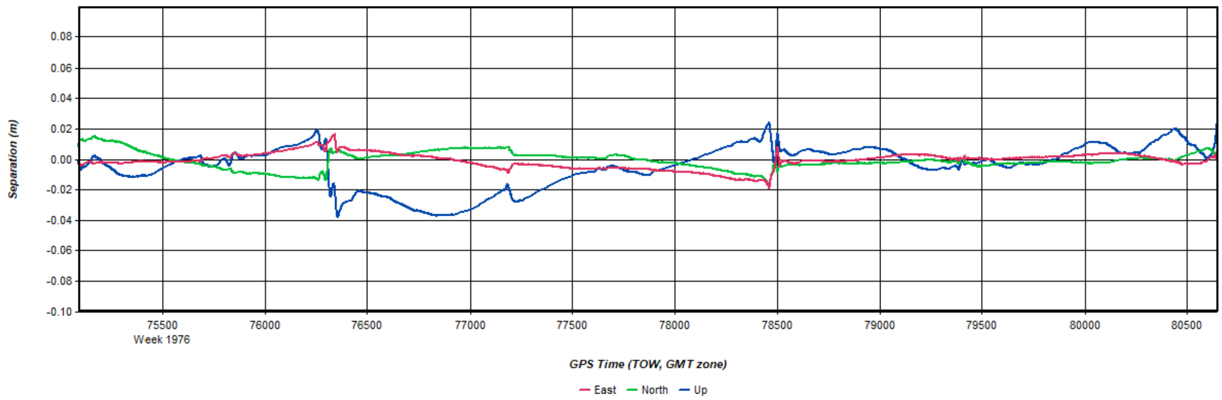
Process	3DEP_LaSalle_20171119_201531	by Unknown	on 11/23/2017	at 09:13:03

Figure 2: 3DEP_LaSalle_20171119_201531 [Smoothed TC Combined] - Estimated Position Accuracy Plot



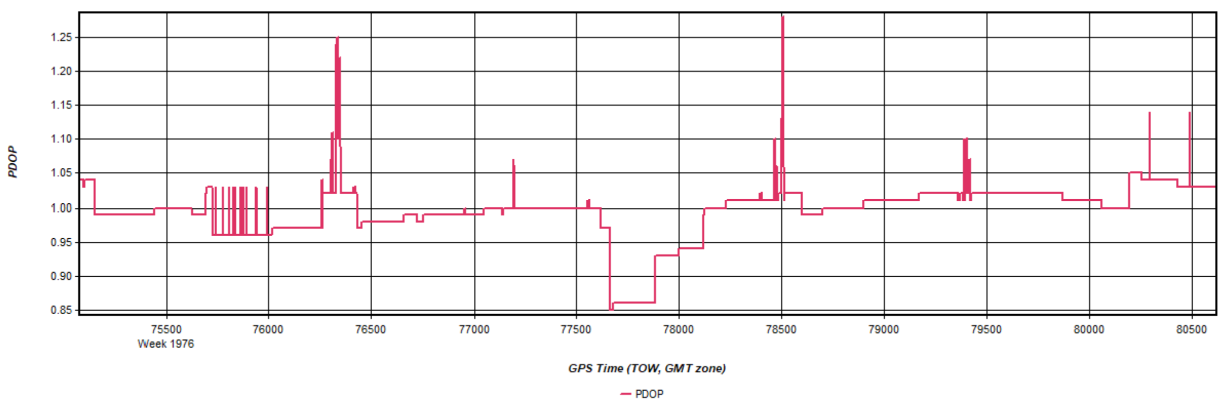
Process	3DEP_LaSalle_20171119_201531	by Unknown	on 11/23/2017	at 09:13:03

Figure 3: 3DEP_LaSalle_20171119_201531 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171119_201531	by Unknown	on 11/23/2017	at 09:13:03

Figure 4: 3DEP_LaSalle_20171119_201531 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171119_201531	by Unknown	on 11/23/2017	at 09:13:03

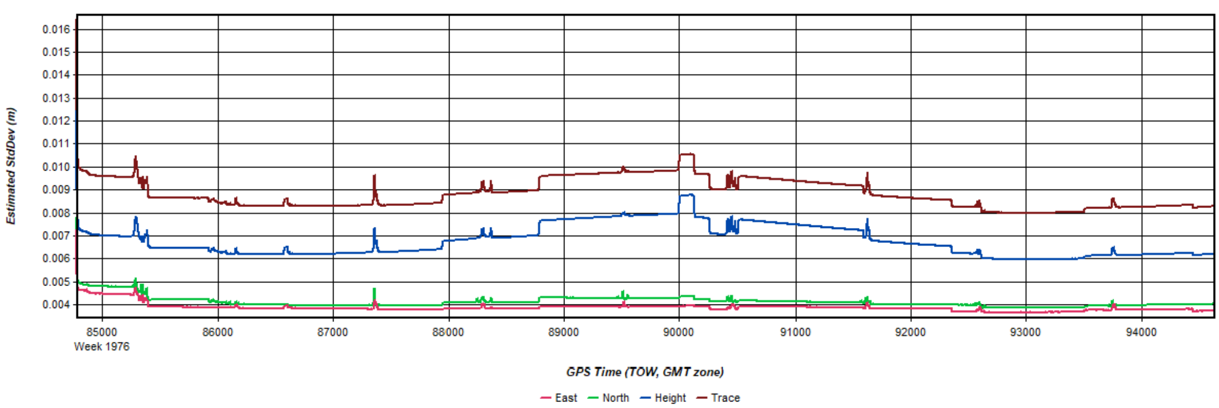
Output Results for 3DEP_LaSalle_20171119_233133

Inertial Explorer Version 8.60.6717
06/08/2018

Figure 1: Smoothed TC Combined - Map

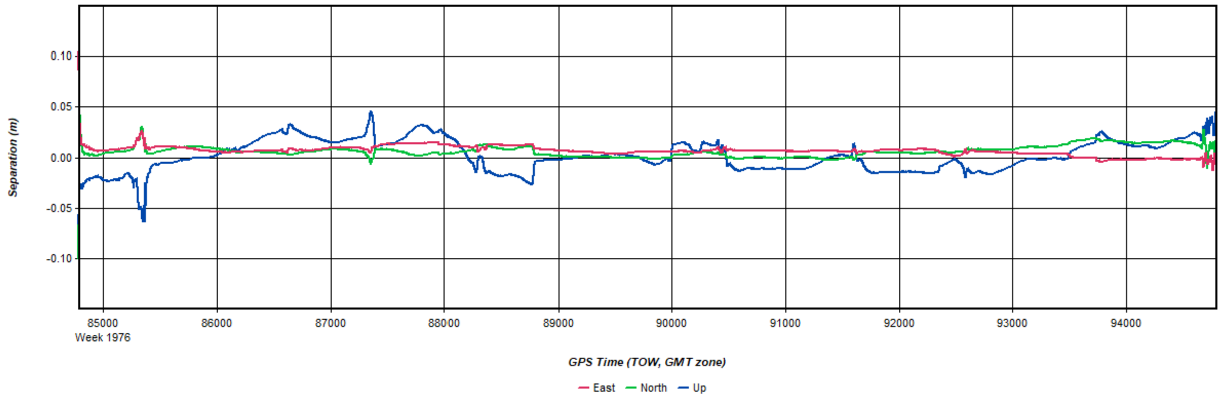
Process	3DEP_LaSalle_20171119_233133	by Unknown	on 11/23/2017	at 09:13:37

Figure 2: 3DEP_LaSalle_20171119_233133 [Smoothed TC Combined] - Estimated Position Accuracy Plot



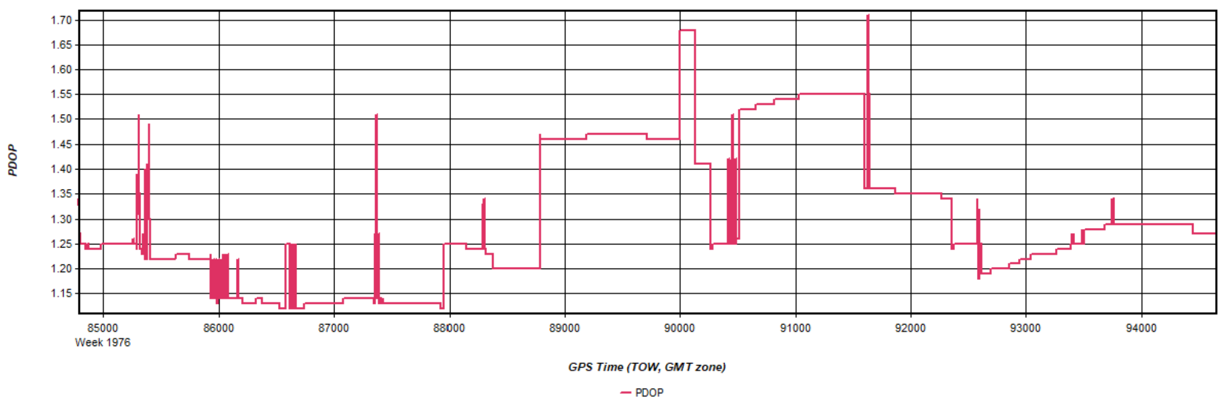
Process	3DEP_LaSalle_20171119_233133	by Unknown	on 11/23/2017	at 09:13:37

Figure 3: 3DEP_LaSalle_20171119_233133 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171119_233133	by Unknown	on 11/23/2017	at 09:13:37

Figure 4: 3DEP_LaSalle_20171119_233133 [Smoothed TC Combined] - PDOP Plot

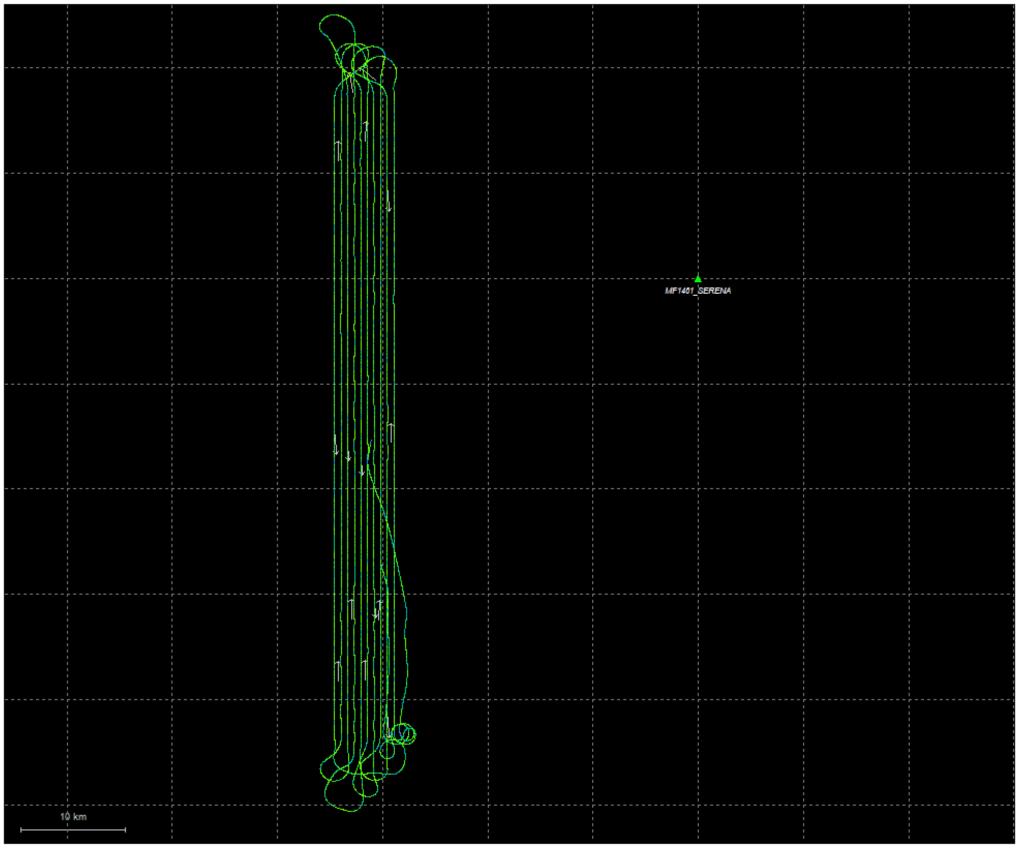


Process	3DEP_LaSalle_20171119_233133	by Unknown	on 11/23/2017	at 09:13:37

Output Results for 3DEP_LaSalle_20171120_041318

Inertial Explorer Version 8.60.6717
06/08/2018

Figure 1: Smoothed TC Combined - Map



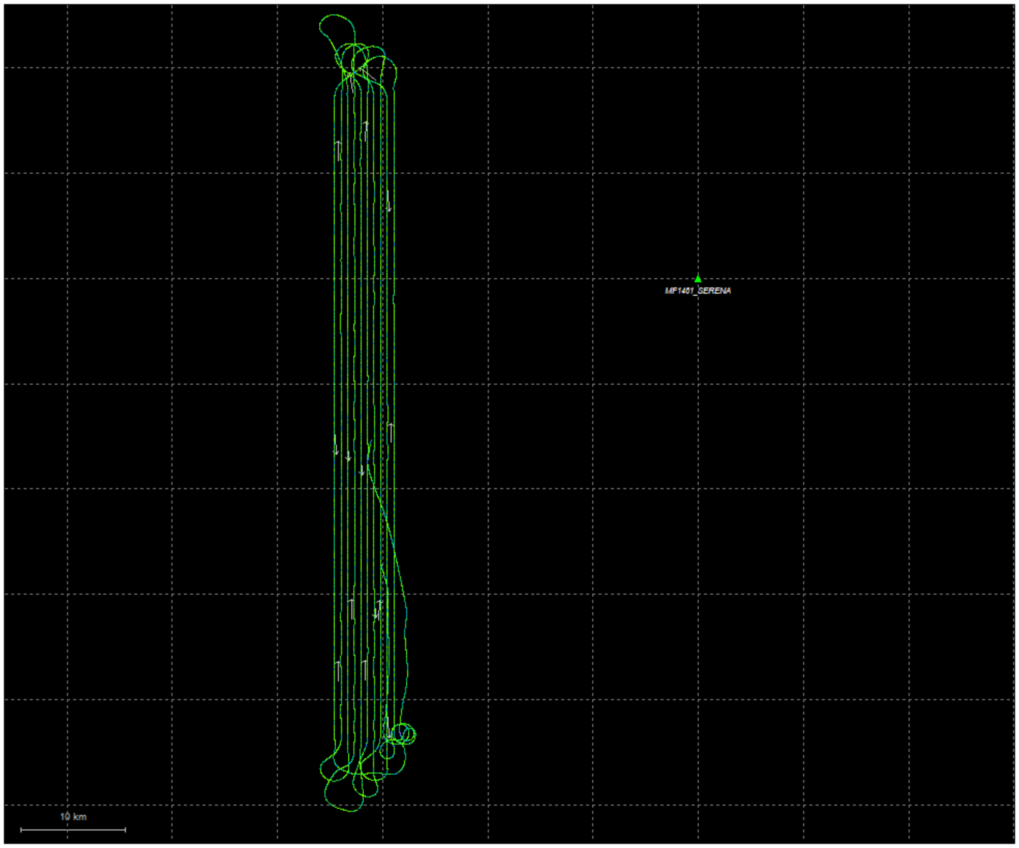
Process	3DEP_LaSalle_20171120_041318	by Unknown	on 11/27/2017	at 10:03:01

Figure 2: 3DEP_LaSalle_20171120_041318 [Smoothed TC Combined] - Estimated Position Accuracy Plot

Output Results for 3DEP_LaSalle_20171120_041318

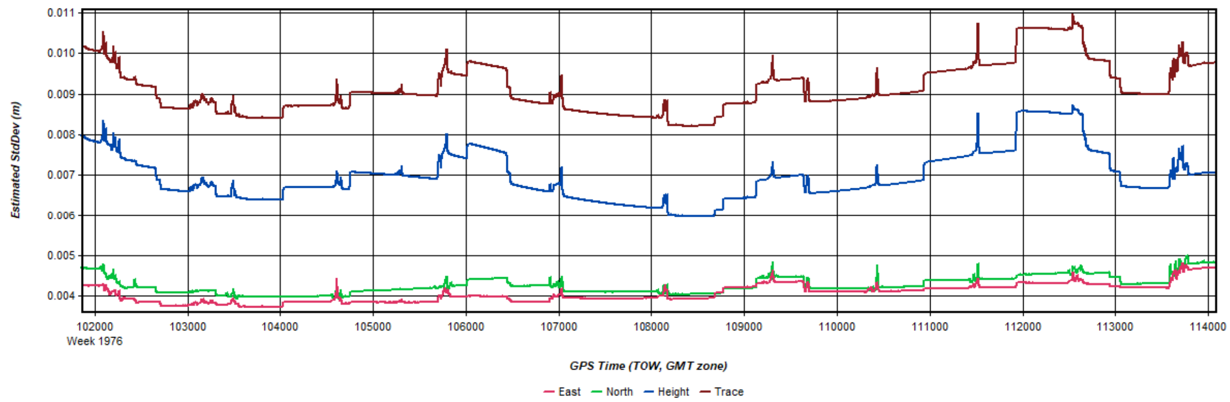
Inertial Explorer Version 8.60.6717
06/08/2018

Figure 1: Smoothed TC Combined - Map



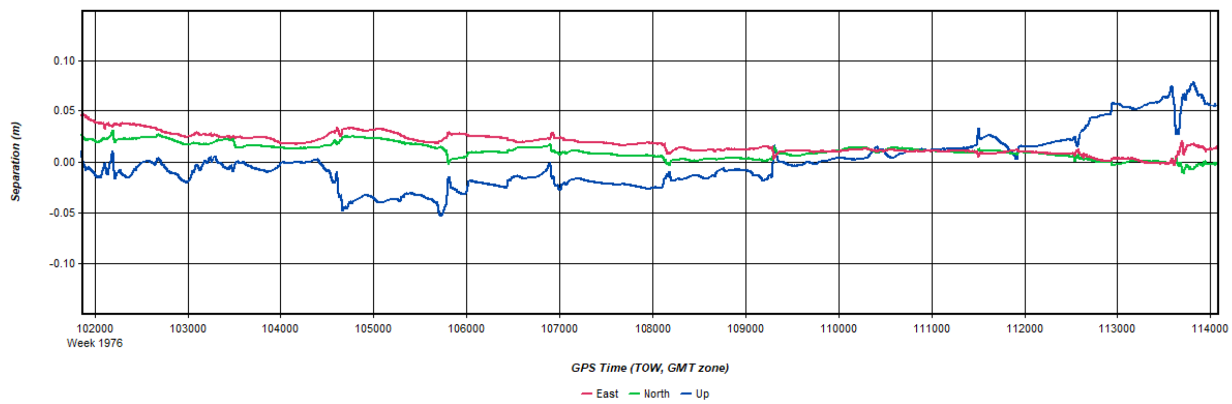
Process	3DEP_LaSalle_20171120_041318	by Unknown	on 11/27/2017	at 10:03:01

Figure 2: 3DEP_LaSalle_20171120_041318 [Smoothed TC Combined] - Estimated Position Accuracy Plot



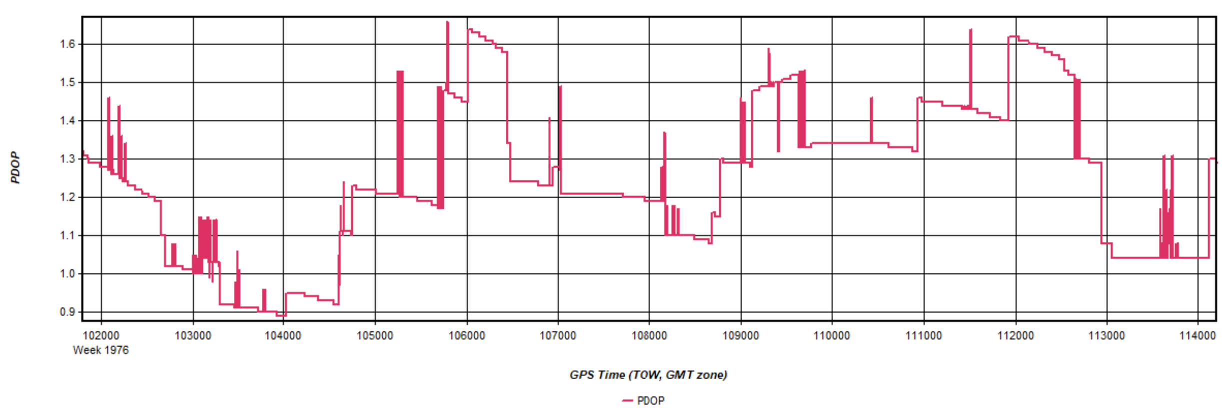
Process	3DEP_LaSalle_20171120_041318	by Unknown	on 11/27/2017	at 10:03:01

Figure 3: 3DEP_LaSalle_20171120_041318 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171120_041318	by Unknown	on 11/27/2017	at 10:03:01

Figure 4: 3DEP_LaSalle_20171120_041318 [Smoothed TC Combined] - PDOP Plot

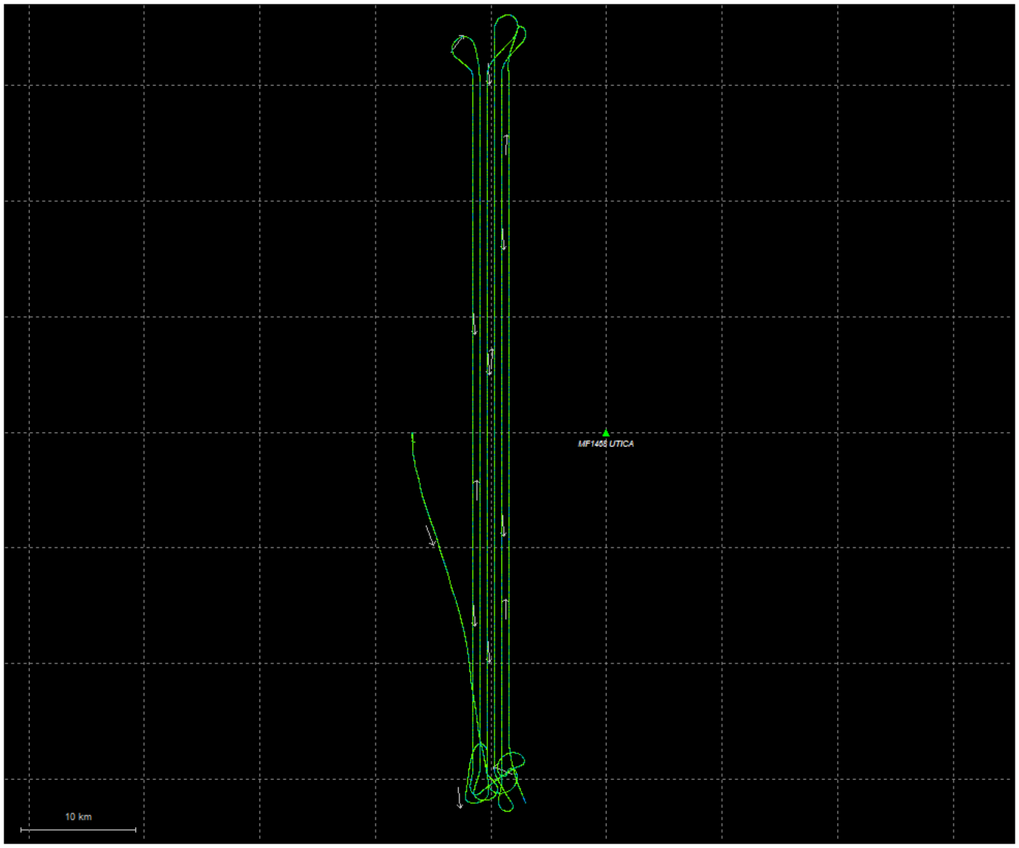


Process	3DEP_LaSalle_20171120_041318	by Unknown	on 11/27/2017	at 10:03:01

Output Results for 3DEP_LaSalle_20171120_220547

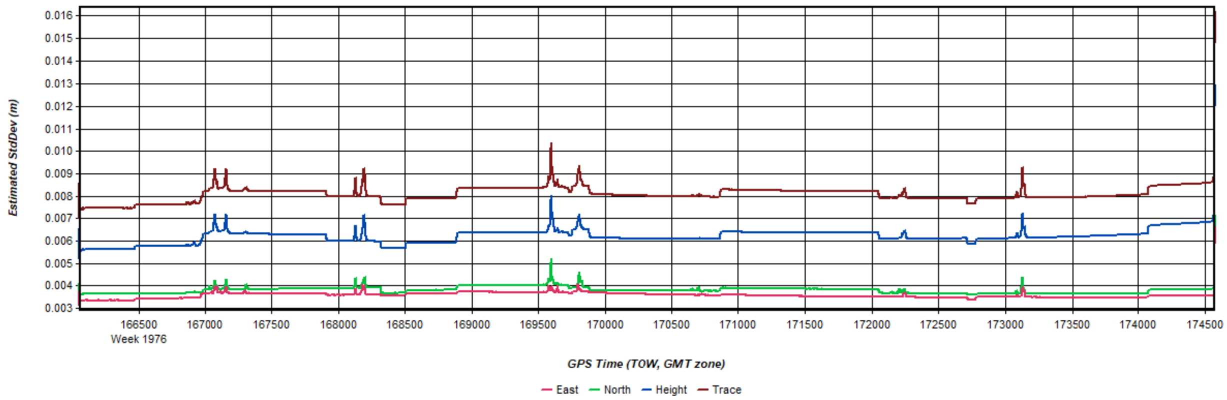
Inertial Explorer Version 8.60.6717
06/08/2018

Figure 1: Smoothed TC Combined - Map



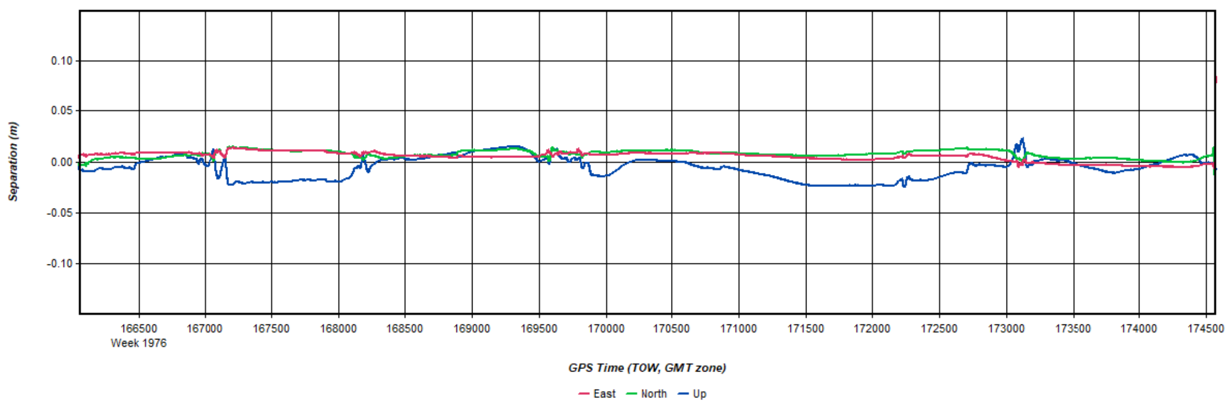
Process	3DEP_LaSalle_20171120_220547	by Unknown	on 11/27/2017	at 10:37:20

Figure 2: 3DEP_LaSalle_20171120_220547 [Smoothed TC Combined] - Estimated Position Accuracy Plot



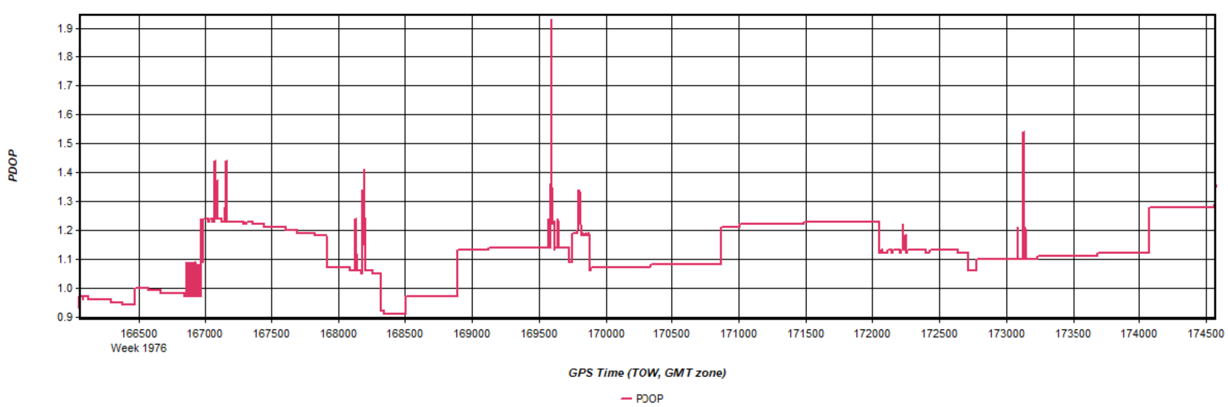
Process	3DEP_LaSalle_20171120_220547	by Unknown	on 11/27/2017	at 10:37:20

Figure 3: 3DEP_LaSalle_20171120_220547 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171120_220547	by Unknown	on 11/27/2017	at 10:37:20

Figure 4: 3DEP_LaSalle_20171120_220547 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171120_220547	by Unknown	on 11/27/2017	at 10:37:20

Output Results for 3DEP_LaSalle_20171121_003020

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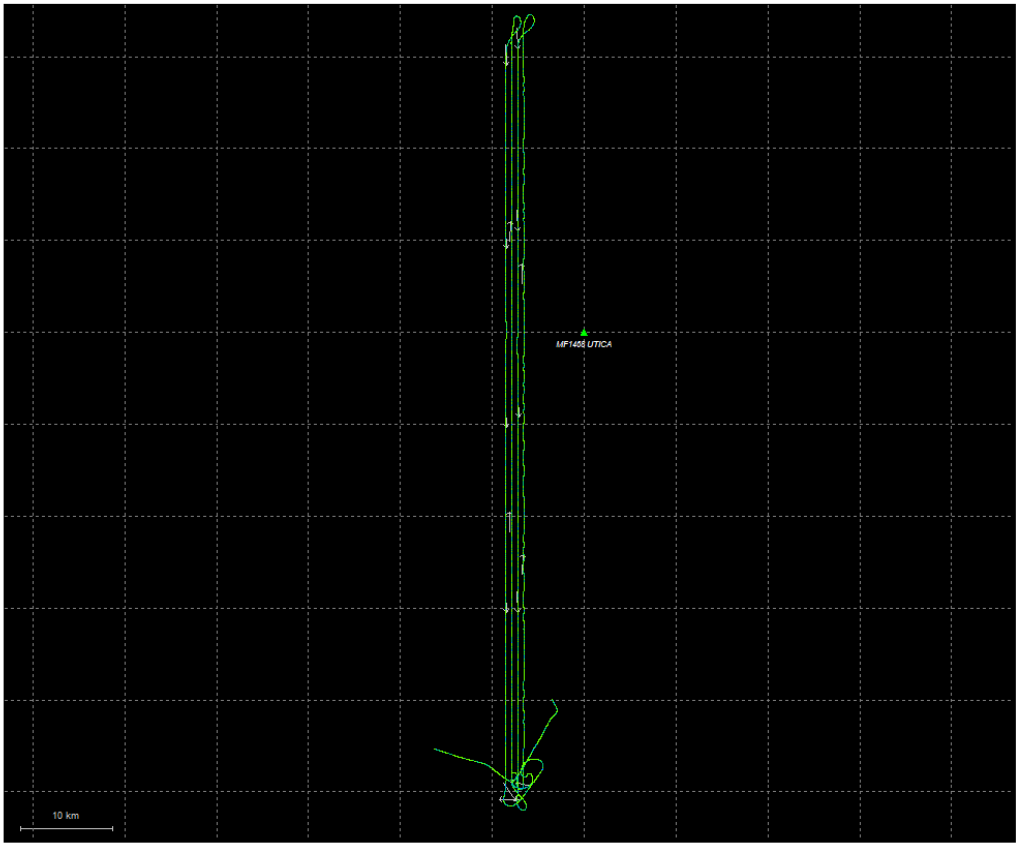
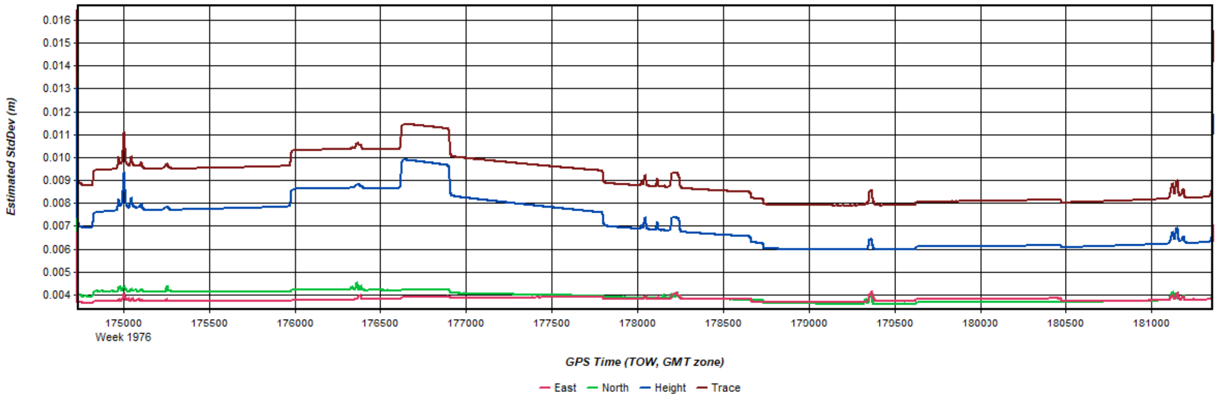
Figure 1: Smoothed TC Combined - Map



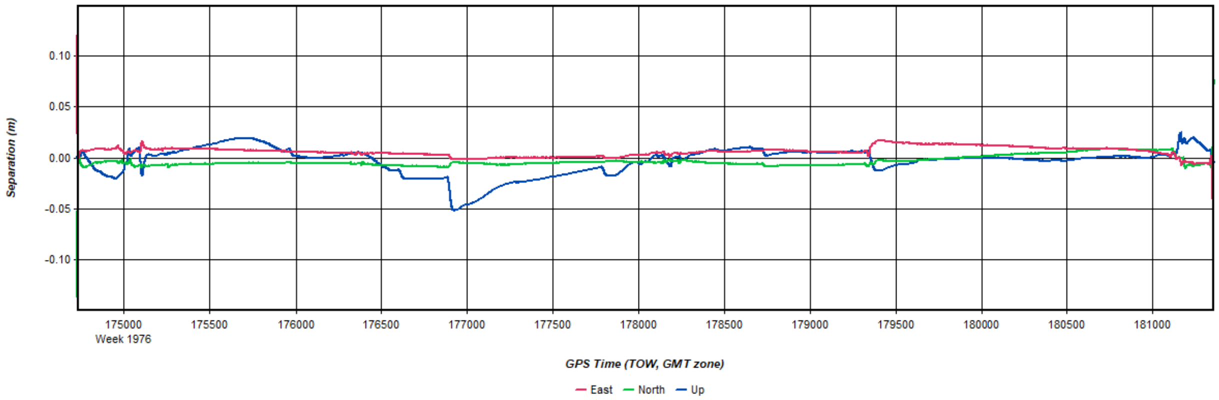
Process	3DEP_LaSalle_20171121_003020	by Unknown	on 11/27/2017	at 10:36:38

Figure 2: 3DEP_LaSalle_20171121_003020 [Smoothed TC Combined] - Estimated Position Accuracy Plot



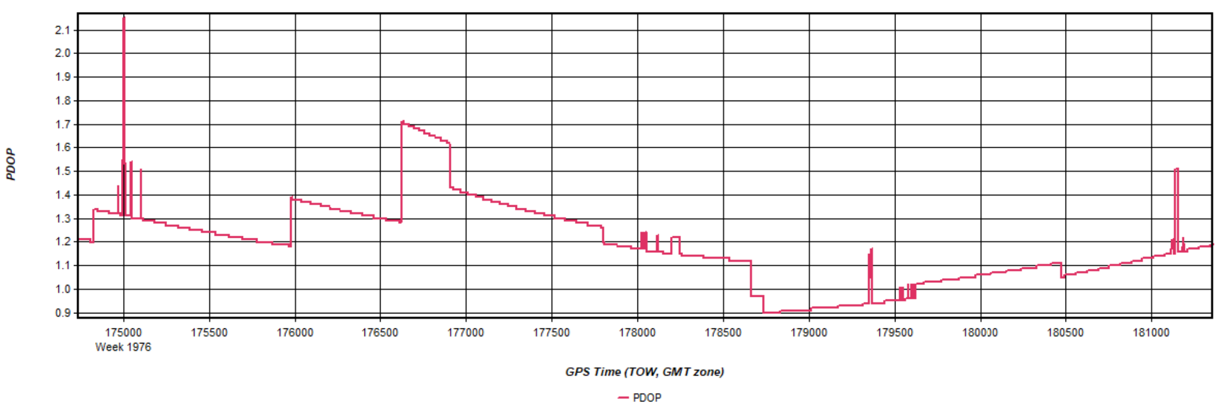
Process	3DEP_LaSalle_20171121_003020	by Unknown	on 11/27/2017	at 10:36:38

Figure 3: 3DEP_LaSalle_20171121_003020 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171121_003020	by Unknown	on 11/27/2017	at 10:36:38

Figure 4: 3DEP_LaSalle_20171121_003020 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171121_003020	by Unknown	on 11/27/2017	at 10:36:38

Output Results for 3DEP_LaSalle_20171121_040631

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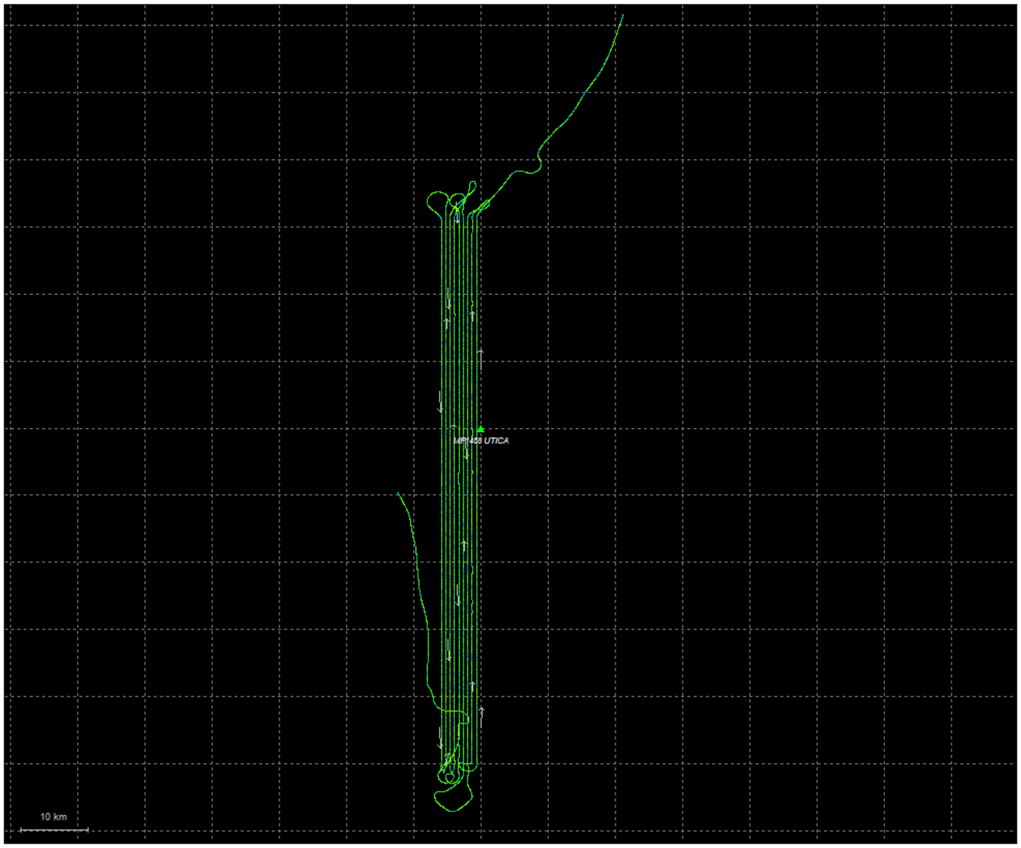
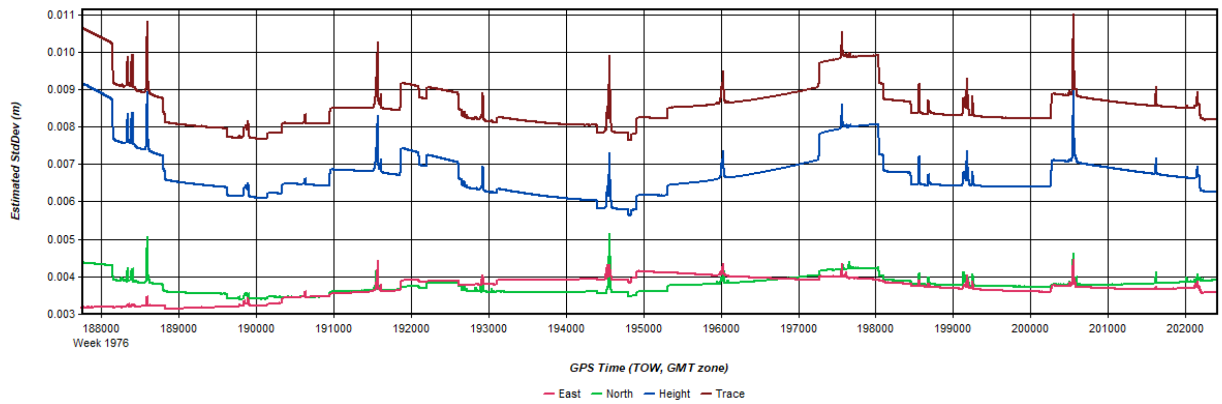
Figure 1: Smoothed TC Combined - Map



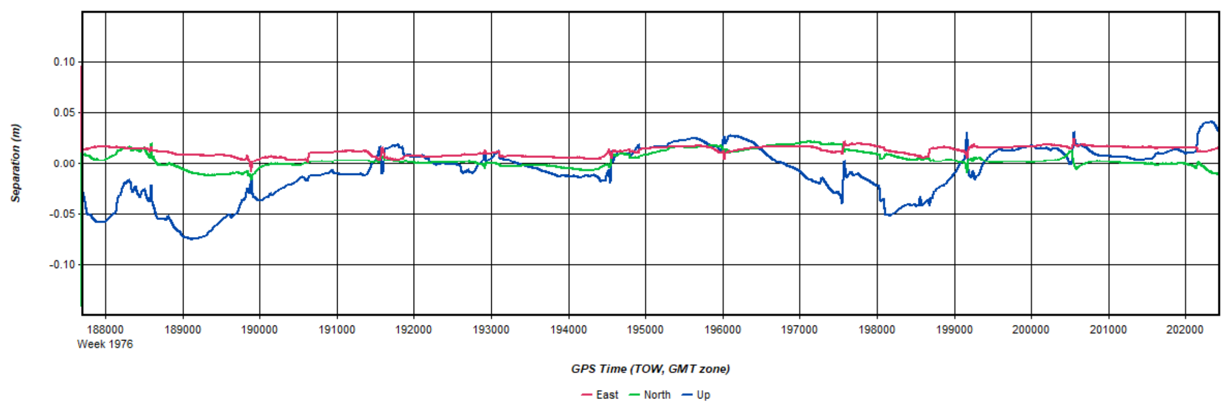
Process	3DEP_LaSalle_20171121_040631	by Unknown	on 11/27/2017	at 11:46:28

Figure 2: 3DEP_LaSalle_20171121_040631 [Smoothed TC Combined] - Estimated Position Accuracy Plot



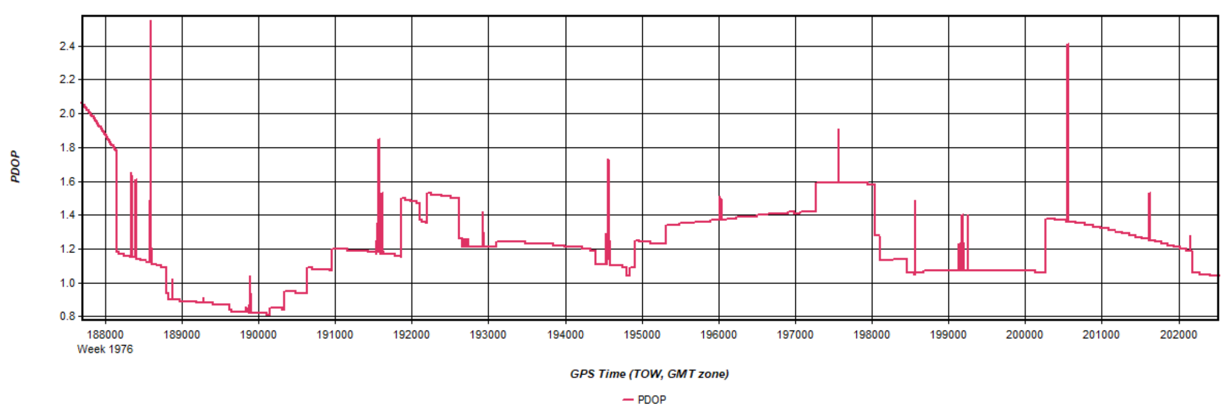
Process	3DEP_LaSalle_20171121_040631	by Unknown	on 11/27/2017	at 11:46:28

Figure 3: 3DEP_LaSalle_20171121_040631 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171121_040631	by Unknown	on 11/27/2017	at 11:46:28

Figure 4: 3DEP_LaSalle_20171121_040631 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171121_040631	by Unknown	on 11/27/2017	at 11:46:28

Output Results for 3DEP_LaSalle_20171121_090423

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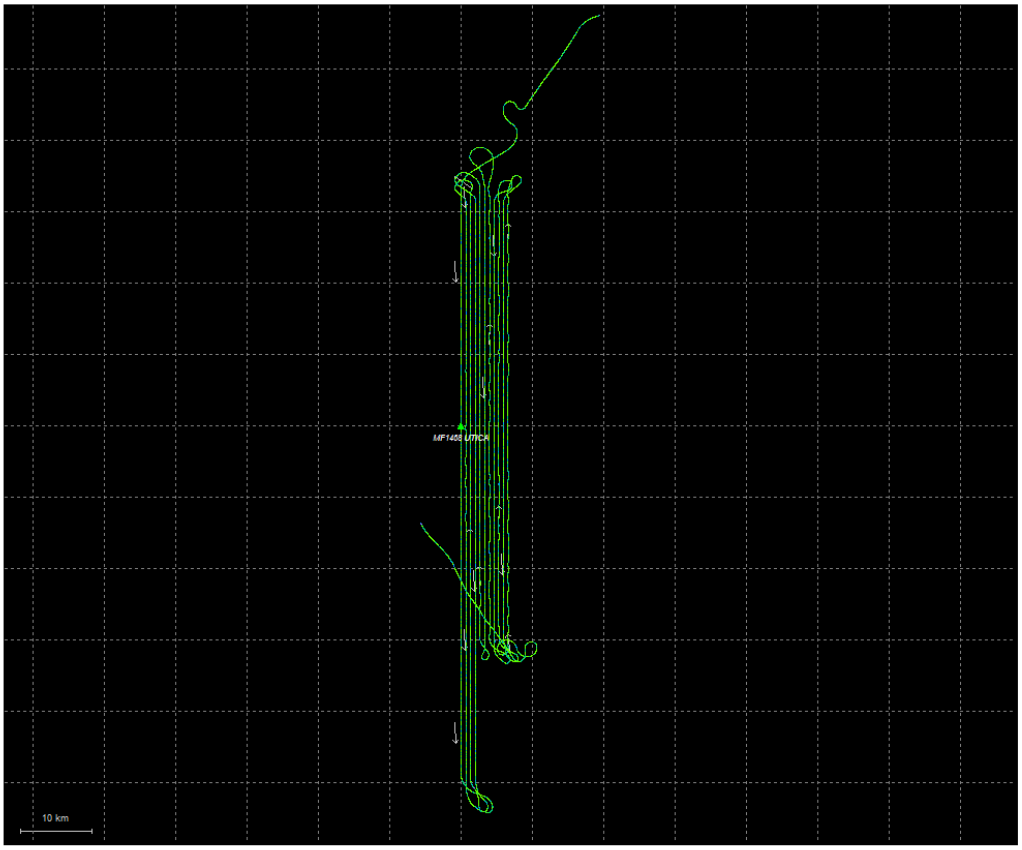
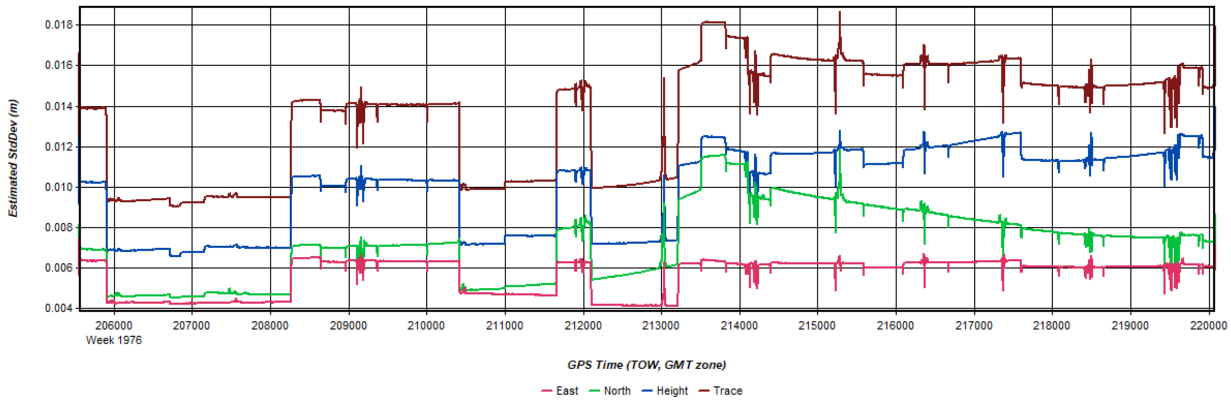
Figure 1: Smoothed TC Combined - Map



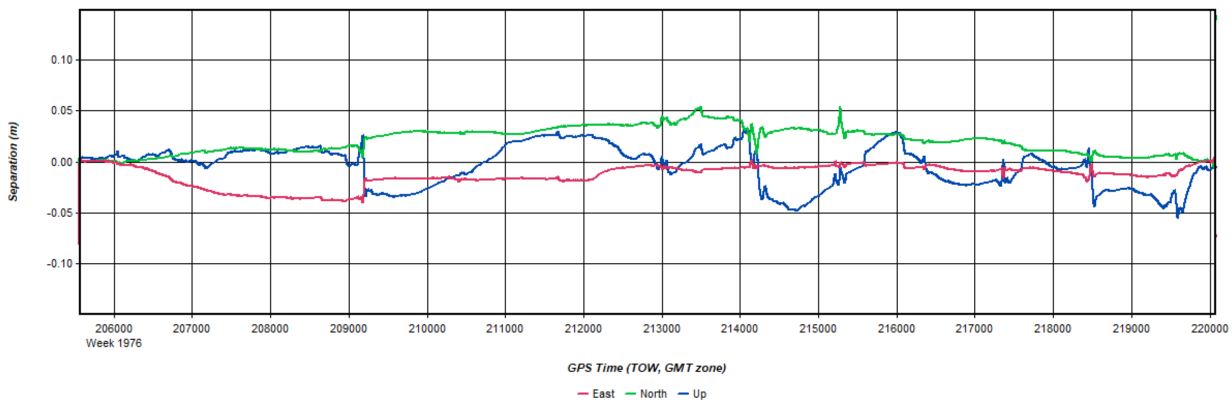
Process	3DEP_LaSalle_20171121_090423	by Unknown	on 11/27/2017	at 14:53:33

Figure 2: 3DEP_LaSalle_20171121_090423 [Smoothed TC Combined] - Estimated Position Accuracy Plot



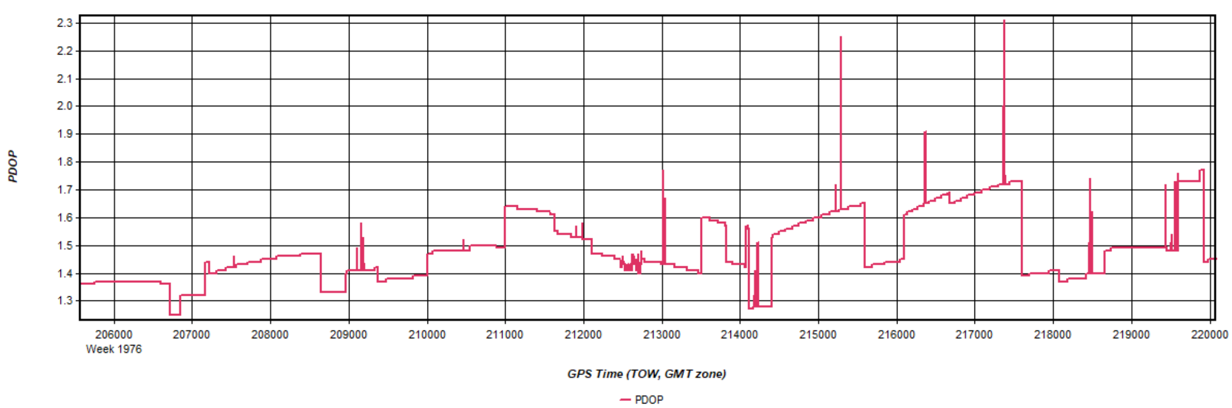
Process	3DEP_LaSalle_20171121_090423	by Unknown	on 11/27/2017	at 14:53:33

Figure 3: 3DEP_LaSalle_20171121_090423 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171121_090423	by Unknown	on 11/27/2017	at 14:53:33

Figure 4: 3DEP_LaSalle_20171121_090423 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171121_090423	by Unknown	on 11/27/2017	at 14:53:33

Output Results for 3DEP_LaSalle_20171121_185927

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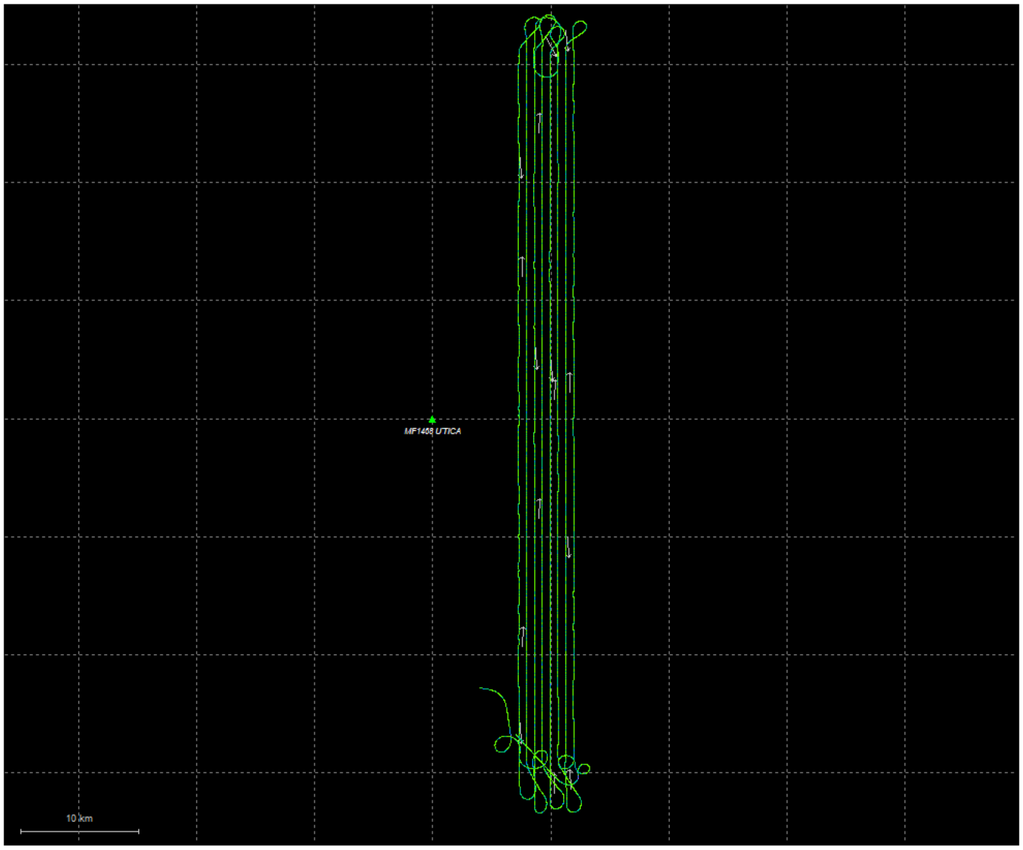
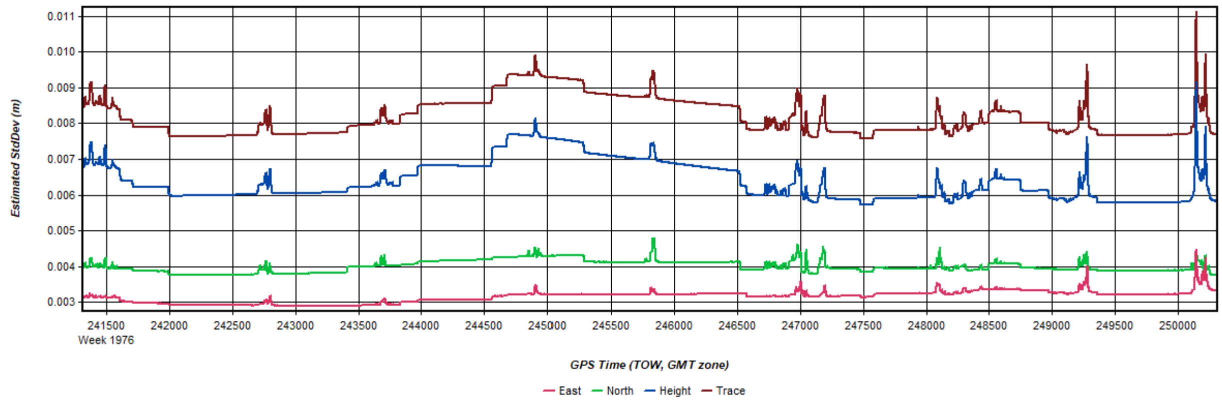
Figure 1: Smoothed TC Combined - Map



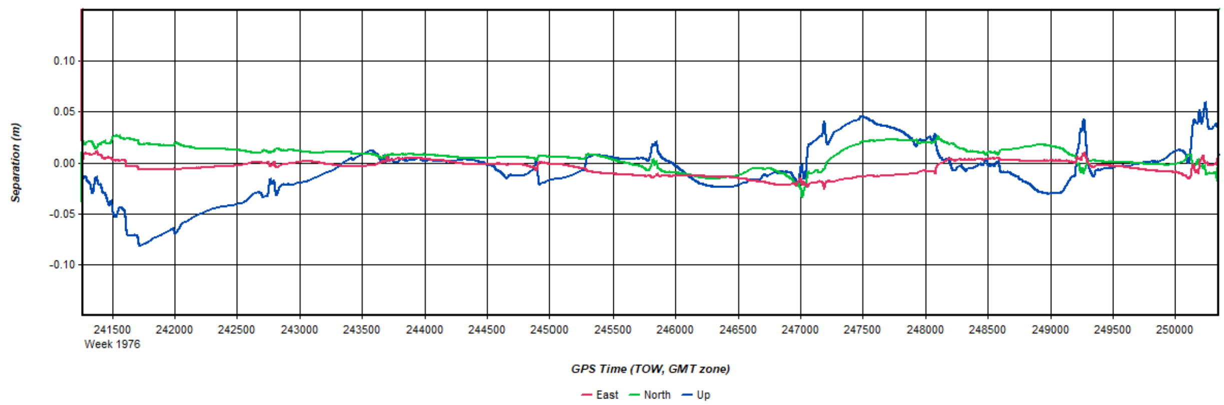
Process	3DEP_LaSalle_20171121_185927	by Unknown	on 11/28/2017	at 12:59:44

Figure 2: 3DEP_LaSalle_20171121_185927 [Smoothed TC Combined] - Estimated Position Accuracy Plot



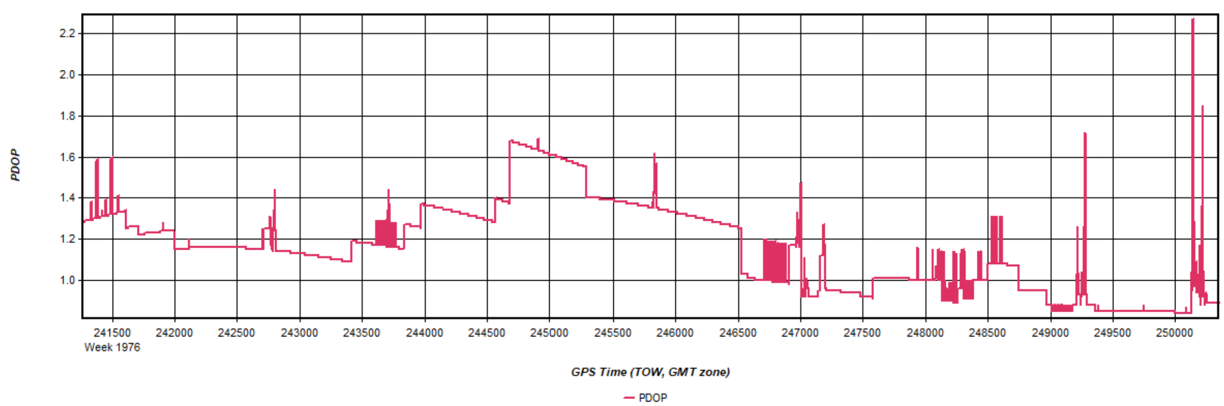
Process	3DEP_LaSalle_20171121_185927	by Unknown	on 11/28/2017	at 12:59:44

Figure 3: 3DEP_LaSalle_20171121_185927 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171121_185927	by Unknown	on 11/28/2017	at 12:59:44

Figure 4: 3DEP_LaSalle_20171121_185927 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171121_185927	by Unknown	on 11/28/2017	at 12:59:44

Output Results for 3DEP_LaSalle_20171121_224333

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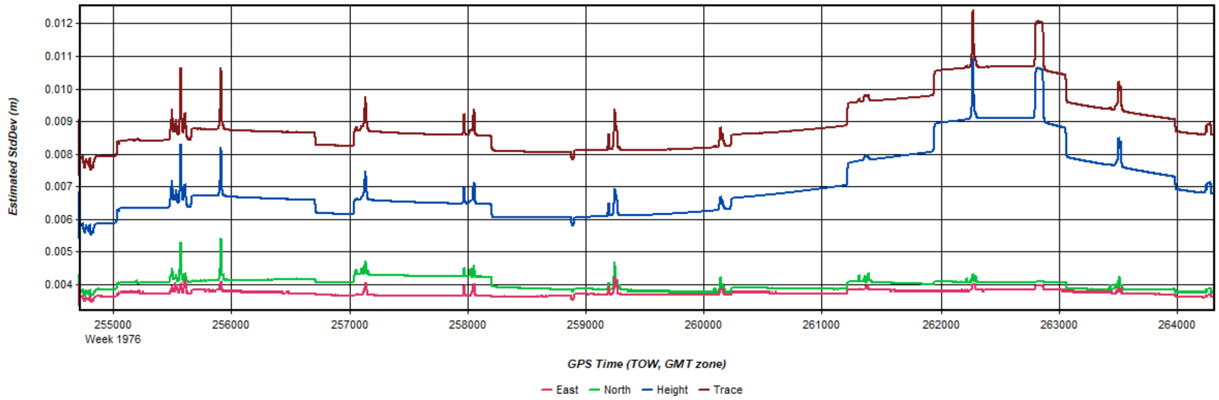
Figure 1: Smoothed TC Combined - Map

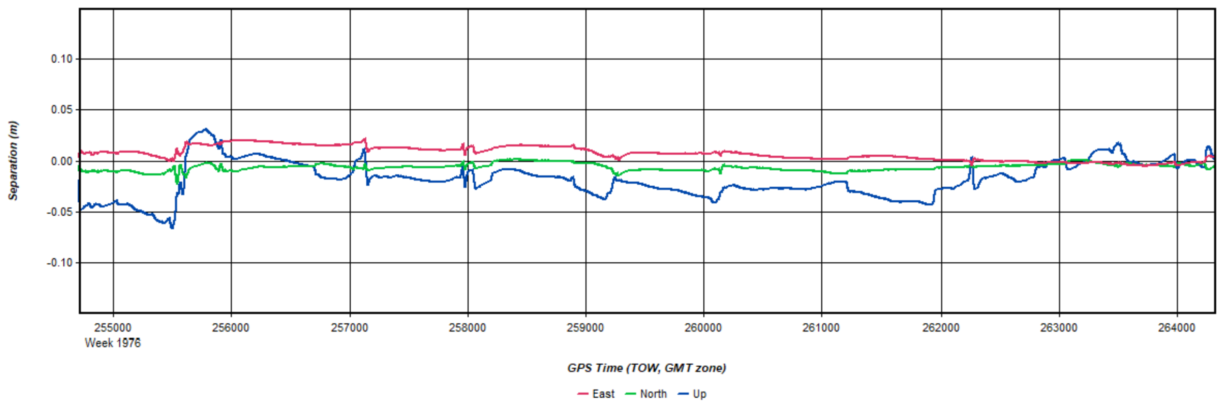
Process	3DEP_LaSalle_20171121_224333	by Unknown	on 11/28/2017	at 13:01:06

Figure 2: 3DEP_LaSalle_20171121_224333 [Smoothed TC Combined] - Estimated Position Accuracy Plot



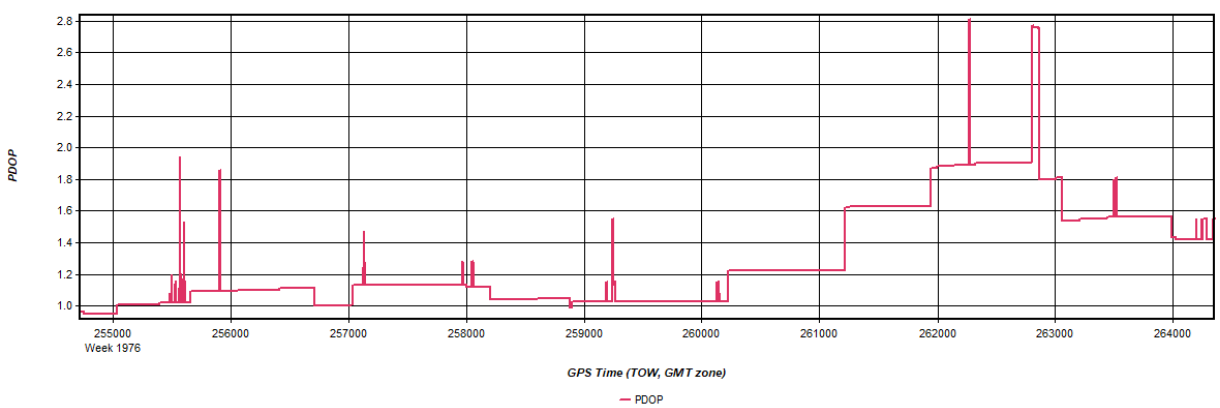
Process	3DEP_LaSalle_20171121_224333	by Unknown	on 11/28/2017	at 13:01:06

Figure 3: 3DEP_LaSalle_20171121_224333 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171121_224333	by Unknown	on 11/28/2017	at 13:01:06

Figure 4: 3DEP_LaSalle_20171121_224333 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171121_224333	by Unknown	on 11/28/2017	at 13:01:06

Output Results for 3DEP_LaSalle_20171121_224333

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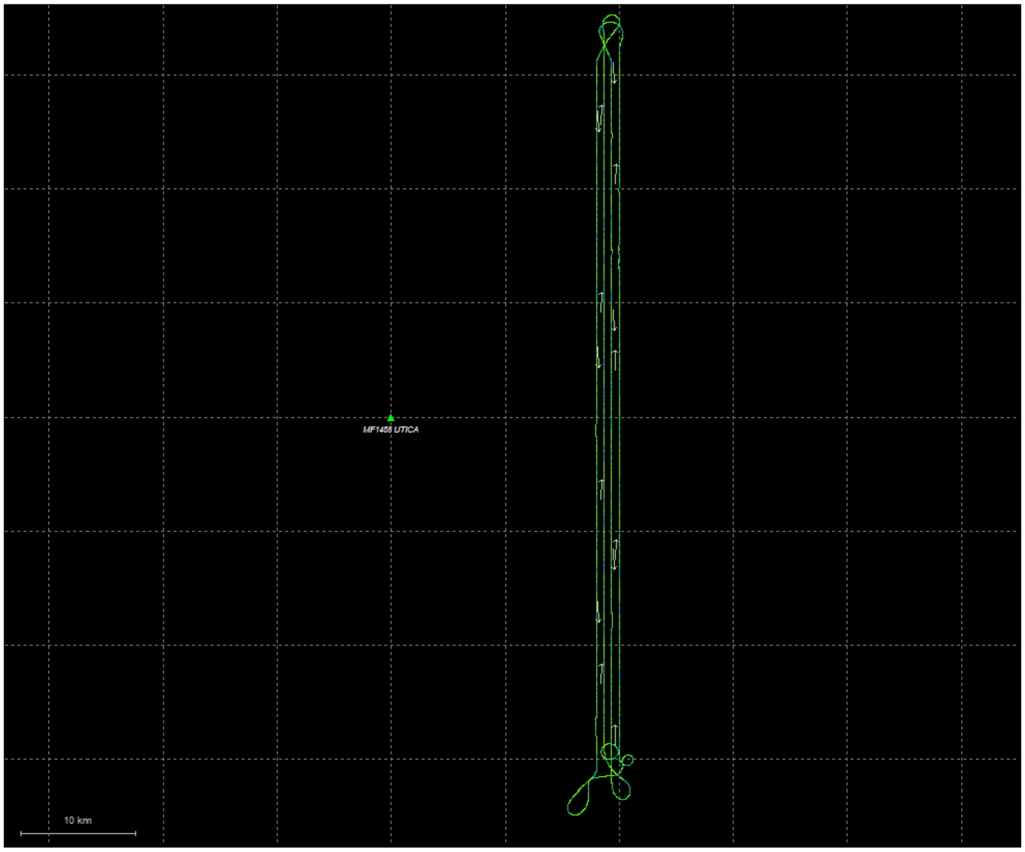
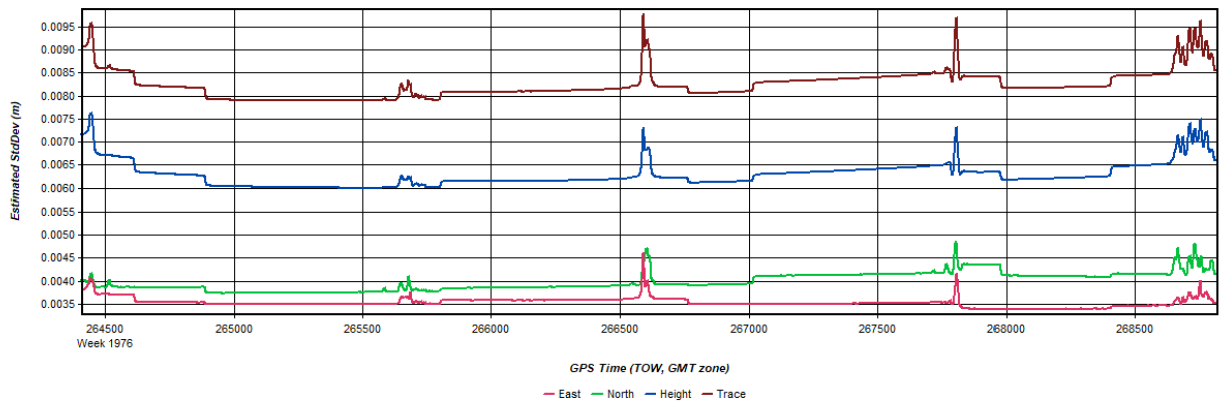
Figure 1: Smoothed TC Combined - Map



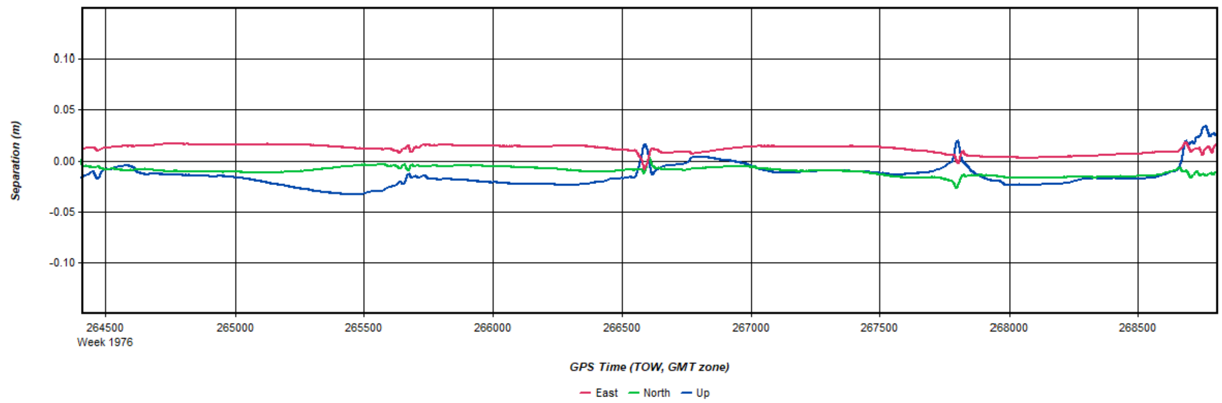
Process	3DEP_LaSalle_20171121_224333	by Unknown	on 11/28/2017	at 12:58:32

Figure 2: 3DEP_LaSalle_20171121_224333 [Smoothed TC Combined] - Estimated Position Accuracy Plot



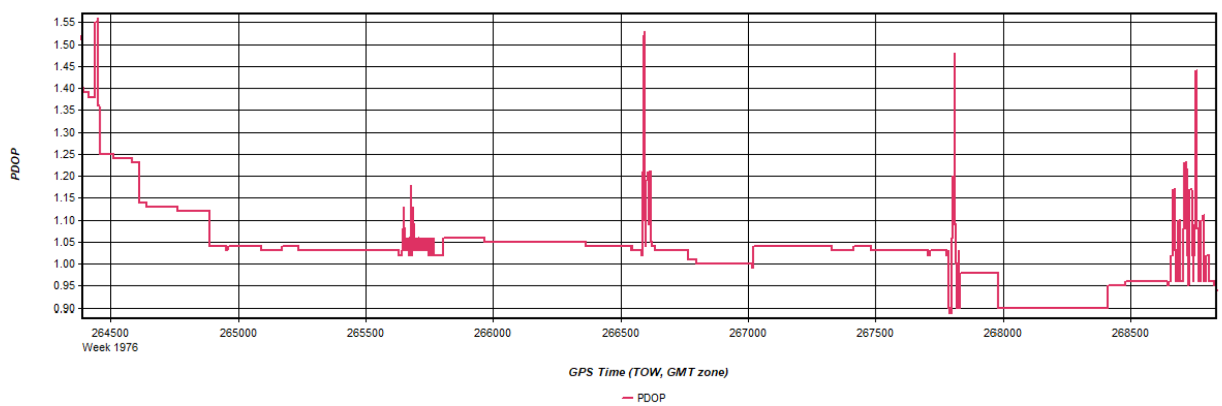
Process	3DEP_LaSalle_20171121_224333	by Unknown	on 11/28/2017	at 12:58:32

Figure 3: 3DEP_LaSalle_20171121_224333 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171121_224333	by Unknown	on 11/28/2017	at 12:58:32

Figure 4: 3DEP_LaSalle_20171121_224333 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171121_224333	by Unknown	on 11/28/2017	at 12:58:32

Output Results for 3DEP_LaSalle_20171122_045415

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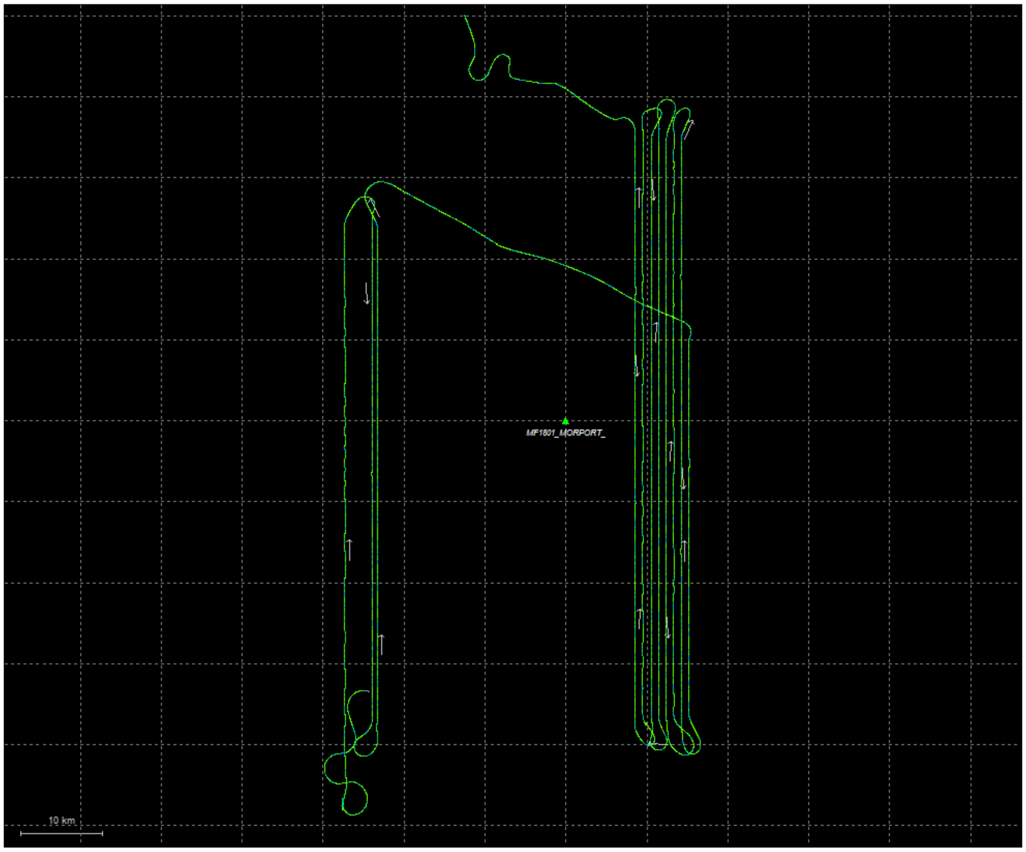
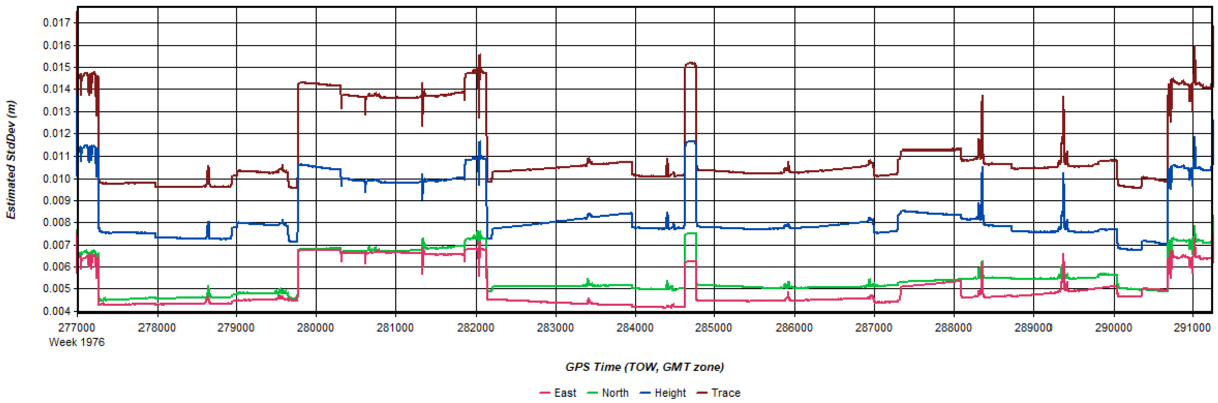
Figure 1: Smoothed TC Combined - Map



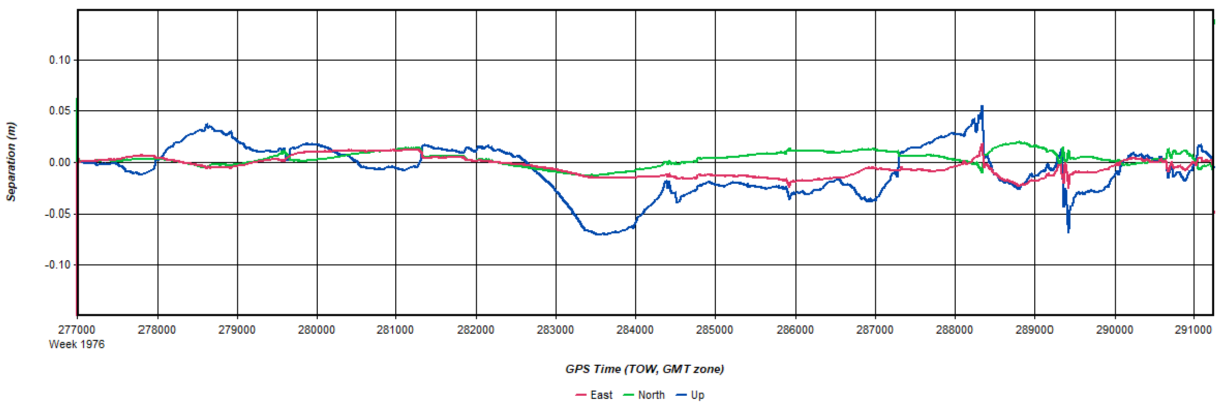
Process	3DEP_LaSalle_20171122_045415	by Unknown	on 11/28/2017	at 17:01:48

Figure 2: 3DEP_LaSalle_20171122_045415 [Smoothed TC Combined] - Estimated Position Accuracy Plot



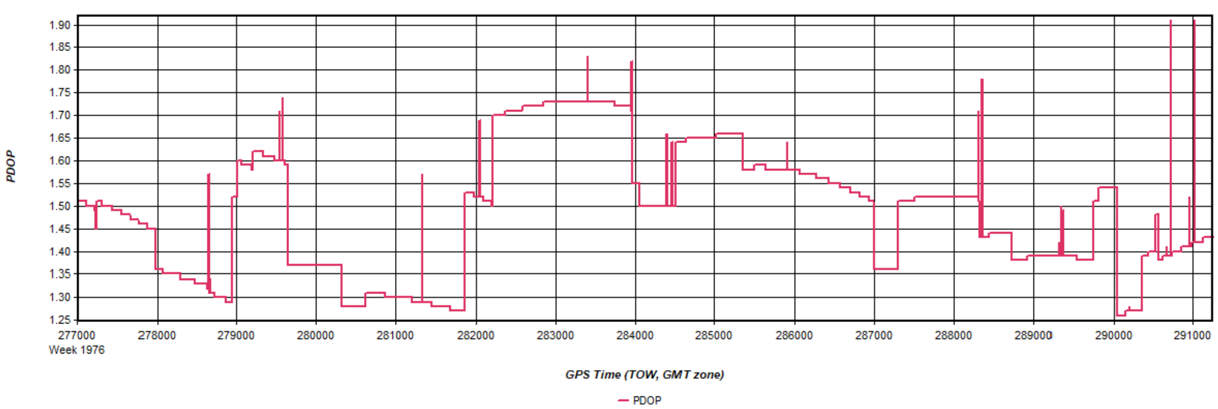
Process	3DEP_LaSalle_20171122_045415	by Unknown	on 11/28/2017	at 17:01:48

Figure 3: 3DEP_LaSalle_20171122_045415 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171122_045415	by Unknown	on 11/28/2017	at 17:01:48

Figure 4: 3DEP_LaSalle_20171122_045415 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171122_045415	by Unknown	on 11/28/2017	at 17:01:48

Output Results for 3DEP_LaSalle_20171122_093009

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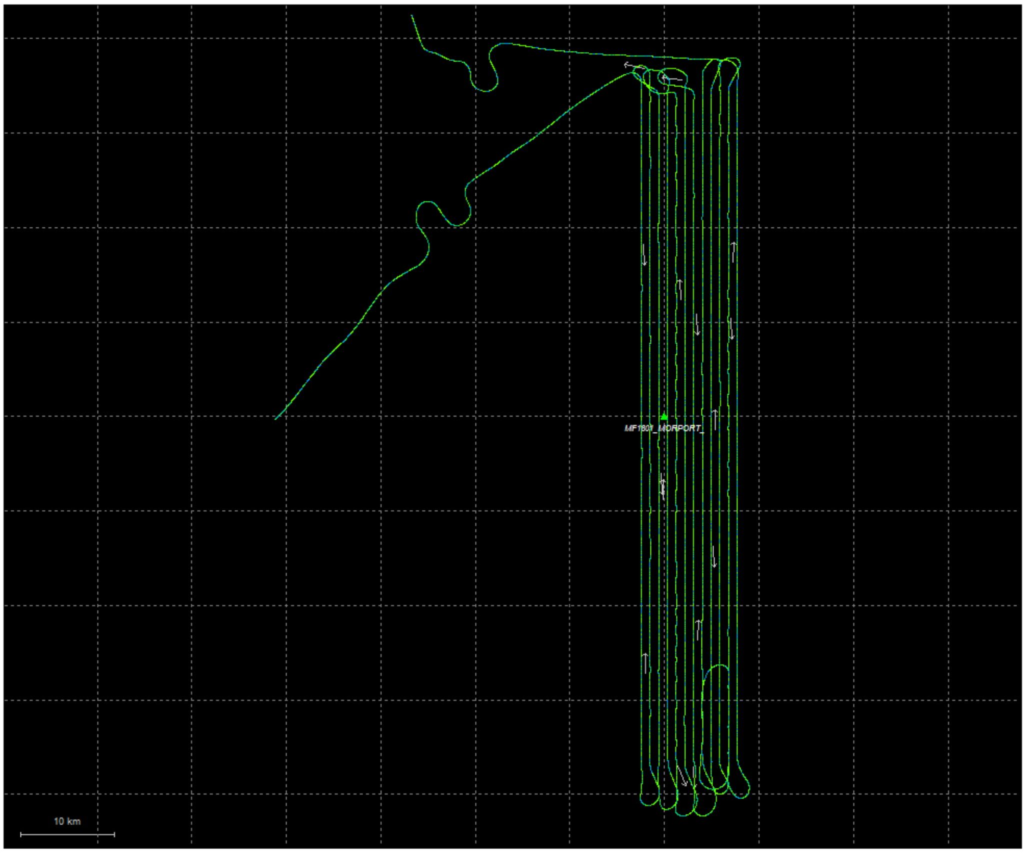
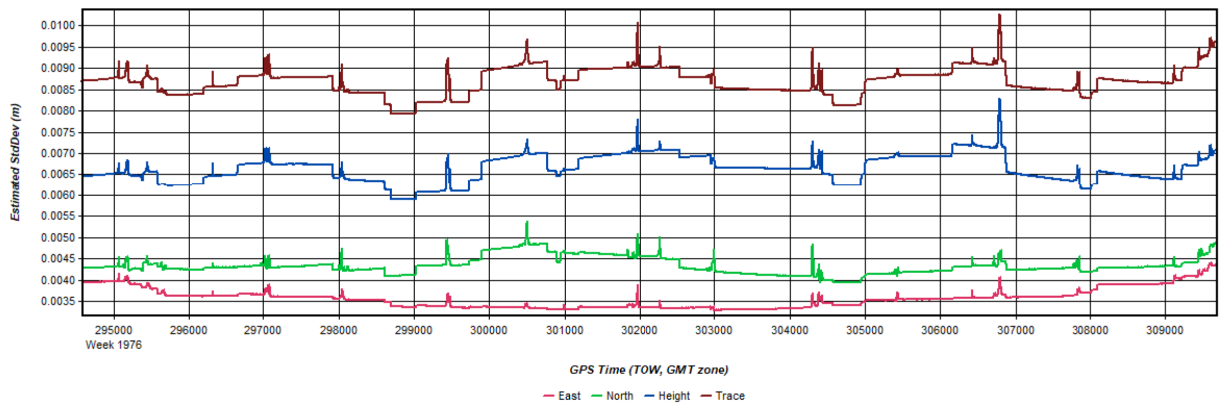
Figure 1: Smoothed TC Combined - Map



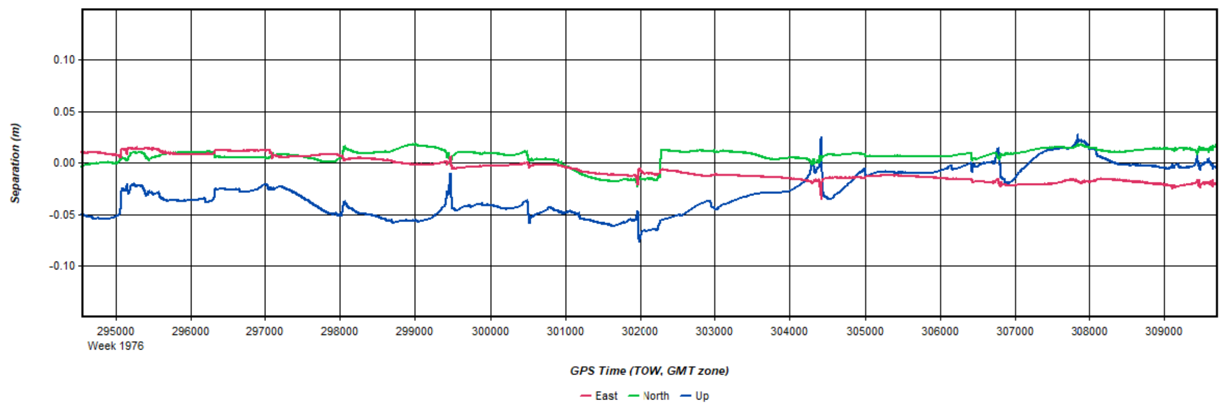
Process	3DEP_LaSalle_20171122_093009	by Unknown	on 11/28/2017	at 14:41:09

Figure 2: 3DEP_LaSalle_20171122_093009 [Smoothed TC Combined] - Estimated Position Accuracy Plot



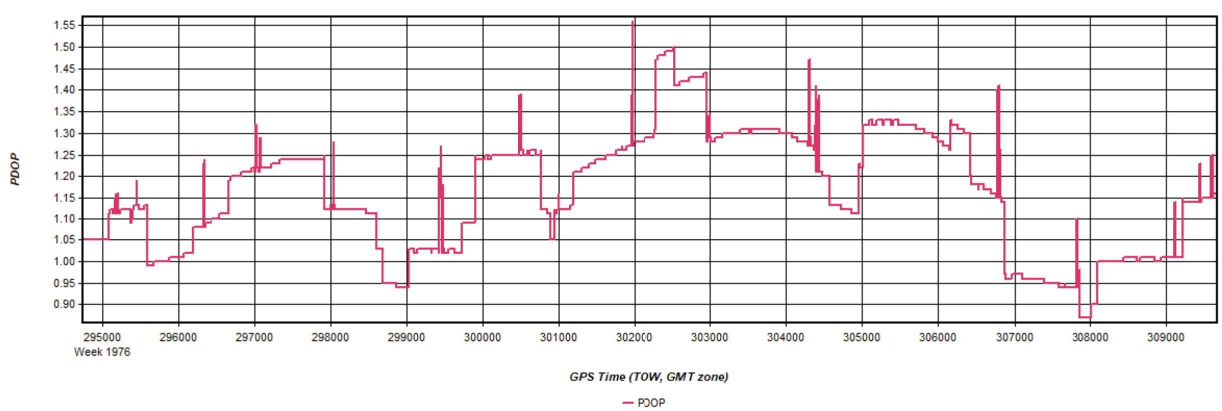
Process	3DEP_LaSalle_20171122_093009	by Unknown	on 11/28/2017	at 14:41:09

Figure 3: 3DEP_LaSalle_20171122_093009 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171122_093009	by Unknown	on 11/28/2017	at 14:41:09

Figure 4: 3DEP_LaSalle_20171122_093009 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171122_093009	by Unknown	on 11/28/2017	at 14:41:09

Output Results for 3DEP_LaSalle_20171122_151109

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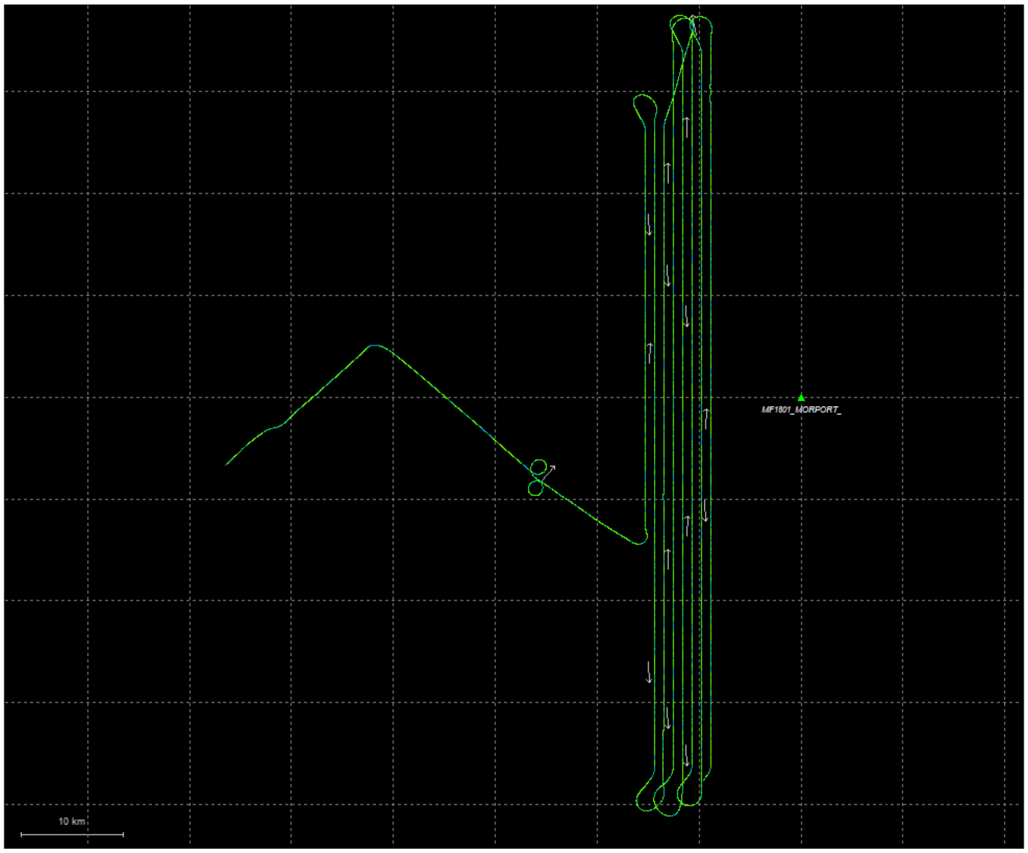
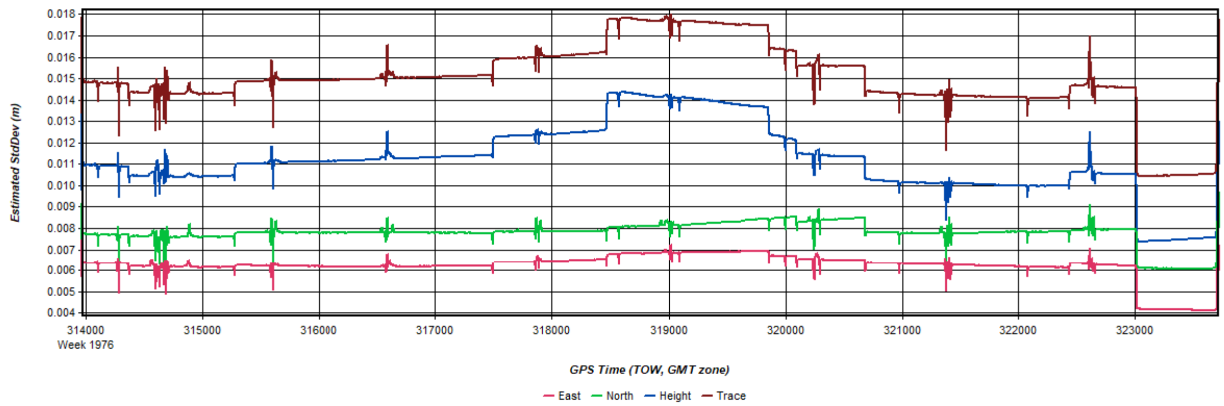
Figure 1: Smoothed TC Combined - Map



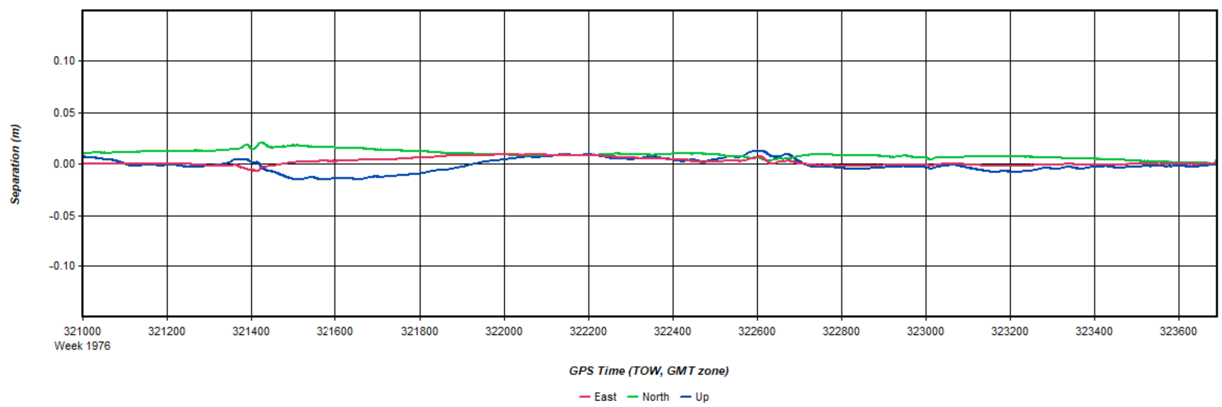
Process	3DEP_LaSalle_20171122_151109	by Unknown	on 11/28/2017	at 16:44:44

Figure 2: 3DEP_LaSalle_20171122_151109 [Smoothed TC Combined] - Estimated Position Accuracy Plot



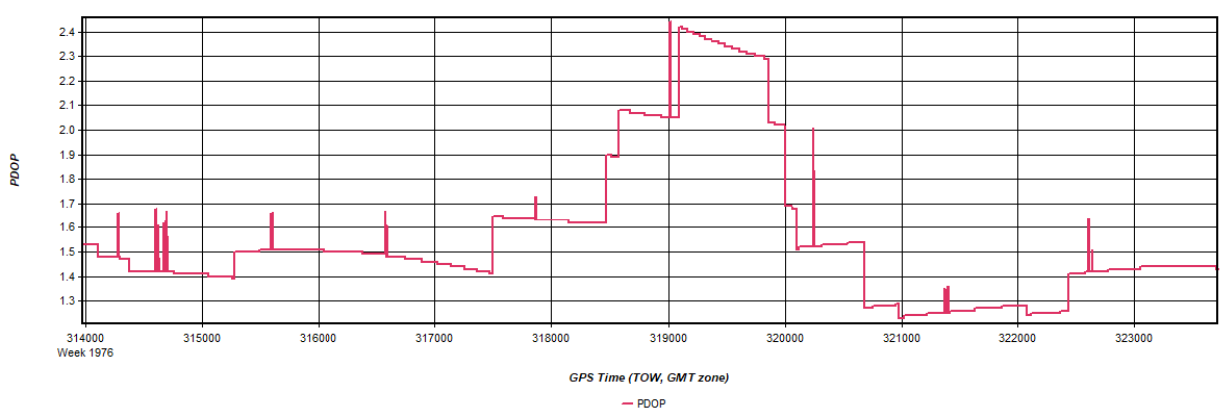
Process	3DEP_LaSalle_20171122_151109	by Unknown	on 11/28/2017	at 16:44:44

Figure 3: 3DEP_LaSalle_20171122_151109 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171122_151109	by Unknown	on 11/28/2017	at 16:44:44

Figure 4: 3DEP_LaSalle_20171122_151109 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171122_151109	by Unknown	on 11/28/2017	at 16:44:44

Output Results for 3DEP_LaSalle_20171122_194241

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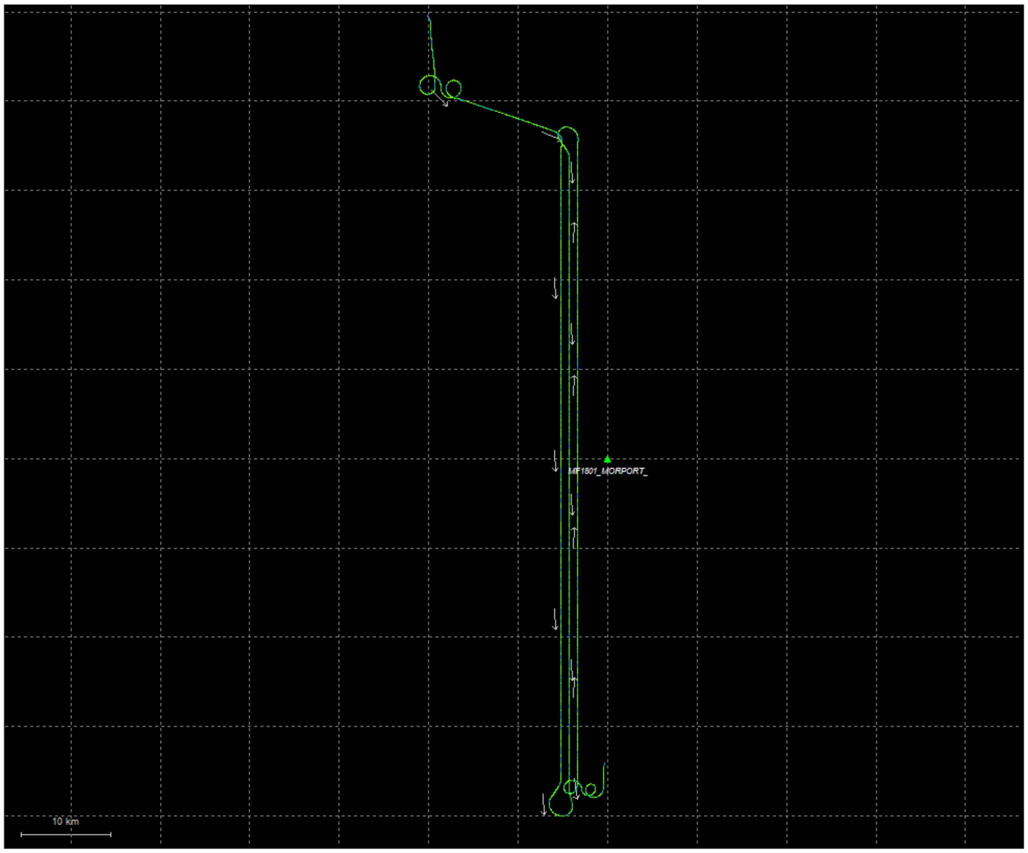
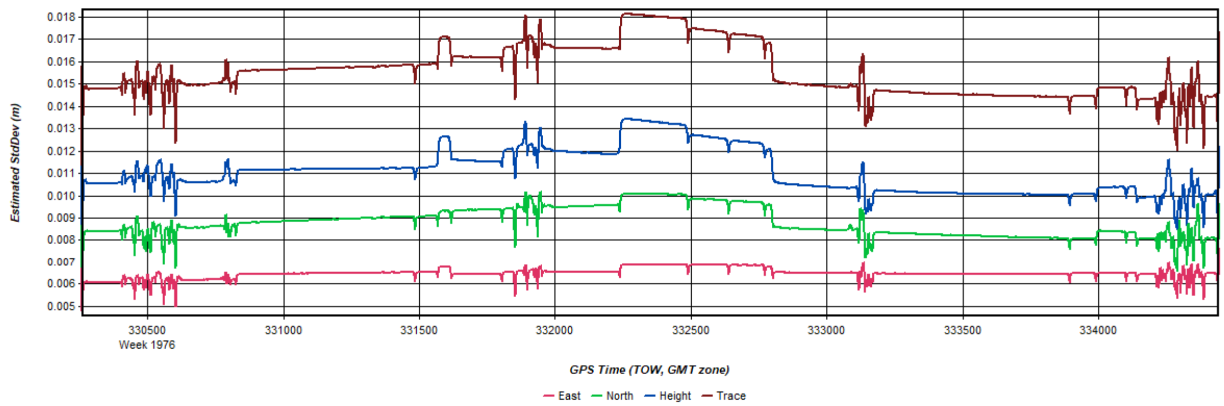
Figure 1: Smoothed TC Combined - Map



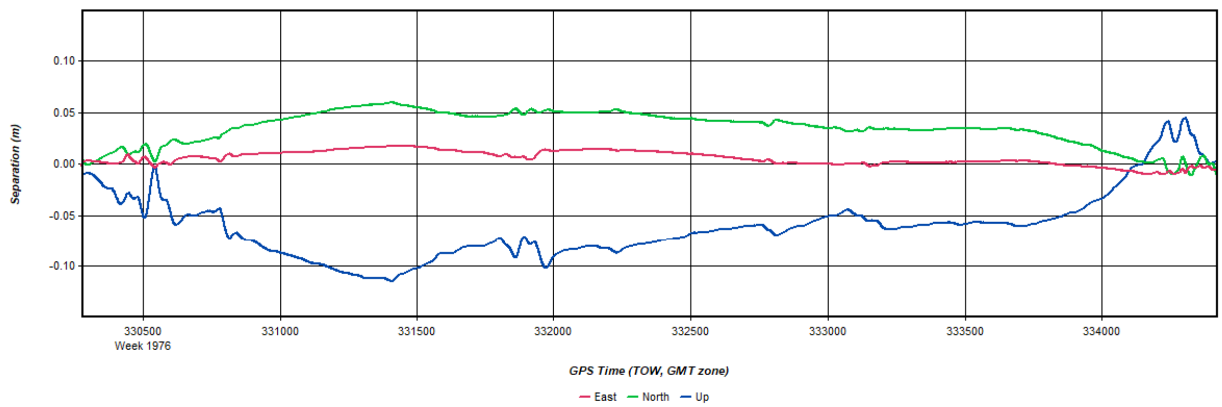
Process	3DEP_LaSalle_20171122_194241	by Unknown	on 11/28/2017	at 17:18:12

Figure 2: 3DEP_LaSalle_20171122_194241 [Smoothed TC Combined] - Estimated Position Accuracy Plot



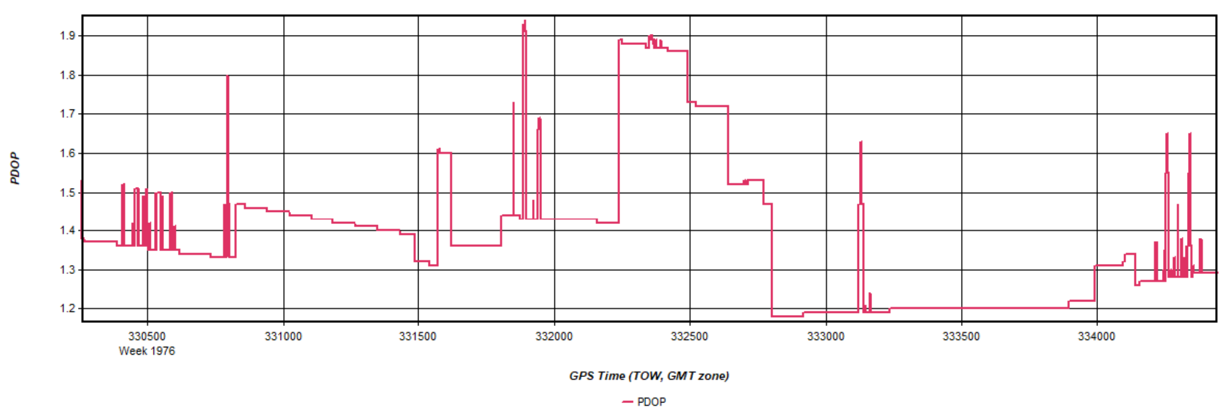
Process	3DEP_LaSalle_20171122_194241	by Unknown	on 11/28/2017	at 17:18:12

Figure 3: 3DEP_LaSalle_20171122_194241 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171122_194241	by Unknown	on 11/28/2017	at 17:18:12

Figure 4: 3DEP_LaSalle_20171122_194241 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171122_194241	by Unknown	on 11/28/2017	at 17:18:12

Output Results for 3DEP_LaSalle_20171122_225808

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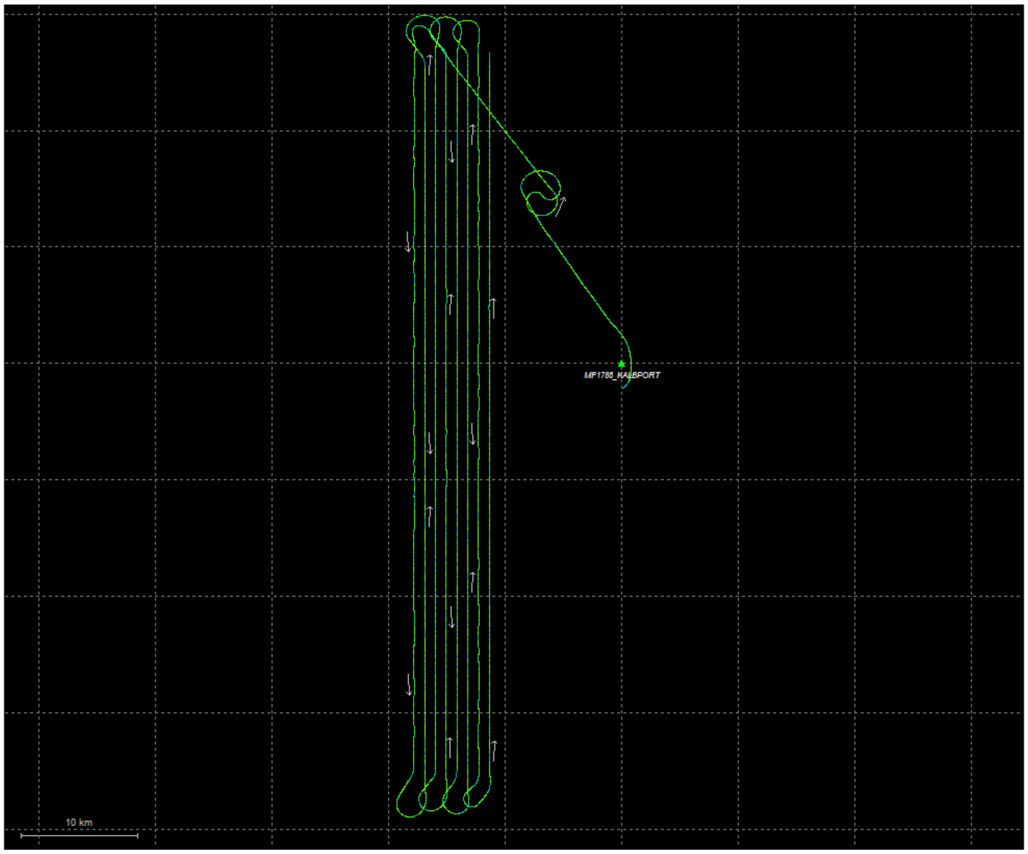
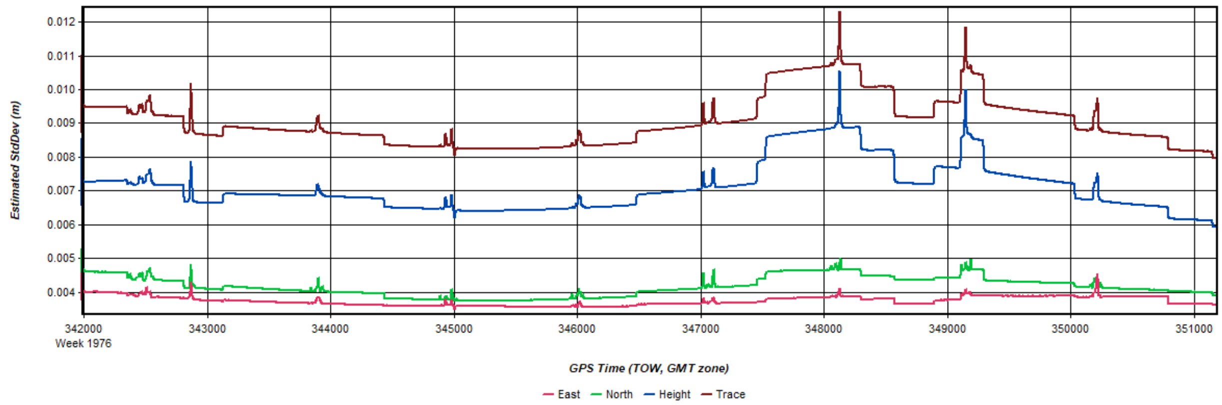
Figure 1: Smoothed TC Combined - Map



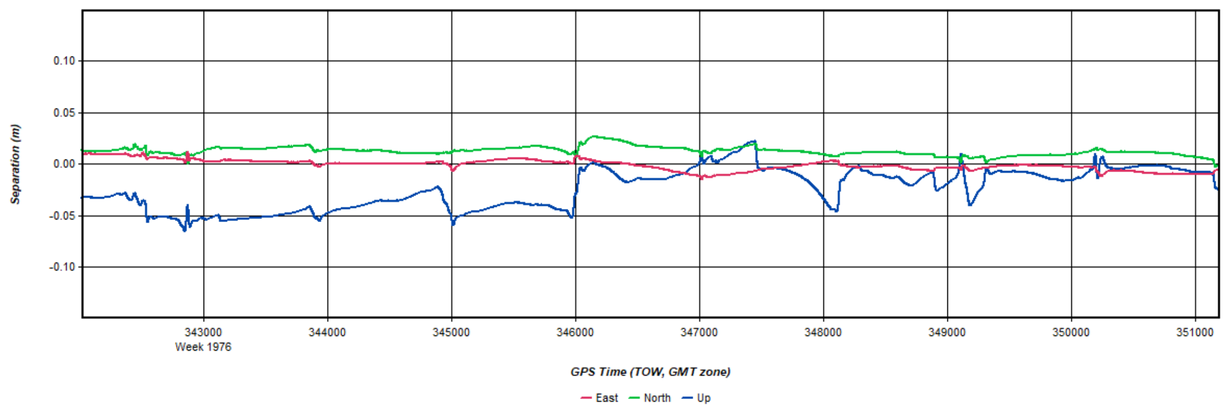
Process	3DEP_LaSalle_20171122_225808	by Unknown	on 11/29/2017	at 08:35:58

Figure 2: 3DEP_LaSalle_20171122_225808 [Smoothed TC Combined] - Estimated Position Accuracy Plot



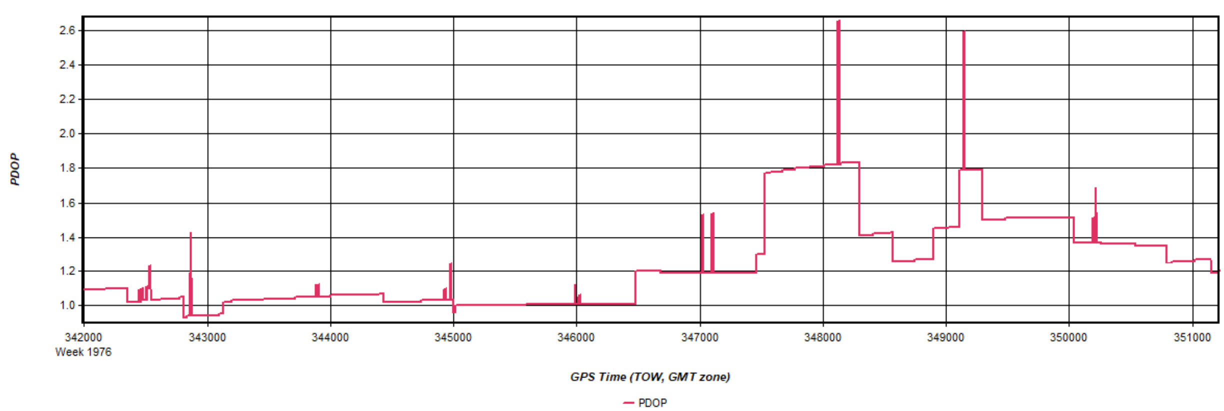
Process	3DEP_LaSalle_20171122_225808	by Unknown	on 11/29/2017	at 08:35:58

Figure 3: 3DEP_LaSalle_20171122_225808 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171122_225808	by Unknown	on 11/29/2017	at 08:35:58

Figure 4: 3DEP_LaSalle_20171122_225808 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171122_225808	by Unknown	on 11/29/2017	at 08:35:58

Output Results for 3DEP_LaSalle_20171122_225808

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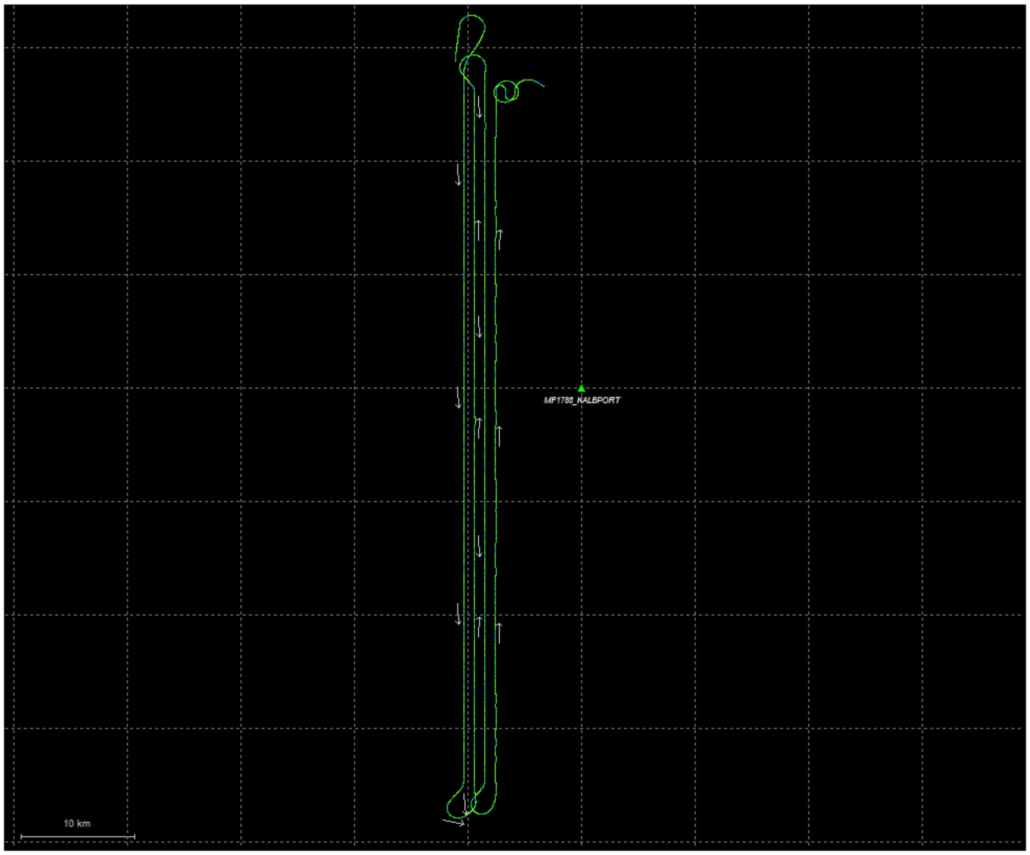
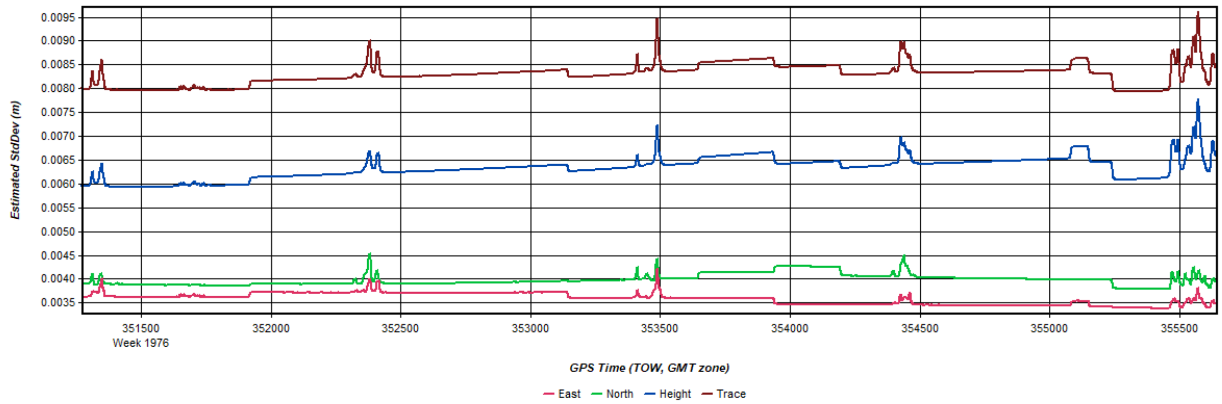
Figure 1: Smoothed TC Combined - Map



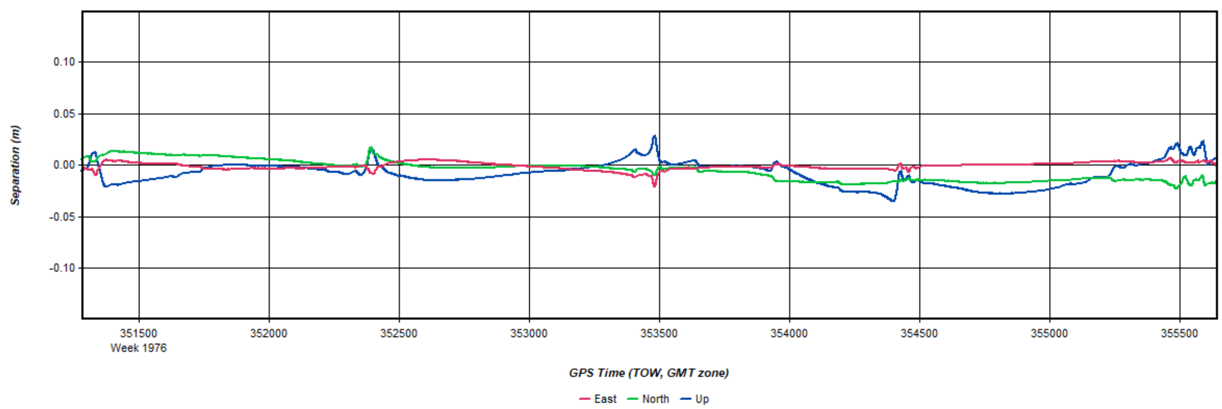
Process	3DEP_LaSalle_20171122_225808	by Unknown	on 11/29/2017	at 08:49:39

Figure 2: 3DEP_LaSalle_20171122_225808 [Smoothed TC Combined] - Estimated Position Accuracy Plot



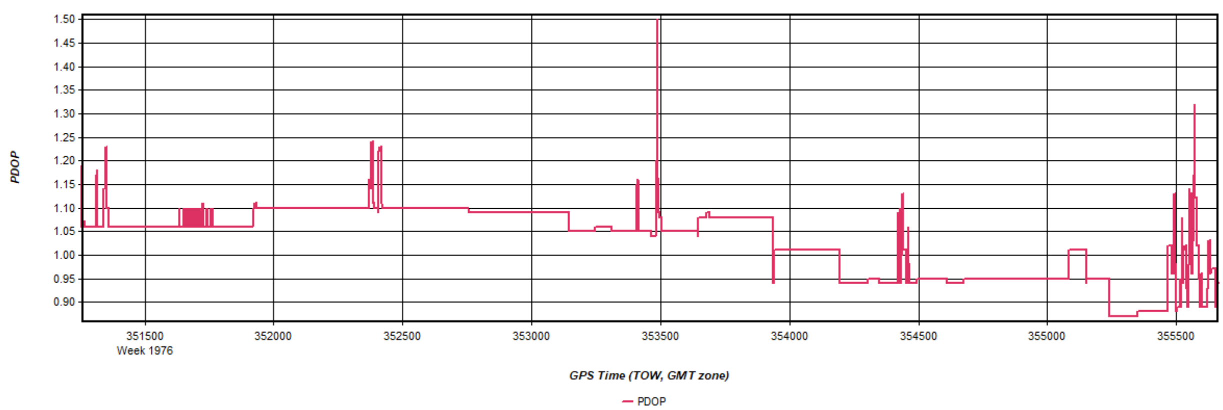
Process	3DEP_LaSalle_20171122_225808	by Unknown	on 11/29/2017	at 08:49:39

Figure 3: 3DEP_LaSalle_20171122_225808 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171122_225808	by Unknown	on 11/29/2017	at 08:49:39

Figure 4: 3DEP_LaSalle_20171122_225808 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171122_225808	by Unknown	on 11/29/2017	at 08:49:39

Output Results for 3DEP_LaSalle_20171123_153058

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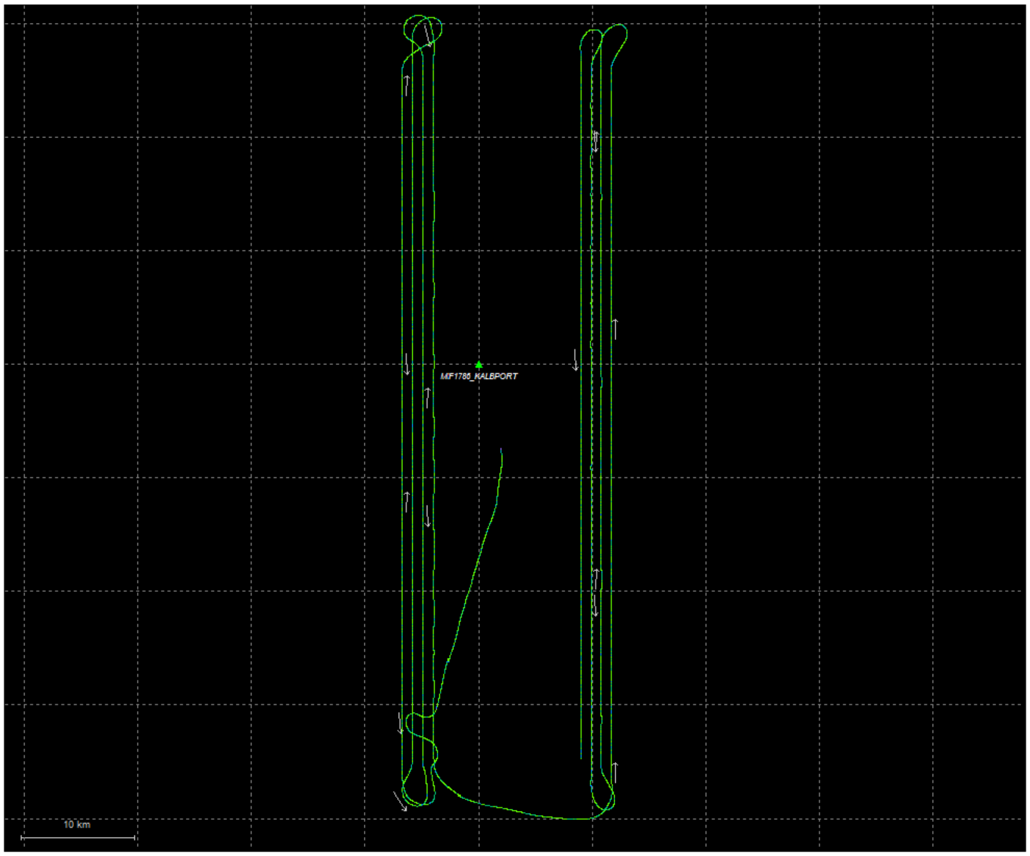
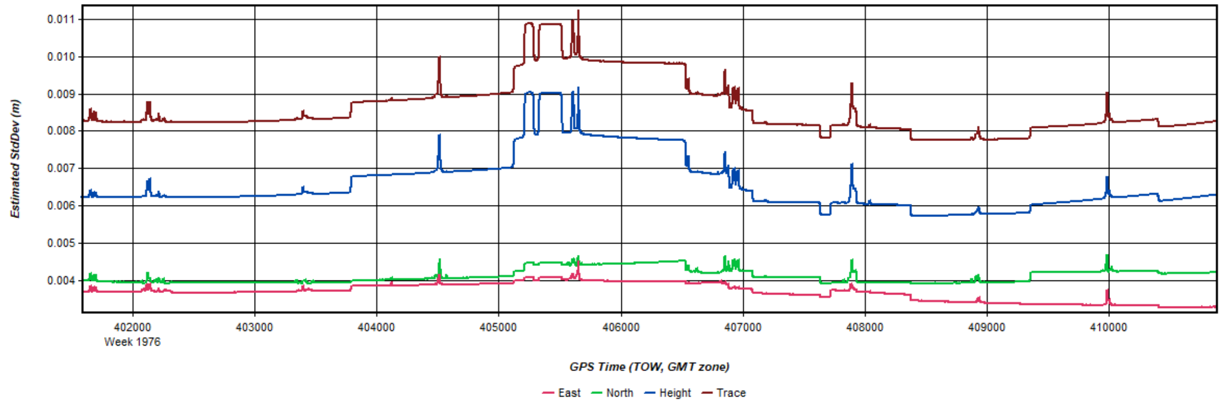
Figure 1: Smoothed TC Combined - Map



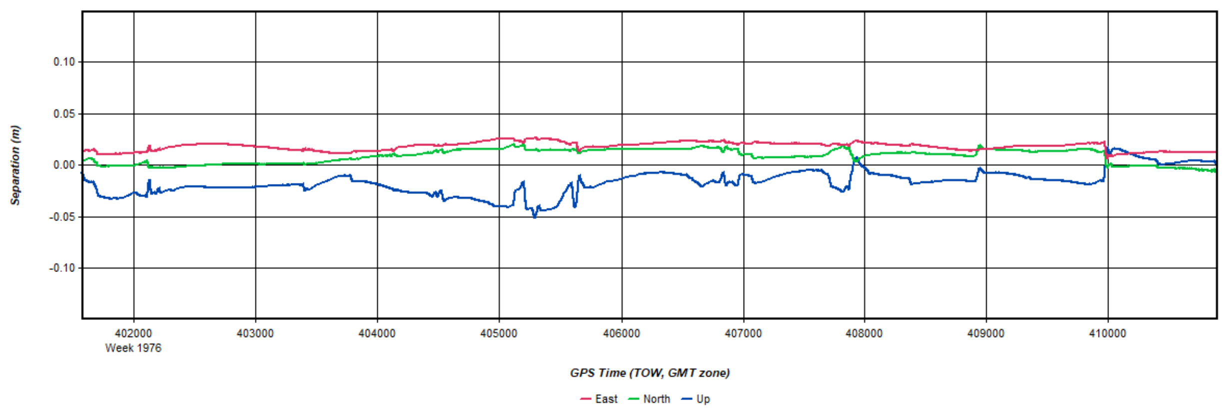
Process	3DEP_LaSalle_20171123_153058	by Unknown	on 11/29/2017	at 09:33:16

Figure 2: 3DEP_LaSalle_20171123_153058 [Smoothed TC Combined] - Estimated Position Accuracy Plot



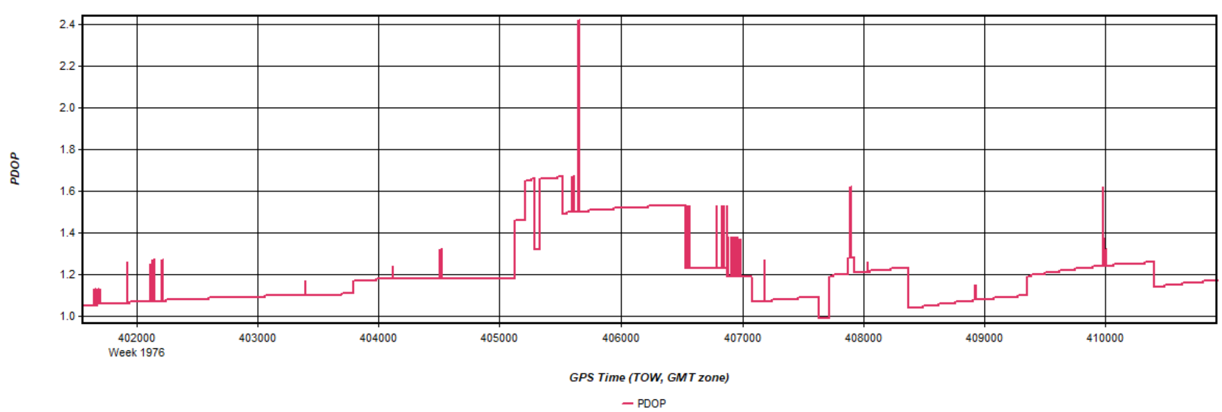
Process	3DEP_LaSalle_20171123_153058	by Unknown	on 11/29/2017	at 09:33:16

Figure 3: 3DEP_LaSalle_20171123_153058 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171123_153058	by Unknown	on 11/29/2017	at 09:33:16

Figure 4: 3DEP_LaSalle_20171123_153058 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20171123_153058	by Unknown	on 11/29/2017	at 09:33:16

Output Results for 3DEP_LaSalle_20171123_153058

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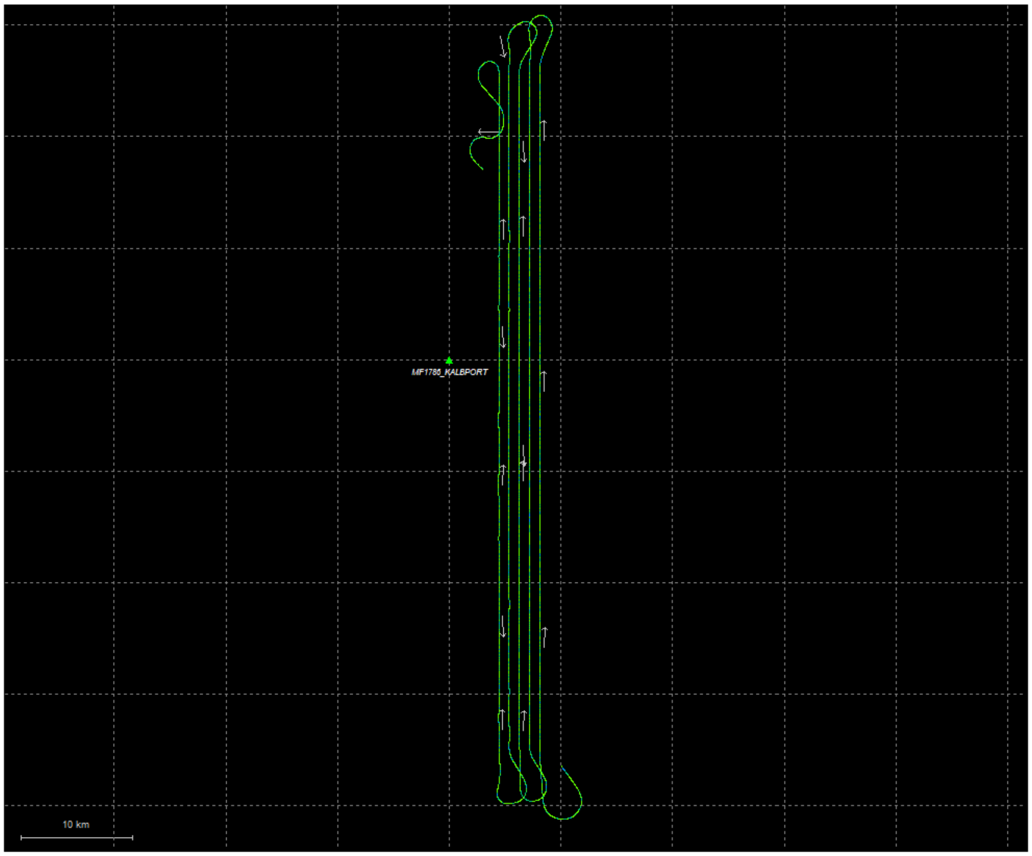
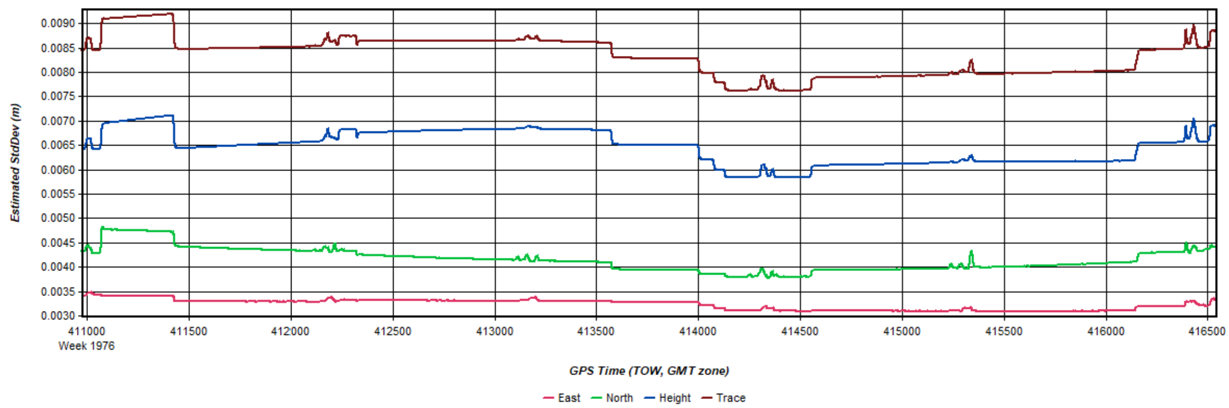
Figure 1: Smoothed TC Combined - Map



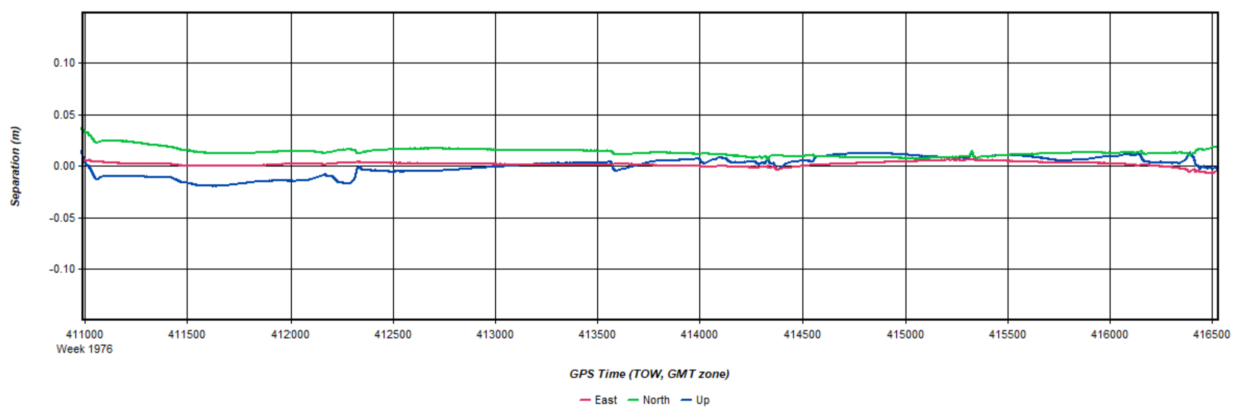
Process	3DEP_LaSalle_20171123_153058	by Unknown	on 11/29/2017	at 09:31:41

Figure 2: 3DEP_LaSalle_20171123_153058 [Smoothed TC Combined] - Estimated Position Accuracy Plot



Process	3DEP_LaSalle_20171123_153058	by Unknown	on 11/29/2017	at 09:31:41

Figure 3: 3DEP_LaSalle_20171123_153058 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171123_153058	by Unknown	on 11/29/2017	at 09:31:41

Object 3DEP_LaSalle_20171123_153058 [Smoothed TC Combined] - PDOP Plot failed--NULL bitmap handle

Output Results for 3DEP_LaSalle_20171123_203113

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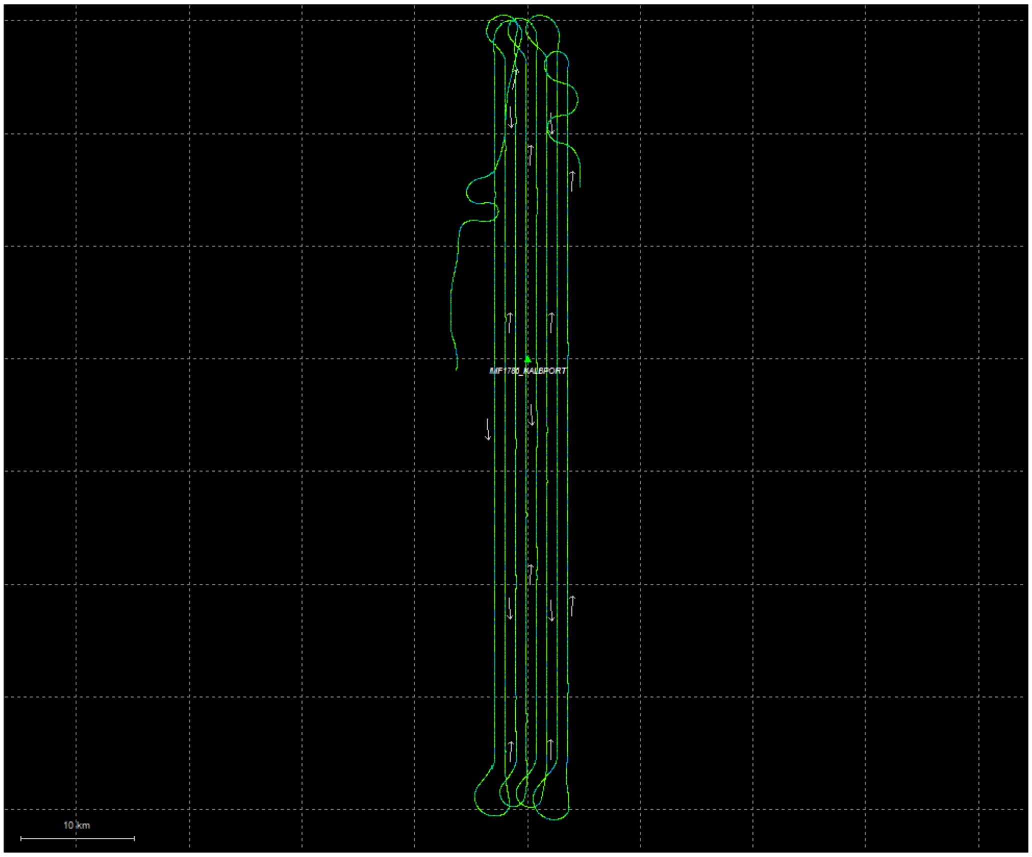
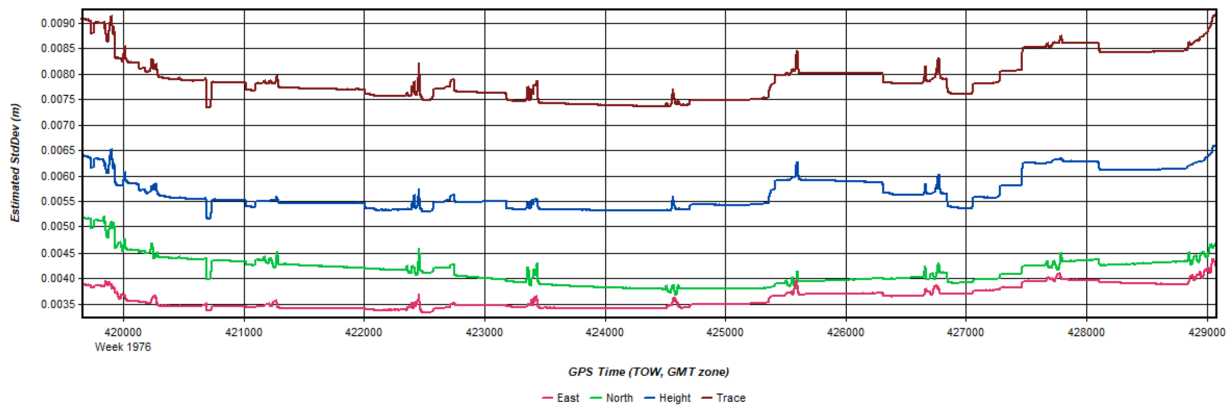
Figure 1: Smoothed TC Combined - Map



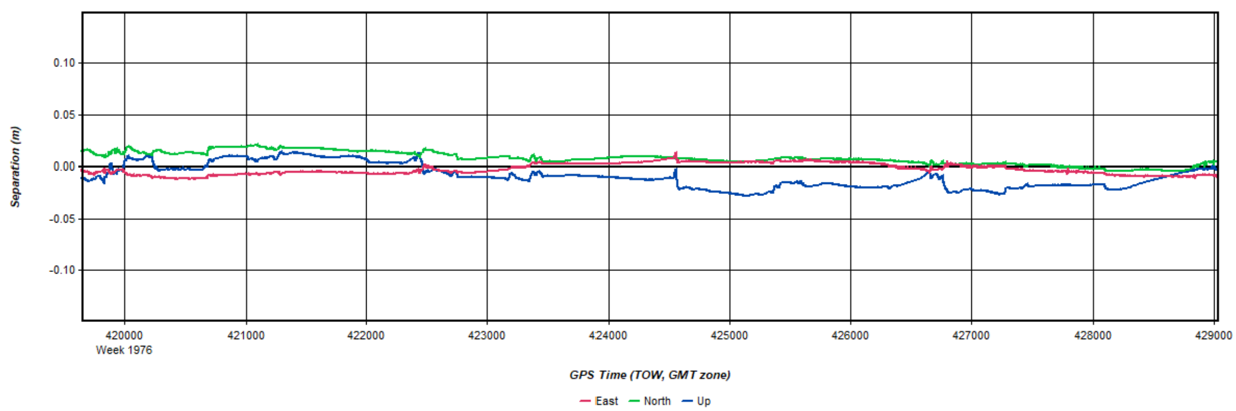
Process	3DEP_LaSalle_20171123_203113	by Unknown	on 11/29/2017	at 10:55:38

Figure 2: 3DEP_LaSalle_20171123_203113 [Smoothed TC Combined] - Estimated Position Accuracy Plot



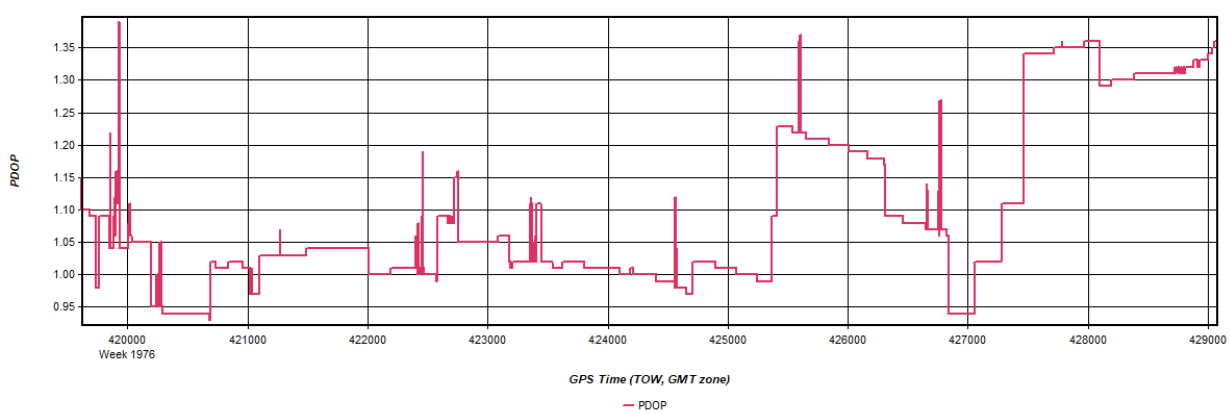
Process	3DEP_LaSalle_20171123_203113	by Unknown	on 11/29/2017	at 10:55:38

Figure 3: 3DEP_LaSalle_20171123_203113 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20171123_203113	by Unknown	on 11/29/2017	at 10:55:38

Figure 4: 3DEP_LaSalle_20171123_203113 [Smoothed TC Combined] - PDOP Plot

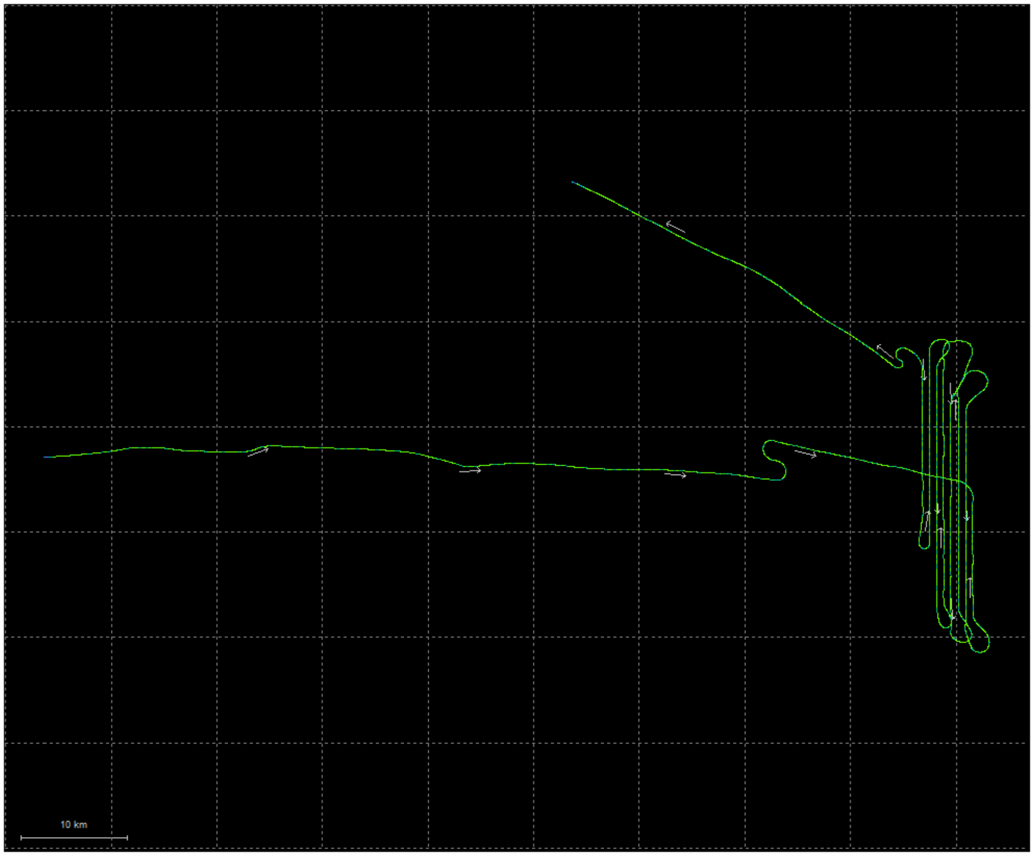


Process	3DEP_LaSalle_20171123_203113	by Unknown	on 11/29/2017	at 10:55:38

Output Results for 3DEP_LaSalle_20180412_223113

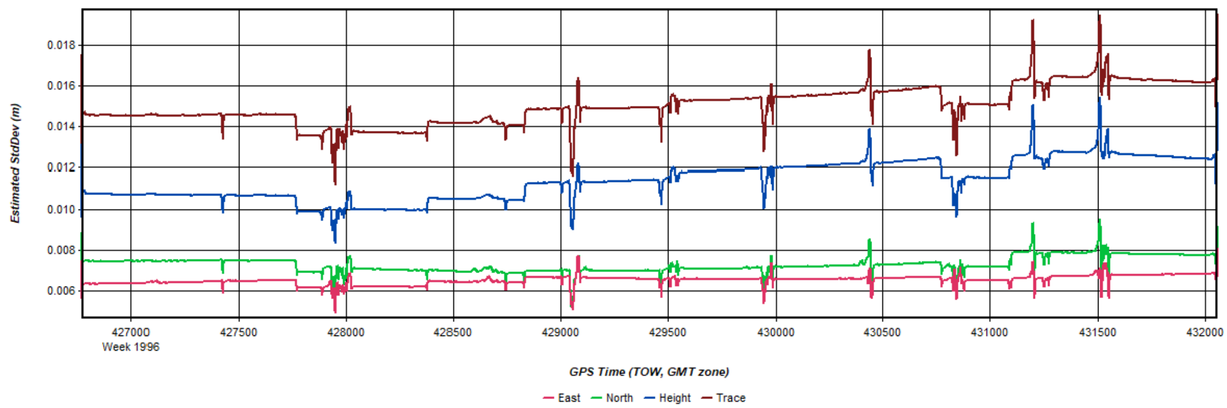
Inertial Explorer Version 8.60.6717
06/08/2018

Figure 1: Smoothed TC Combined - Map



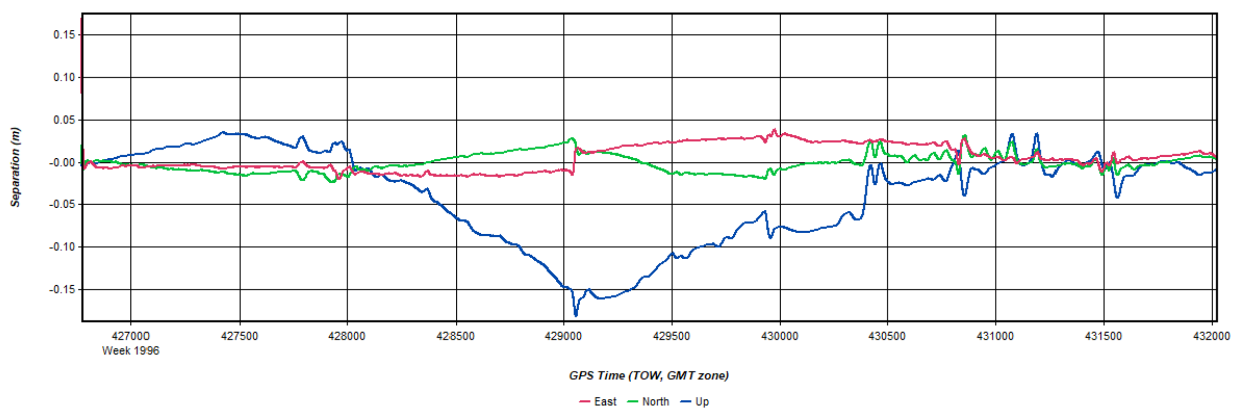
Process	3DEP_LaSalle_20180412_223113	by Unknown	on 4/13/2018	at 13:28:44

Figure 2: 3DEP_LaSalle_20180412_223113 [Smoothed TC Combined] - Estimated Position Accuracy Plot



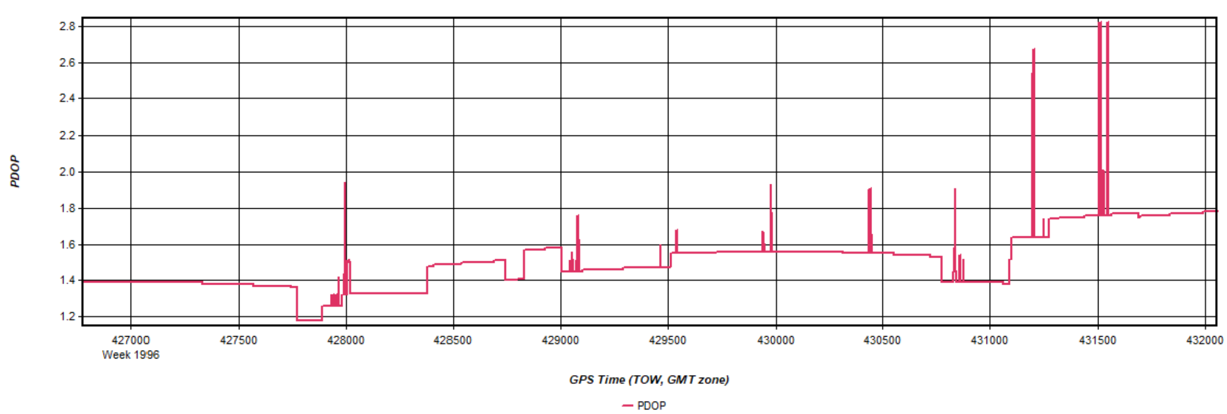
Process	3DEP_LaSalle_20180412_223113	by Unknown	on 4/13/2018	at 13:28:44

Figure 3: 3DEP_LaSalle_20180412_223113 [Smoothed TC Combined] - Forward/Reverse or Combined Separation Plot



Process	3DEP_LaSalle_20180412_223113	by Unknown	on 4/13/2018	at 13:28:44

Figure 4: 3DEP_LaSalle_20180412_223113 [Smoothed TC Combined] - PDOP Plot



Process	3DEP_LaSalle_20180412_223113	by Unknown	on 4/13/2018	at 13:28:44