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Overview

The State of North Carolina Floodplain Mapping Program (NCFMP) has provided ESP Associates, P.A. (ESP) a Request for Delivery Order (RFDO) to perform LiDAR data collection, processing, and generation of Hydro DEM raster products for the Phase 4 area covering portions of the Piedmont and Mountain regions of North Carolina. In addition, the State has requested optional value added products which are addressed separately in this document. ESP has been asked to submit written technical and business proposals in response to the request, compliant with our IDIQ contract No. 286-0000-30 ESP. Our technical and business proposals incorporate lessons learned from Phase 2 operations.

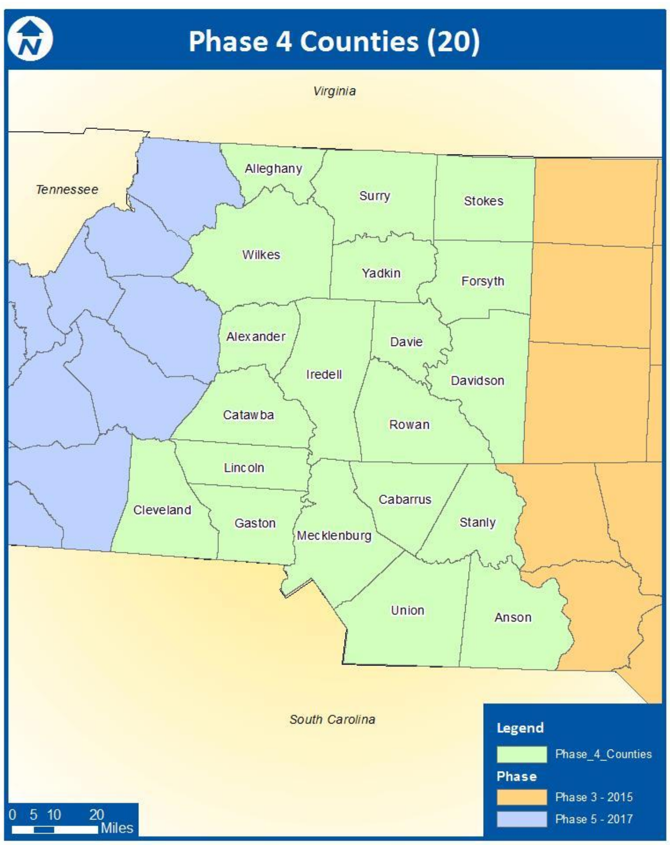
Scope of Work

Data will be collected at ≥30 points per square meter (PPM) to support subsequent high resolution data buy-ups. The baseline data for delivery will cover the entire area shown in Figure 1, plus a 100 meter buffer outside of the tile layout covering the project area. Data will meet the requirements for the current USGS Quality Level 1 (QL1) LiDAR Specification with an aggregate nominal pulse density (ANPD) of ≥8 PPM with an aggregate nominal post spacing of ≤ 0.35 meters. The data must be equivalent to a RMSE of 9.25cm or better for Non-vegetated vertical accuracy (NVA). The counties included with this delivery are shown in Table 1 and in Figure 1, below.

Table 1: Counties included with this delivery order (20)

2016 North Carolina LiDAR Collection				
Alexander	Cleveland	Iredell	Stokes	Catawba
Alleghany	Davidson	Lincoln	Surry	Gaston
Anson	Davie	Mecklenburg	Union	Stanly
Cabarrus	Forsyth	Rowan	Wilkes	Yadkin

Figure 1: 2016 Phase 4 LiDAR project area map



Task 1: LiDAR Data Acquisition

Task 1 will include the necessary subtasks for the acquisition of LiDAR data. The following is a summary of the scope of services for Task 1.

Task 1a: Planning, Coordination, Flight Operations, and Specifications

Overview

The ESP team will be acquiring, processing, and delivering the requested LiDAR data and the derivative products. For Task 1, the LiDAR data will be acquired by the ESP team member Harris Corporation (Harris) using a Geiger-mode Avalanche Photodiode (GmAPD) sensor. The data will be collected to meet an aggregate nominal pulse density (ANPD) of ≥30 PPM with delivery of 8PPSM at an aggregate nominal post spacing (ANPS) of ≤0.35 meters. The data shall be equivalent to a RMSE of 9.25 cm or better for NVA based on current USGS specifications (modified to State-required 9.25 cm from USGS-required 10 cm.

Kickoff Meeting

Once this technical proposal has been accepted by the State, a kickoff meeting will be held with the ESP team, the State, and other relevant stakeholders. This meeting will be held before the data collection to reach consensus and acquire State approval on the data collection flight plan, acquisition plan parameters, reporting mechanisms, communication plan, and identification of the project's points of contact (POC). This meeting will also establish the protocol for potential ground condition issues during acquisition, such as heavy rain, flooding, leaf out, snow, or other unforeseeable circumstances.

Flight Operations Management

Harris will conduct flight operations management for the aerial LiDAR collection and will report to ESP during all phases of the acquisition. Their responsibilities will include data acquisition plan, daily ongoing flight plan management, crew coordination, issue mitigation, coordination with Military Operation Areas (MOAs), as well as daily progress reporting to ESP via ESP's Daily Activity Reports. Status of collection will be updated to the State by ESP North Carolina either on a daily or weekly basis, as determined in the kickoff meeting.

Project Boundary and Buffer

ESP has submitted a project boundary digitally to the State for evaluation and approval. ESP understands that the buffer requirement based on North Carolina Specifications for LiDAR Base Mapping is currently 2,000 feet. ESP believes this is unnecessary for evaluation of the data seam between the USGS and NRCS collection areas and would like to propose a smaller buffer to facilitate cost savings for the State. This approach to the buffer requirement was successfully used for Phase 2. Figure 2 (below) shows the LiDAR tiles that will be captured and processed by ESP for delivery to the State. Figure 3 (below) illustrates the LiDAR tiles and the 100 meter buffer that will be implemented relative to the political boundaries for the counties ESP will be performing LiDAR acquisition. Please note that ESP requests that the State reduce the project boundary buffer from 2,000 feet to 100 meters. This recommendation is also summarized in Appendix A, Requested Technical Specification Exemptions.

Figure 2: LiDAR tile scheme map

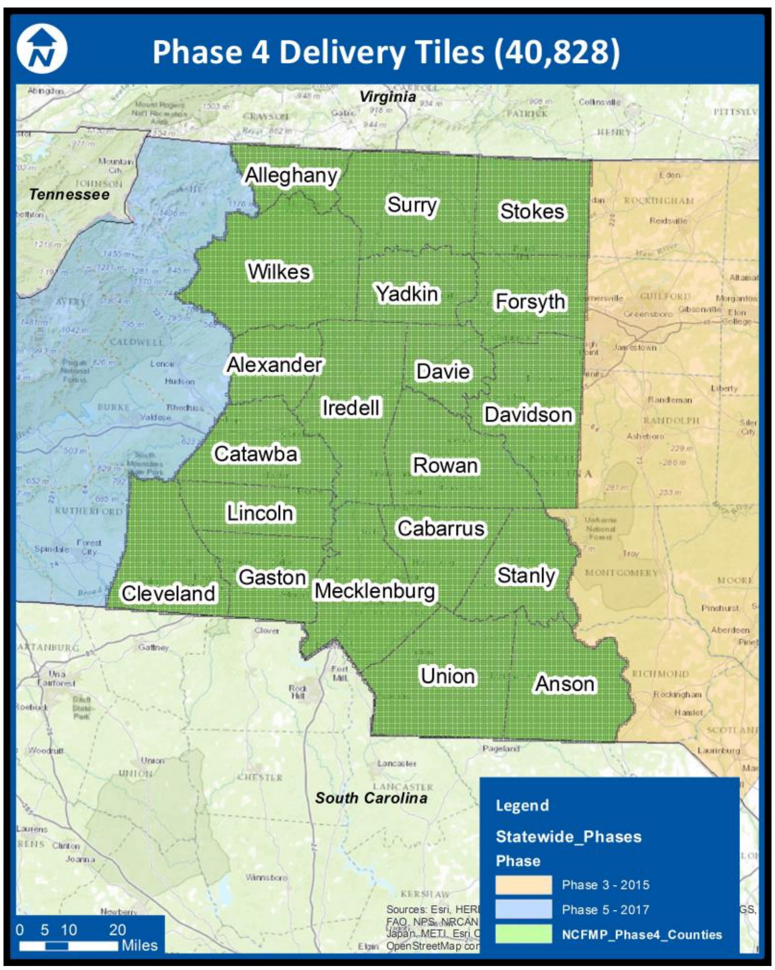
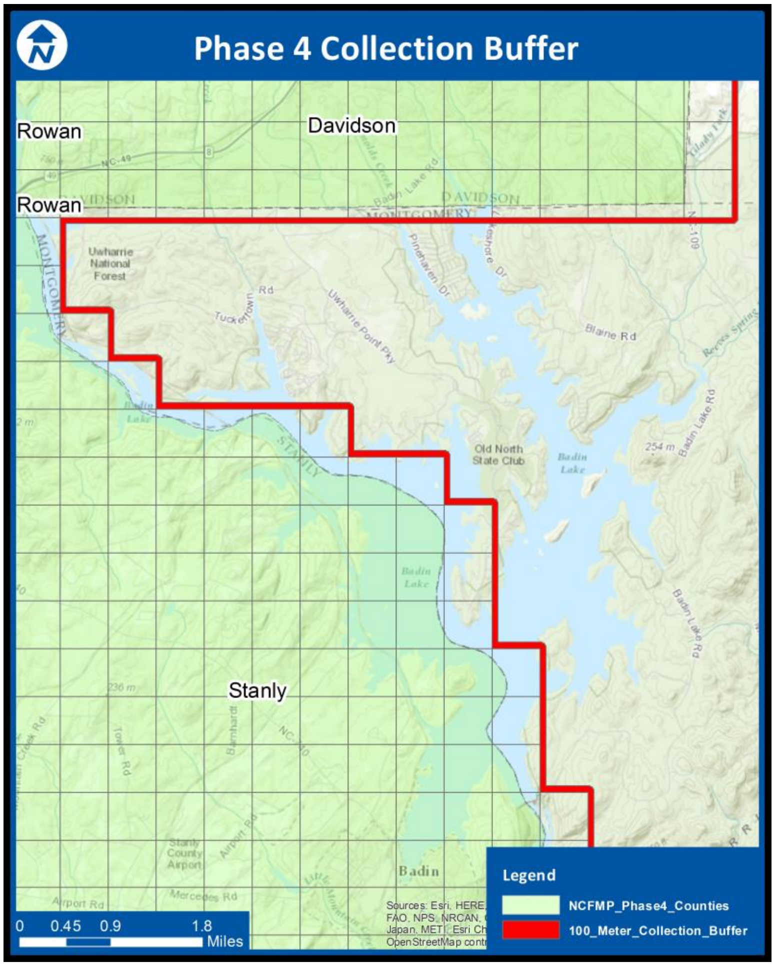


Figure 3: LiDAR tile scheme and 100 meter buffer



Task 1b: Data Acquisition

Acquisition Specifications

The GmAPD LiDAR system that will be used on the project shall meet/exceed the minimum specifications for the State and the USGS. Included in Appendix B of this technical proposal is a listing of all hardware and software that is planned for use within this delivery order. Table 2 (below) details the specific acquisition specifications that will be followed as part of this delivery order. *Note: Vegetated Vertical Accuracy (VVA) and Supplemental Vertical Accuracy (SVA) can only be computed post-classification.*

Table 2: Acquisition parameters for Phase 4

Parameter	Specification
Boundary buffer	≥ 100 meters beyond tile boundaries
Nominal Post Spacing (NPS)	≤ 0.35 meters, including overlap
Signal returns	N/A (GmAPD systems are not multiple return systems)
Intensity	Each return pulse
Overlap	≥ 55%
Maximum line length	≤ 150km (92 miles)
Maximum Scan Angle	≤40 Degrees
Maximum line time	≤ 20 minutes
Clustering	Regular grid of with a cell size of 8*NPS ≥ 90% of cells will contain at least one LiDAR point
Vertical accuracy	$RMSE_z$ = 9.25cm (NVA) NVA= 18.13 cm at 95% CI SVA = 26.9cm at 95th percentile VVA = 26.9cm at 95th percentile

Acquisition Conditions

The LiDAR acquisition team will adhere to the following environmental guidelines as shown in Table 3. Any request to deviate from this plan due to unforeseen circumstances will be clearly and immediately communicated to the State for written approval as/if necessary.

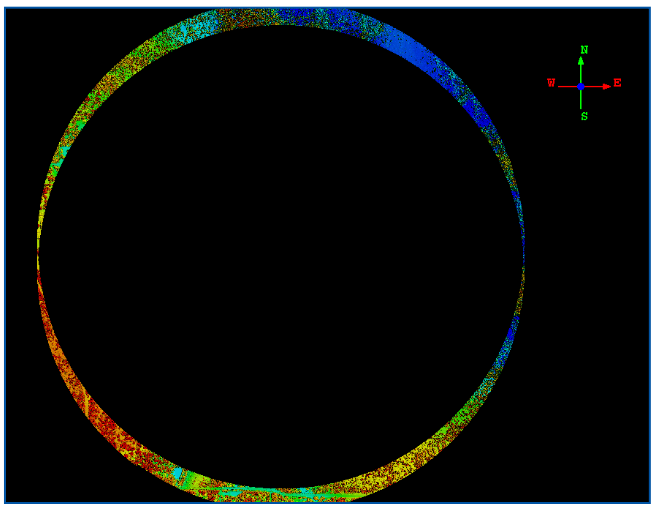
Table 3: Environment condition parameters data acquisition

Parameter	Specification
Acquisition window	Winter/Spring 2016
	April 15, 2016 acquisition cut-off
Atmospheric conditions	Cloud and fog free
	Snow free (light, undrafted snow may be acceptable)
	No unusual flooding or inundation
	Leaf-off
Tidal conditions	Not applicable to this phase of the program

Flight Line Overlap

ESP is aware of the 50% overlap requirement based on the North Carolina Specifications for LiDAR Base Mapping. This specification was based on older sensor technologies, which could not achieve the Ground Sample Distance (GSD) requirements without this amount of overlap. The GmAPD sensor being used by ESP is a Palmer scanner which collects data in a circular scan pattern on the ground. The forward overlap of each scan is significantly greater than a 50% overlap and the standard sidelap of swaths collected by the GmAPD sensor is always 55% or greater. *Due to this standard collection parameter of the GmAPD sensor, the ESP team will not require an exemption from the 50% overlap requirement.* Figure 4 depicts a single scan pattern from the sensor.

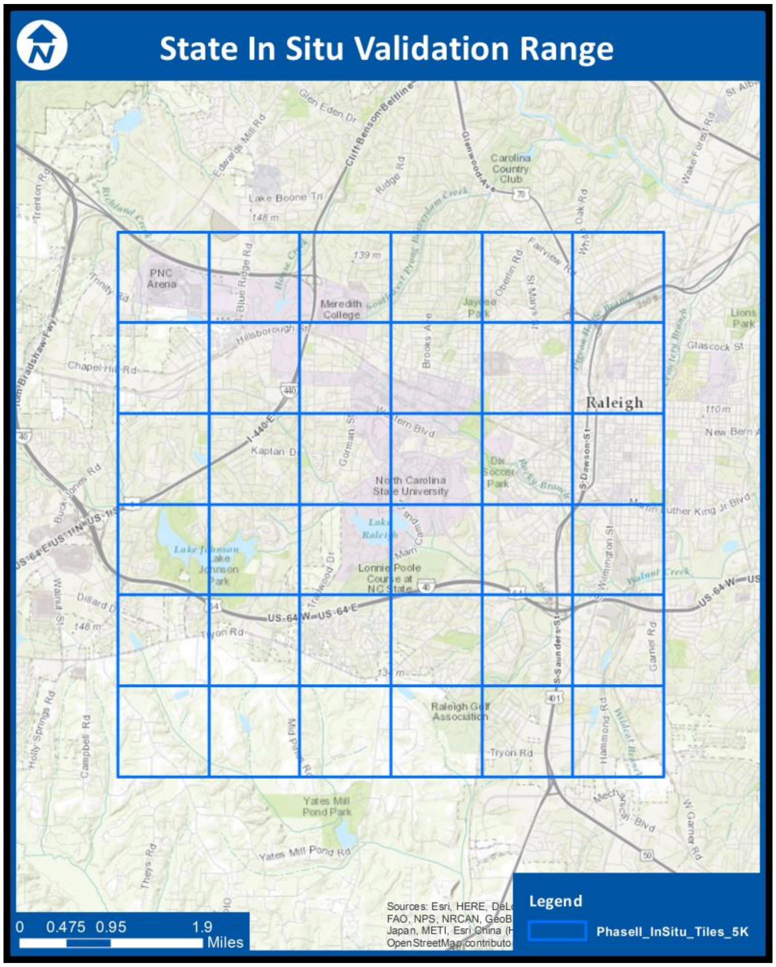
Figure 4: GmAPD scan pattern example



***In Situ* Validation Range**

ESP is aware of the North Carolina *In Situ* Validation Range Requirement. The purpose of this requirement is to validate the LiDAR sensor in a working environment to prove that it can correctly and consistently acquire data that meet the specifications of the project. ESP will utilize the In Situ range established during Phase 2 of the program. This validation range is illustrated in Figure 5.

Figure 5: *In Situ* validation range



Daily Calibration Flights (Pre/Post Mission)

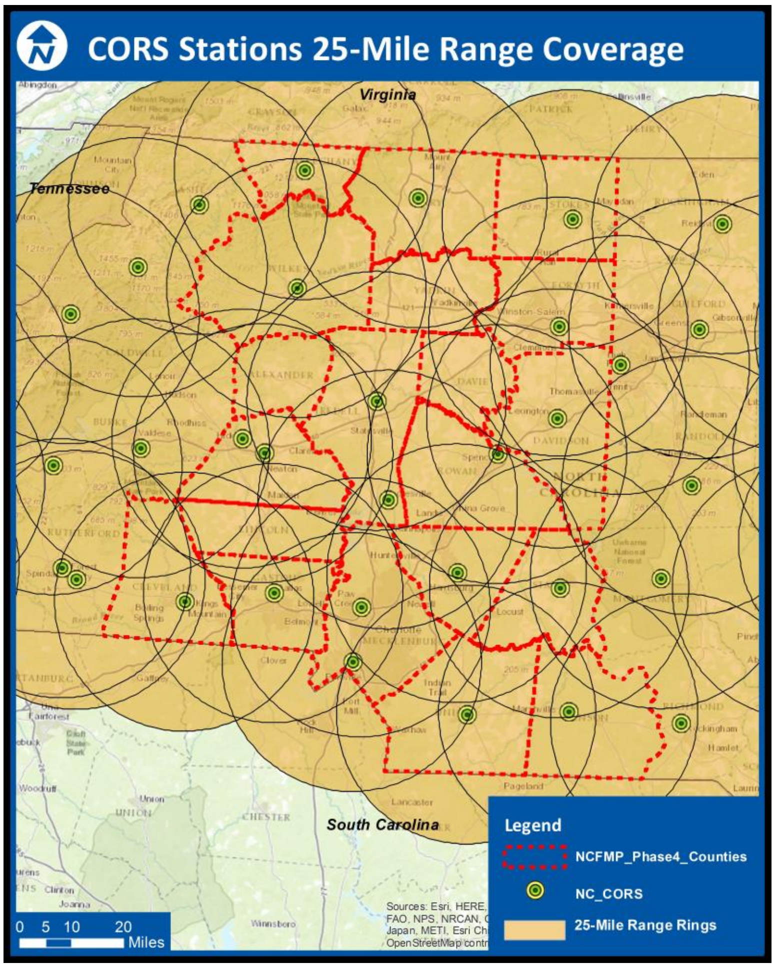
ESP is aware of the State's LiDAR specification regarding the pre- and post-flight collection of calibration flights over established control to boresight LiDAR sensors. Based on ESP's experience, this requirement is based on older calibration procedures that lacked methods for bundle adjustment, a procedure commonly used today to meet and exceed project accuracy. The bundle adjustment approach for GmAPD LiDAR is a more robust approach that will better address the ≤5 centimeter flight line-to-flight line separation and fundamental 9.25 centimeter accuracy requirements. This process is akin to traditional photogrammetric aerotriangulation and will be further detailed in **Task 1d Calibration**. Please note that ESP requests that the State waive the pre- and post-flight flight calibration requirement and accept our new calibration methodology. This will also be included in Appendix A, Requested Technical Specification Exemptions.

Data Acquisition Plan

The data collection plan has been broken into sub-blocks which limit flight line length to 92 miles. This equates to a maximum online time of ≤ 20 minutes for each flight line to reduce any potential inertial drift which improves inertial precision. Because of the technology being used, the aircraft is able to cover more ground within the 20 minute threshold. In addition, each block contains a cross flight collection which will be used for the bundle adjustment calibration procedure.

GPS Coverage Considerations
As illustrated in Figure 6, roving base stations will not be required due to the dense Continuously Operating Reference Station (CORS) network in the State of North Carolina. This figure portrays the 1-second frequency CORS stations with a 25 mile radius. As shown, the requirement to maintain less than 50 km (31 miles) from each base station is easily satisfied using the existing network.

Figure 6: North Carolina CORS network availability, 50-mile radius rings



Military Operation Areas (MOAs) and Restricted Areas
Based on the current military tile and bounds layer, there are currently no identified MOAs within the Phase 4 project area. However, this will be reviewed and verified with the State to ensure that the current information is correct. In the event that MOAs are present, all of ESP's team members have faced the challenges of MOAs, Restricted, and Temporary Flight Restricted (TFR) airspaces in previous projects, including in prior years of the North Carolina Statewide Ortho-imagery program. We understand that coordination with MOAs requires contacting the proper authorities to arrange to

either capture data in off-hours or be granted non-interfering access during “hot” hours. In many cases, data acquisition must occur when the range is “cold”. Since LiDAR can take place during evening hours, as opposed to imagery acquisition during daylight hours, the option remains to acquire data outside of the operating hours of the MOA, which is typically between sunrise and sunset.

Restricted and TFR areas are another matter, if present, and will require help from the State to determine a suitable solution. In all cases, ESP will present detailed flight plans to the required authorities to both pursue a solution with each and keep them fully informed. Harris’ acquisition manager will coordinate these issues in advance with the State and the appropriate authorities and keep all aircrews informed of the proper approach. In most cases, the pilot will take over direct communication leading up to the day of flight.

Data Coverage Verification

Validation of field data is a time-critical process. Since re-mobilizations have significant financial and schedule impacts, each collection team will ensure all data have been completely and accurately acquired before leaving the project site. Data is downloaded from the aircraft’s on-board computers and backed up on field hard drives immediately after the completion of each mission. The data will be sent overnight to the office and verified for:

1) ***Visual inspection*** – Coverage to project extents, appropriate ANPD, cloud shadows, data irregularities (e.g., unusual data voids, extreme vertical/horizontal misalignments, and other anomalies).
2) ***Quality inspection*** – Airborne GPS (ABGPS) and Inertial Measuring Unit (IMU) data are processed to a preliminary stage sufficient to complete a quantitative location and quality analysis of the data collected. Dilution of Precision (DOP), combined separation and other quality GPS/inertial metrics reviewed to ensure trajectory solutions will support final accuracies. LAS files are generated to visually compare against the project’s boundary. For any data gaps or other identified data problems, new flight lines are generated to cover the problem areas and sent electronically to the sensor operator on-site.

The entire data coverage verification process is typically completed within 12 to 24 hours for each mission flown.

Task 1c: Calibration

Overview

The calibration of GmAPD LiDAR data is similar to the aerotrigulation process used in photogrammetry, and therefore offers a robust solution to achieving high accuracy at altitudes exceeding the capabilities of traditional sensors. For this delivery order Harris will perform calibration of all LiDAR missions flown by the Geiger-mode sensor. The calibration process and results will be under the oversight of a North Carolina Professional Land Surveyor.

Comparison
In contrast to older procedures using pre- and post-mission calibration flights, our proposed calibration procedure alleviates the outdated calibration flights requirement in the North Carolina Land Records specification by adding cross-flights (cross ties) to each flight block, providing for a higher level relationship to bundle adjust all flight lines as a whole rather than making the assumption that the pre- and post- calibration will hold throughout the duration of a single flight mission. In essence, this breaks the process down to small blocks of adjustment which are subsequently adjusted to the larger area via the project control network.

Project Calibration Accuracy Specifications
Final calibrated data will meet project specifications to support a to a fundamental RMSE of 9.25 cm (3.64 inches) or better for vertical accuracy (NVA) and subsequent 1 foot contour accuracy. Detailed testing methods and reports will be compliant with project specifications and can be found in the section Task 9: Quality Assurance/Quality Control Plan of this document.

Procedure
The process will ensure all LiDAR acquisition missions were carried out in a manner conducive to post-processing an accurate dataset. Significant attention will be given to GPS baseline distances and GPS satellite constellation geometry and outages during the trajectory processing. Verification that proper ABGPS surveying techniques were followed including: pre- and post- mission static initializations and review of in-air IMU alignments, if performed, both before and after on-site collection to ensure proper self-calibration of the IMU accelerometers and gyros were achieved.

Relative Accuracy Calibration (Data Precision)
A minimum of one cross-flight is planned throughout each project block area across all flight lines and over roadways where possible. The cross-flight provides a common control surface used to remove any vertical discrepancies in the LiDAR data between flight lines and aids in the bundle adjustment process with review of the roll, pitch, heading (omega, phi, kappa). The cross-flight is critical to ensure flight line ties across the sub-blocks and the entire project area. The areas of overlap between flight lines are used to calibrate (aka boresight) the LiDAR point cloud to achieve proper flight line-to-flight line alignment in all six degrees of freedom. This includes adjustment of IMU and scanner-related variables such as roll, x, y, z, pitch, heading, and timing interval (calibration range bias by return). Each LiDAR mission flown is independently, reviewed, bundle adjusted (boresighted), and/if necessary, improved by a hands-on boresight refinement in the office.

Non-vegetated Vertical Accuracy Verification
Once this relative accuracy adjustment is complete, the data will be adjusted to the high order GPS calibration control to achieve a zero mean bias for NVA accuracy computation, verification, and reporting. Please note the final accuracy testing procedures, methods and reporting are covered in the QA/QC section of this proposal and are compliant with USGS specifications.

Task 2: Ground Survey Support for Acquisition

Task 2 will include the establishment of ground survey control in support of data acquisition operations.

Task 2a: Ground Control

Supplemental Project Survey Ground Control

ESP will collect approximately 390 well-distributed GPS survey control points to supplement ABGPS accuracy. Each location will be double occupied to validate accuracy. No control panels will be placed as part of this effort. This control will be used to facilitate calibration of LiDAR flight lines/blocks, perform mean adjustment, and test final fundamental accuracy of the data. The vertical accuracy checkpoints will adhere to the following guidelines:

1) Located only in open terrain where there is a high probability that the sensor will have detected the ground surface without influence from surrounding vegetation.
2) On flat or uniformly sloping terrain at least five (5) meters away from any breakline where there is a change in slope.
3) Checkpoint accuracy shall satisfy a Local Network accuracy of 5 cm at the 95% confidence level.

Task 3: Classification of LiDAR Points

Task 3 will include the classification of all LiDAR points as captured in Task 1. The following is a summary of the technical approach and scope of services for Task 3.

Task 3a: Algorithm Development and Classification

Overview

The LiDAR filtering process encompasses a series of automated and manual steps to classify the boresighted point cloud dataset. Each project represents unique characteristics in terms of cultural features (urbanized vs. rural areas), terrain type, and vegetation coverage. These characteristics are thoroughly evaluated at the onset of the project to ensure that the appropriate automated filters are applied and that subsequent manual filtering yields correctly classified data. Data is most often classified by ground and “unclassified”, but specific project applications can include a wide variety of classifications including but not limited to buildings, vegetation, water, etc.

The ESP team will classify the LiDAR point cloud in accordance with the following classifications as shown in Table 4.

Table 4: Project classification scheme

Class	Description	Class	Description
1	Processed Unclassified	8	Undefined
2	Ground	**9**	Water (Hydro Cleaned Areas)
3	Low Vegetation (0.5 – 3ft)	10	Breakline Proximity
4	Medium Vegetation (3 – 10ft)	11	Noise (High Point)
5	High Vegetation (10-220 ft)	13	Roads
6	Buildings (Automated)	14	Bridges
7	Noise (Low Point)		

Traditional Overlap Classes

The Geiger LiDAR sensor is flown utilizing a 55% sidelap (overlap between data swaths). Because of this project design, the overlap classes (traditionally 17, 18 and 19) will not be used for this project.

Auto Filter (Classification)

A filtering macro(s), which may contain one or more filtering algorithms, will be developed and executed to derive LAS files separated into the different classification groups as defined in the ASPRS classification table. The macros are tested in several portions of the project area to verify the appropriateness of the filters. Often, there is a combination of several filter macros that optimize the filtering based on the unique characteristics of the project. Automatic filtering generally yields a ground surface that is 85-90% valid, so additional editing (hand filtering) is required to produce a more robust ground surface.

Task 3b: Manual Edits and Corrections

Re-classification Editing

The next task associated with LiDAR classification is to manually re-classify (or hand-filter) "noise" and other features that may remain in the ground classification after the auto filtering. A cross-section of the post-auto-filtered surface is viewed to assist in the reclassification of non-ground data artifacts. Certain features such as berms, hilltops, cliffs and other features may have been aggressively auto-filtered and points will need to be re-classified into the ground classification. Conversely, above-ground artifacts such as decks, bushes, and other subtle features may remain in the ground classification after automated filtering and will need to be classified manually out of the layer. Edits will ensure that VVA and CVA accuracy requirements will be met.

Based on our experience with Phase 2 of the program, the manual edits and corrections that make up the majority of this task are related to:

1) Building points in the vegetation class
2) Vegetation points in the building class
3) Subtle ground features missing in heavily vegetated areas

4) Bridge classification edits where the bridge deck meets the ground

The following is an example of re-classification of the non-ground points (elevated features) that need to be excluded from the true ground surface. Figure 7 illustrates a small building that was incorrectly auto-filtered. Data in the colorized TIN orthographic and point profile view displays vegetation in green (High, Medium, Low, classes 3, 4, and 5) and building in blue (Class 6) which needs to be manually re-classified. Figure 8, shows the result of the re-classification using hand-filtering.

Figure 7: Error after vegetation and building auto-filters

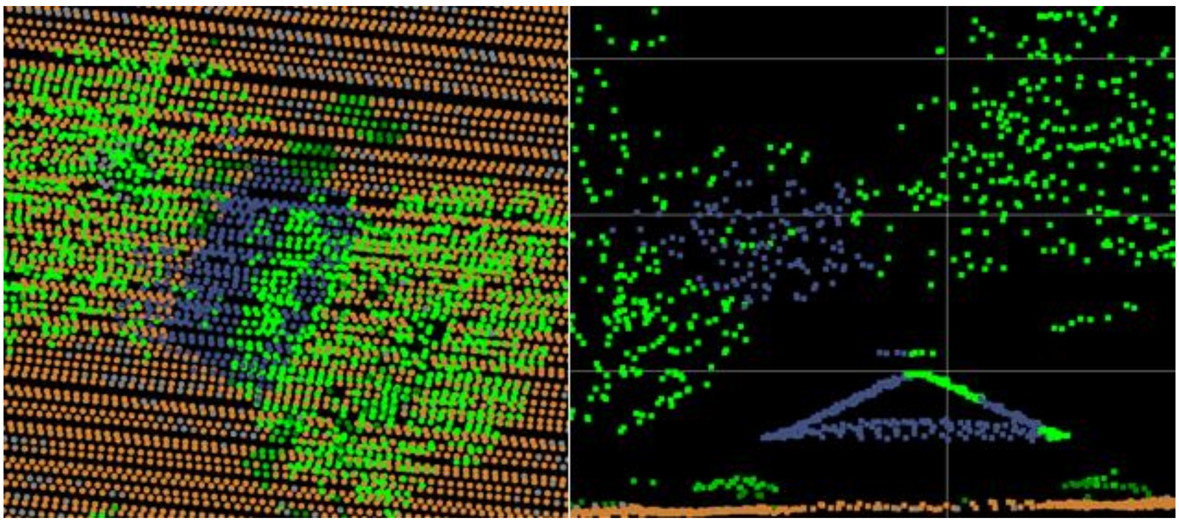
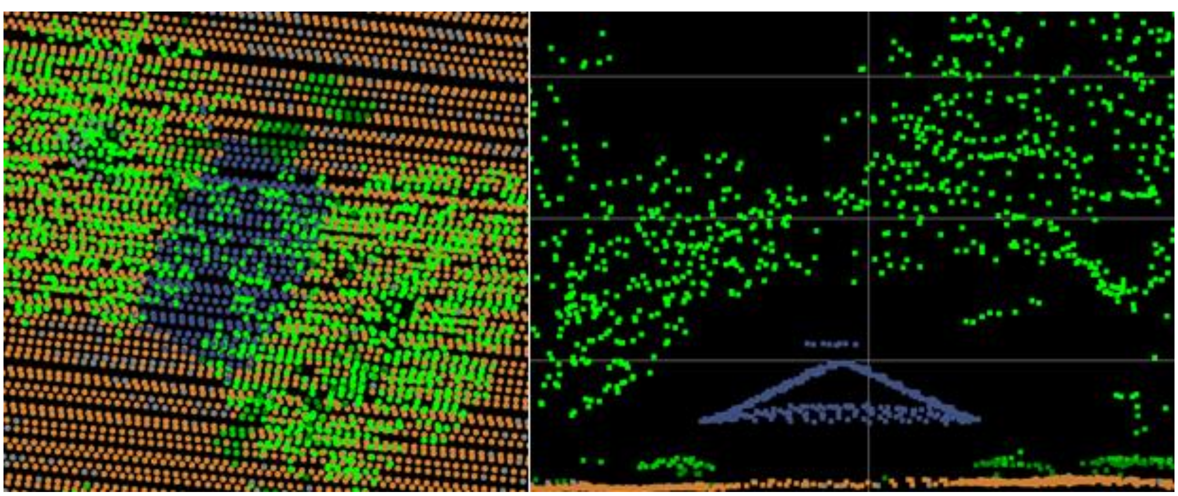


Figure 8: Correct classification after manual hand-filtering



The ESP team will use a combination of automated and semi-automated routines to classify buildings and vegetation. We expect that the classified buildings will meet a filtering criterion in the range of 90-95%. While every effort will be made to optimize this result, no further manual cleanup of the building feature class is planned for this project, so some residual points will exist in this data class.

Recommended Guidelines

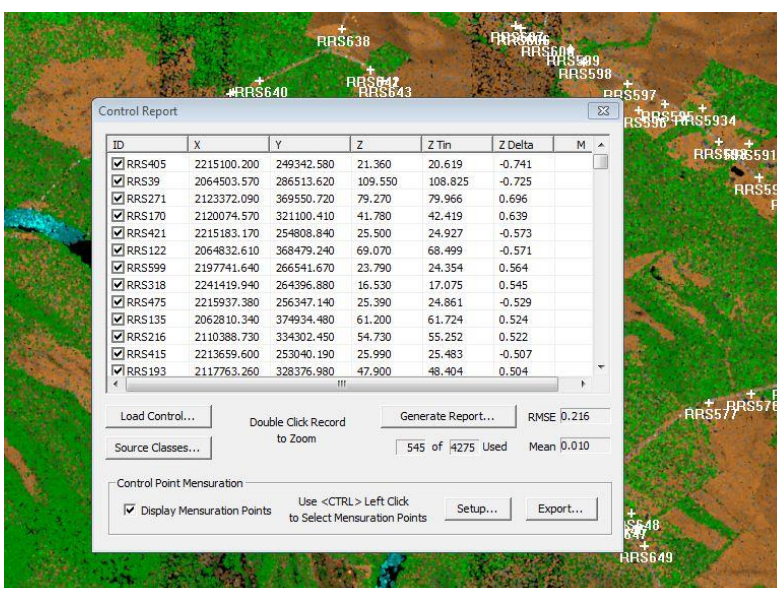
ESP recommends the following guidelines for the base classifications in order to ensure that all project stakeholders understand the minimum acceptable criteria for product:

1) We recommend a 2% of error budget for the general classifications of this product. This is to specifically set guidance for project stakeholders during QA tasks and to prevent unreasonable expectations for this product.
2) As with prior work with the State, ESP will review all QA calls and will address them to the satisfaction of the State. However, we seek to mitigate situations where a QA call flags individual points or small numbers of points as this "over-engineers" the product while stressing a budget that was not designed to support a "zero-tolerance" approach to classifications

NVA Accuracy Check

Once manual editing has been completed and quality checked, a Control Report is generated to validate that the accuracy of the ground surface is within the defined NVA accuracy specifications. Each surveyed ground check point is again compared to the LiDAR surface by interpolating an elevation from a Triangulated Irregular Network (TIN) of the surface. This derived report provides an in-depth statistical report, including an RMSE of the vertical errors; a primary component in most accuracy standards and a statistically valid assessment of the fundamental accuracy of the final ground surface. An example of the Control Report dialog is displayed in Figure 9.

Figure 9: Example of NVA Control Report



Task 4: Development of DEMs in ESRI Grid Format

Task 4 will include the generation of Hydro-flattened Digital Elevation Models (DEMs) for a 3.125-foot, 10- foot, and 20-foot resolution product. We understand that the State will be producing the 50-foot resolution product using internal resources. The following is a summary of the technical approach and scope of services for Task 4.

Task 4a: Hydro-Breakline Generation

Overview

Prior to the DEM generation, breaklines will be collected to further define (hydro-flatten) the terrain and enhance the accuracy of the LiDAR DEMs. Breaklines for this project consist of two primary categories; water bodies ≥ 2 acres and rivers ≥ 100 feet in width. Industry accepted practice will be utilized to compile hydrographic breaklines in 2D directly from the LiDAR bare earth data. Color cycles in the TIN model provide a clear indication of where breaklines are to be collected. During this step, polygon/polyline vertices are created at highly accurate horizontal/vertical coordinates providing for a hydro-flattened DEM. Figure 10 illustrates a raw (bare earth) DEM and Figure 11 illustrates a hydro-flattened DEM with water points reclassified and excluded from the TIN generation.

Figure 10: Raw bare earth DEM, not hydro-flattened

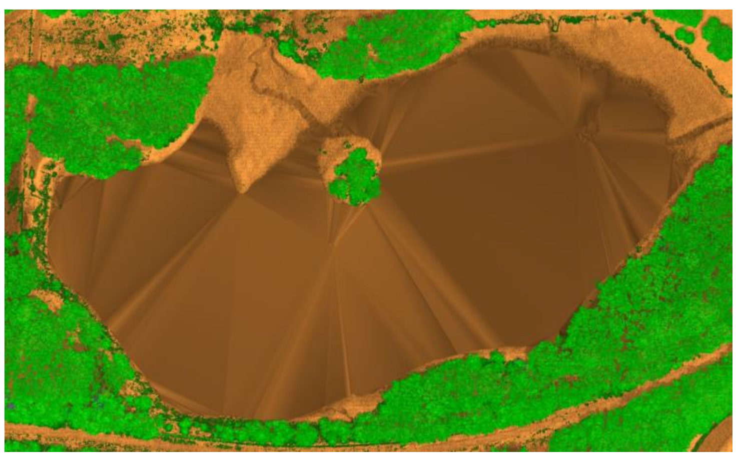
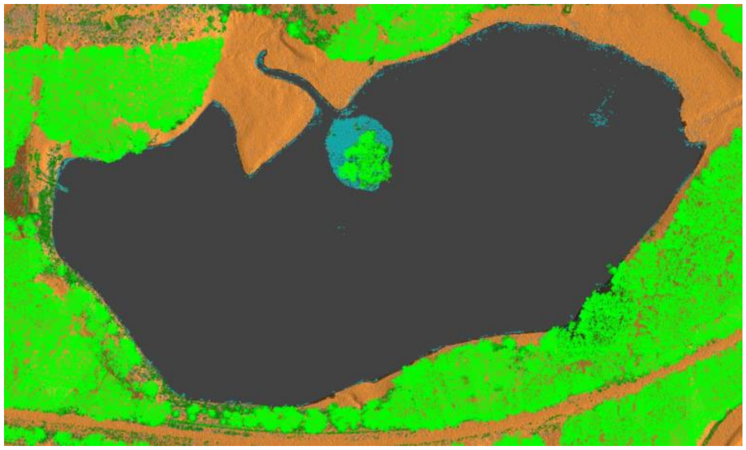


Figure 11: Hydro-flattened DEM



ESP Analyst will only color the non-ground portion of the TIN gray in areas of flat water surface. This provides the technician with a quick, visual QC to ensure that the water body polygon was collected at one elevation around the feature.

The collection of breaklines in a 2D environment provides significant advantages over "LiDARgrammetry" or "Photogrammetric" approaches, which often introduce optical disparity when compared to the LiDAR DEM, as they are separate processes with no direct correlation (Coupling) to the LiDAR data. Both of these processes rely on stereoscopic procedures which can manifest vertical errors above/below the LiDAR terrain surface and have horizontal errors relative to water body and conveyance embankments (Toe). With the ESP team approach, breakline elevations/positions are extracted directly from the LiDAR bare earth data eliminating the risk of a horizontal/vertical miss-match to the DEM.

Hydro-Flattening Specifications

Hydro-flattening breaklines will be compiled based on the guidelines and principles outlined in the NGP-USGS LiDAR Base Specification Version 1.0. The following hydro-flattening requirements will be adhered to for this project.

Inland Ponds and Lakes:

- 2-acre or greater surface area (~350' diameter for a round pond).
- Flat and level water bodies (single elevation for every bank vertex defining a given water body).
- The entire water surface edge must be at or just below the immediately surrounding terrain.
- Long impoundments such as reservoirs, inlets, and fjords, whose water surface elevations drop when moving downstream, should be treated as rivers.

Inland Rivers:

- 100' nominal width. This should not unnecessarily break a stream or river into multiple segments. At times it may squeeze slightly below 100' for short segments. Data producers should use their best professional judgment.

- Flat and level bank-to-bank (perpendicular to the apparent flow centerline); gradient to follow the immediately surrounding terrain.
- The entire water surface edge must be at or just below the immediately surrounding terrain.
- Rivers should **not** break at bridges. Bridges should be removed from DEM. When the identification of a feature as a bridge or culvert cannot be made reliably, the feature should be regarded as a culvert.

Islands:

- Permanent islands ≥1 acre shall be delineated.

Non-Tidal Boundary Waters:

- Represented only as an edge or edges within the project area; collection does not include the opposing shore.
- The entire water surface edge must be at or below the immediately surrounding terrain.
- The elevation along the edge or edges should behave consistently throughout the project. May be a single elevation (i.e., lake) or gradient (i.e., river), as appropriate.

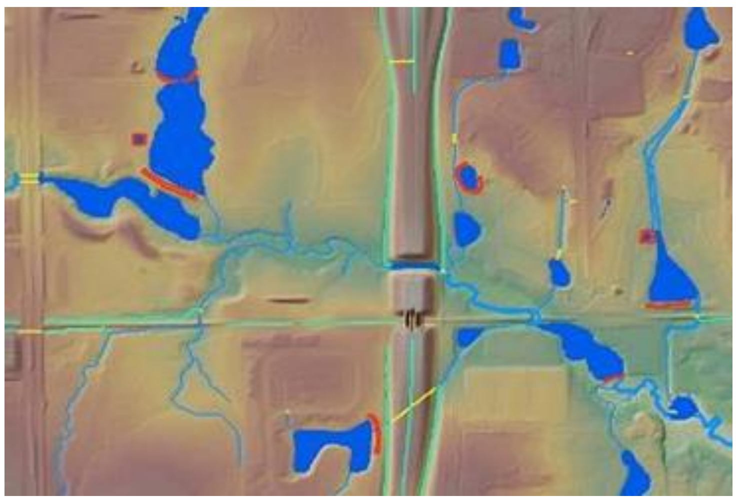
Tidal Waters:

- Water bodies such as oceans, seas, gulfs, bays, inlets, salt marshes, very large lakes, etc. Includes any significant water body that is affected by tidal variations.
- Tidal variations over the course of a collection and between different collections will result in discontinuities along shorelines. This is considered normal and these "anomalies" should be retained. The final DEM should represent as much ground as the collected data permits.
- Variations in water surface elevation resulting in tidal variations during a collection should NOT be removed or adjusted, as this requires either the removal of ground points or the introduction of unmeasured ground into the DEM. The USGS NGP priority is on the ground surface, and accepts the unavoidable irregularities in water surface.
- Scientific research projects in coastal areas often have very specific requirements with regard to how tidal land-water boundaries are to be handled. For such projects, the requirements of the research will take precedence.
- Coordination should be concurrent with the USGS and NRCS project areas to ensure unintended disparities are not created along the coastline.

Water Bodies Procedure (Lakes and Ponds)

Using a TIN with elevation color ramp and/or contours to illustrate the lowest elevation, the LiDAR technician will measure the lowest LiDAR point elevation at or slightly below the water body. The breakline is set (Z-locked) and compiled (traced) to the appropriate elevation horizontally based on the TIN color contrast and/or displayed real-time contour display. Once the polygon is complete (closed) the interior points are reclassified to water (class 9). This step is repeated for each water body breakline that is being collected. Islands within water bodies shall be compiled at the lake elevation and interior points retained as ground. Hydro-flattened water bodies are illustrated in Figure 12.

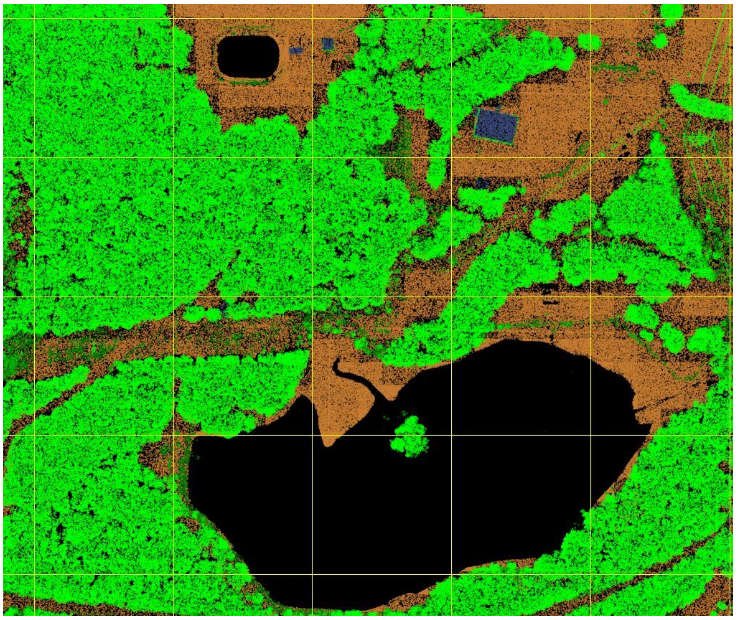
Figure 12: TIN surface with hydro-flattened water bodies



Please note ESP has reviewed and tested the existing hydro layer. ESP may use them as general guidance in this process, but it is understood that they will not facilitate a high level of accuracy given the resolution the QL2 LiDAR data.

Minimum Map Unit Tool
During Phase 2, ESP developed a minimum map unit tool to assist the technicians in determining whether or not island, ponds and other closed water bodies needed to be collected based on the project minimum map units of ≥1 acre for permanent island and ≥2 acres for closed water bodies. This tool introduces greater efficiency to the hydro collection process and doubles as a quality control tool. Figure 13 is an example of this tool in use. Grid displayed is a 2-acre grid. The smaller pond would not be required in the hydro layer but the larger pond would.

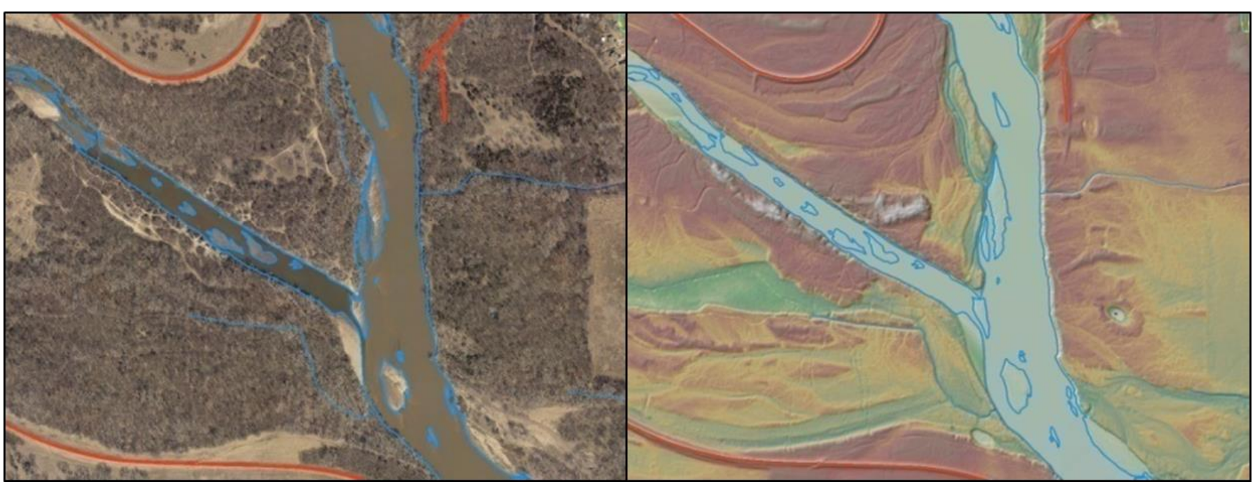
Figure 13: Minimum Map Unit Tool displaying a 2-acre grid over LiDAR



Water Lines Procedure (Rivers and Streams)

Double line drain features (rivers) will be enforced monotonically (have downhill directionality) for linear hydrographic features. Hydrographic breakline collection is always completed in a downhill direction. Any vertices compiled will always be lower in elevation from the previous point; if not, it retains the same elevation as the previous point. River breaklines are compiled on one side of the hydro feature first. Next, the second side of the river is compiled with the elevation of the opposing side (perpendicular to) being applied to enforce monotonic behavior. Islands within river shall be compiled separately and reflect the opposing banks monotonic behavior. Figures 14 below illustrates the affect that using islands along with river breaklines will have among a terrain model that has been hydro-flattened.

Figure 14: Hydro-flattened terrain model along a river with islands



Breakline Tile Seams at Project Boundary

Non-Tidal Areas:
These areas will compiled to the 2015 Phase 4 LiDAR tile boundary and treated the same as their representative features with the following exceptions:

1) Rivers will be broken at the tile edge with elevations representing their final monotonic value(s).
2) Water bodies will be closed at the tile seam with their representative (Z- locked) elevation.
3) In both instances partial Islands may exist and will be closed at the tile seam to reflect appropriate elevations as described in the previous processes.

Task 4b: Hydro-flattened DEMs

Final DEM Grid Generation
Final breaklines and LiDAR bare earth points will be utilized to produce the final hydro-flattened terrain as a TIN. This model will be used to produce the final DEMs and cut to the new statewide (5,000 x 5,000) tile scheme. Three hydro-flattened terrain raster's will be developed at the required 3.125, 10, and 20 foot regular grid spacing in the ESRI format with the appropriate metadata.

Grids will be calculated using the Calculate Pyramid Properties dialog within the ESRI Terrain development tool.

Task 5: Terrain Datasets by County

ESP will compile ESRI terrain datasets for each county in the Phase 4 LiDAR collection area. The following is a summary of the technical approach and scope of services for Task 5.

Task 5a: Terrain Dataset Compilation

Process Overview
Each countywide terrain will be stored in an individual file geodatabase format in Arc version 10.0 or later. The terrains will be loaded with the processed LiDAR LAS file bare earth points, which have been converted to multipoint features. These multipoint features will be stored as the Surface Feature Type (SFType) "mass points" and will be embedded into the terrain. The most current county boundary from the State will be used as SFType "hard clip". Any breaklines developed as part of the project will also be included within the terrain and will have the appropriate SFType assigned based on the type of input feature. The pyramid type will be set to the Z tolerance setting and the pyramid properties and levels will be calculated using the calculate pyramid properties dialog within the ESRI terrain development tool.

Task 6: High Detail Road and Bridge Classifications

ESP will conduct a highly detailed road and bridge classification in the LiDAR point cloud. The following is an outline of the technical approach and scope of services for Task 6.

Task 6a: High Detail Road Polygon Collection

Process Overview
Based on the lessons learned during Phase 2, ESP will classify the road points in the LiDAR by using a comprehensive collection process for mapping road edge, bridge deck, and road island. ESP understands that the seed file to be used for Phase 4 is the LRS Statewide Primary and Secondary Road Arcs contained with the "RomeLrs" geodatabase communicated to ESP on February 3, 2016.

Using the collected LiDAR data as well as ancillary reference files such as the latest State orthophotos, technicians will collect road edge polygons delineating the edge of pavement along all road surfaces contained within the State's seed file. The process will utilize the planimetric tool within ESP Analyst. This allows the technician to edit the polygon while mapping if need be and closes the polygon correctly upon completion of the drawing. The technician is able to view the LiDAR, orthophoto, and LRS road centerlines simultaneously. A transparency slider bar allows the technician to adjust how visible the LiDAR is. Figures 15 and 16 illustrates an example of road polygon collection and subsequent classification on Geiger data similar to what will be flown for Phase 4.

Figure 15: Orthophoto overlaid with Geiger LiDAR and LRS road centerline

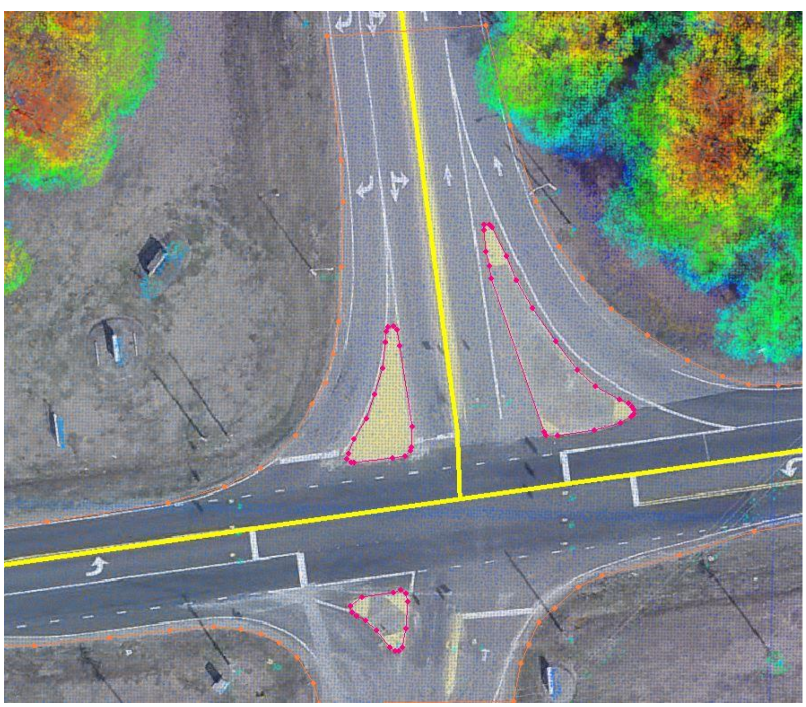
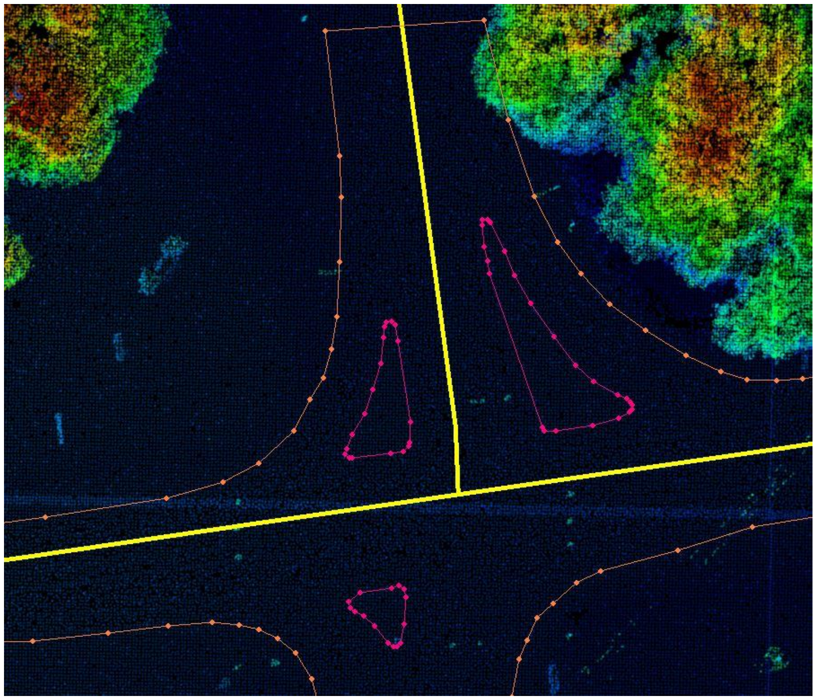


Figure 16: Road edges and islands captured as separate layers

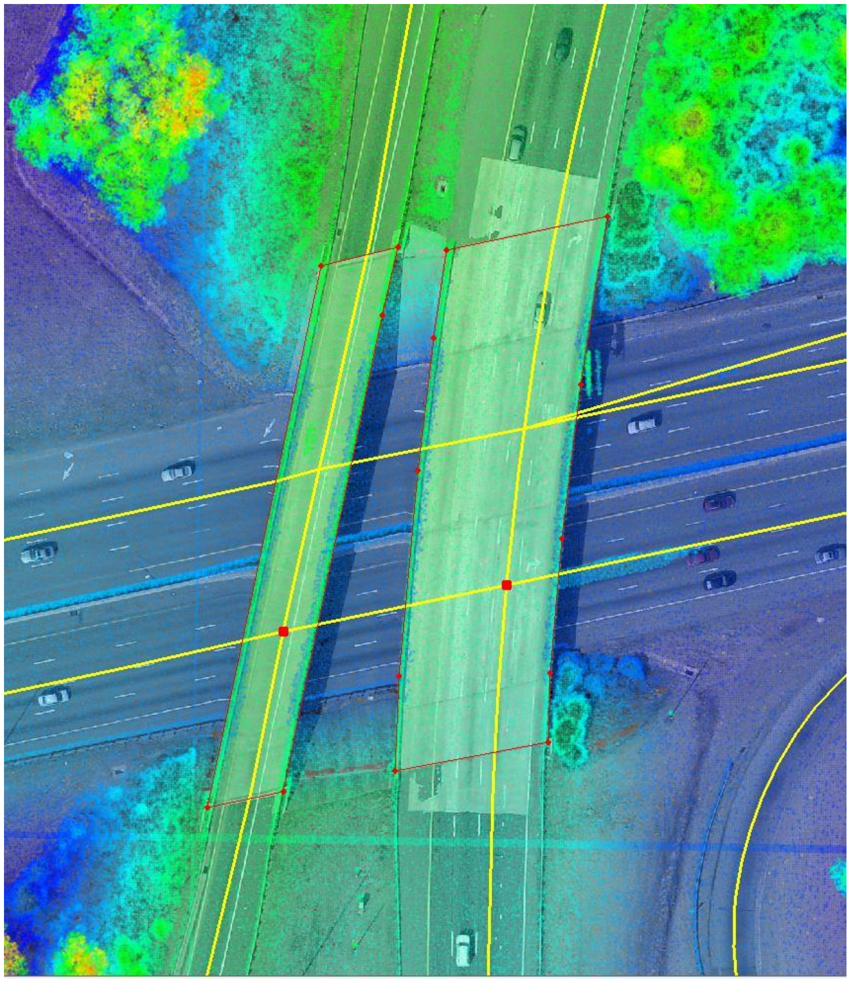


Task 6b: High Detail Bridge Deck Collection

Process Overview

Bridges will be classified as they are found during the road collection phase. Supplementing the bridge classification will be the latest bridge location file provided by the State. This will provide the technicians with a quick check to ensure that none were missed, and will serve as a QA file at the end of the classification process. Figures 17 and 18 illustrate the ability of the technician to view these references while mapping and the final product.

Figure 17: Orthophoto overlaid with Geiger LiDAR, LRS road centerlines, and bridge point file



Task 6c: High Detail Road Polygon Collection

Process Overview

Upon completion of the road, bridge and road island polygon collection, the roads and bridges will be automatically classified using the files. This process is run in batch and will usually be run on an entire county deliverable. Figure 20 illustrates what the finished product looks like.

Figure 18: Completed product with road classified and islands retained in ground classification

Recommended Guidelines

ESP recommends the following guidelines for these products in order to ensure that all project stakeholders understand the minimum acceptable criteria for the road and bridge classifications:

1) It is understood that reference imagery and the LiDAR have their own error budgets which will affect the position of the polygons. However, it is reasonable that the horizontal accuracy of road polygons should be within ~0.5 meters of the position within the LiDAR. Other factors, such as the technician's interpretation of where the edge of pavement is, can affect line placement.
2) Bridge polygon extents will be mapped where the bridge seam is visible. At times, the bridge seam may not be evident. The bridge classification is manually reviewed/edited to fix any issues where the bridge points are short or overextended where the deck meets ground or road. When a bridge classification is corrected in the point cloud, this will result in the original bridge deck not matching the fixed classification perfectly. ESP will not be responsible for re-adjusting the bridge deck polygons under this task.
3) Stakeholders should allow for road and bridge classifications to fall within reasonable error parameters. ESP recommends about a 2% threshold of classification error which is similar to other specifications.

ESP will deliver the collected road polygons in ESRI shapefile format in a GDB.

Task 7: Intensity Images

ESP will compile intensity images for each LiDAR tile processed. The following is a summary of the technical approach and scope of services for Task 7.

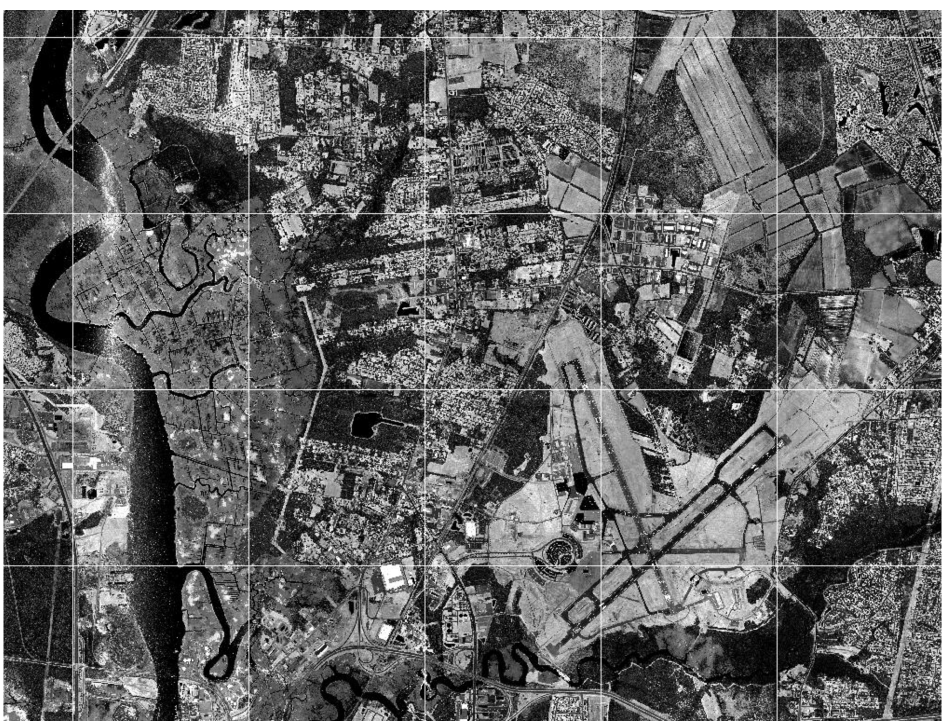
Task 7a: Intensity Image Generation

Process Overview

Once the LiDAR point cloud has been classified and has passed both the internal and independent quality control, LiDAR intensity images will be generated. Each of these images will be generated using the classified LiDAR points and their associated intensity returns, with the exception of Class 7 Noise and Class 12 Flight Line Overlap. The intensity image will be exported in grayscale, 8-bit, GeoTIFF format using the same tile scheme as the other LiDAR deliverables. For the purposes of this proposal it is assumed the 8-bit format will be an Unsigned 8-bit depth with 256 available unique values from 0 to 255. The GeoTIFF intensity image will have a raster cell size of 5 feet.

Every attempt will be made to achieve homogeneity across the project area in image appearance. There will, however, be some variance in the appearance, especially over water bodies and other features where the reflected signal is either absorbed or reflected to a degree greater than normal. Figure 19 illustrated an areas where bright reflectance off of the river gives intensity values outside of what is expected, affecting an otherwise homogenous scene.

Figure 19: Intensity image exhibiting high reflectance values off of water



Task 8: Building Change Detection

As part of Task 9 ESP will perform a Building Change Detection analysis and provide an updated S_BUILDING feature class file for each of the 20 counties. The following is a summary of the technical approach and scope of services for Task 9A.

Task 8a: Building Change Detection

Process Overview
ESP will conduct a building change analysis that distinguishes the exact building features that are either no longer present (removed) or new buildings (added). This analysis will provide a visual representation in the infrastructure growth or removal. There will be one final dataset delivered for each of the 20 Counties within the Phase 4 area.

Task 8b: Updated S_BUILDING datasets

Process Overview
ESP will utilize the latest S_BUILDING dataset in order to make updates based on the newly collected and classified LiDAR data. In order to perform these updates, there will be generalized building footprint files generated from the LiDAR data. These generalized footprints will run through a series of spatial analysis with the existing S_BUILDING dataset in order to provide us with spatial locations for manual review.

Any location where there is a new building that was not previously established, will be manually digitized to appropriately represent the building structure. Any structures less than 500 square feet will not be added unless it appears to be a structure that is lived in. Features will be removed from the S_BUILDING dataset if they are not present in the newly classified data. The newly added building features will be assigned a unique Building ID as well as having the HAG & LAG populated based on the newly collected LiDAR.

Task 9: Quality Assurance/Quality Control (QA/QC) Plan

ESP will implement a QA/QC plan to ensure that each phase of the project is adhering to the aforementioned specifications, and accuracy requirements. The following is a summary of the technical approach and scope of services for Task 9.

Process Overview
The ESP QA/QC workflow is designed with built-in redundancy, taking into account human error and the lessons learned by team members from years of providing similar services. ESP understands that the responsibility of ensuring quality rests with every individual working on the project and has structured the QA/QC workflow to include checks for each step of the planning, acquisition, and production tasks.

ESP will utilize a series of documents and checklists to monitor and control the QA/QC processes for this project. Checklists will be filled out by the individuals conducting the QA/QC and then reviewed by senior technicians so that a record exists of the completed of QA/QC tasks. T

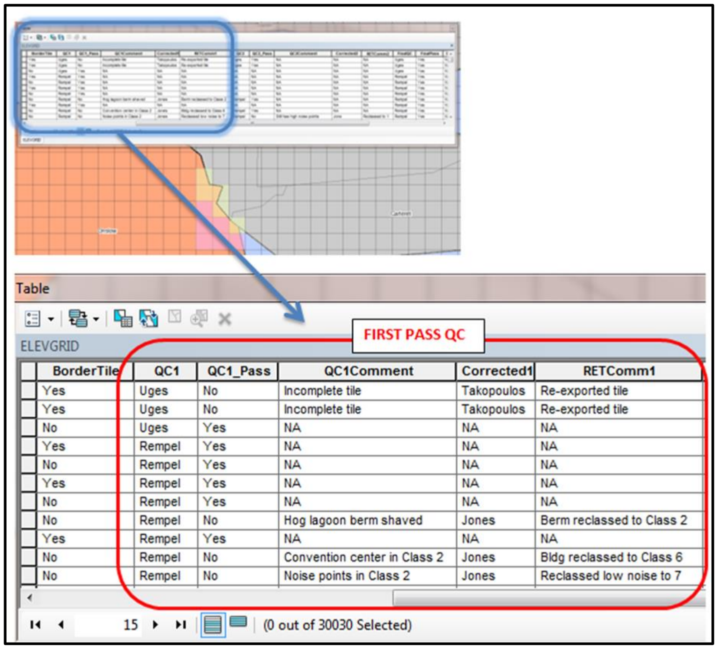
QA/QC Feedback Loop
ESP's QA/QC workflow incorporates a feedback system by which the errors found are tracked in a concise manner. All rejections are reviewed again after resubmittal by the production team to ensure that the QA/QC call was addressed and to ensure that no additional errors were erroneously introduced as a result of the fix. This documentation will also be used as input to continually improve the workflow.

The documentation and review of products that consist of multiple tiles (such as the LiDAR LAS) will be tracked through the use of the project tile layout by modifying the attribute table. This approach will allow ESP to track the following during each QA/QC review:

1) Border tiles (to ensure coordination with the other team and boundary coverage)
2) Issues identified
3) Individuals conducting the QA/QC
4) Individuals making corrections
5) Number of iterations to solve an issue
6) Final approval

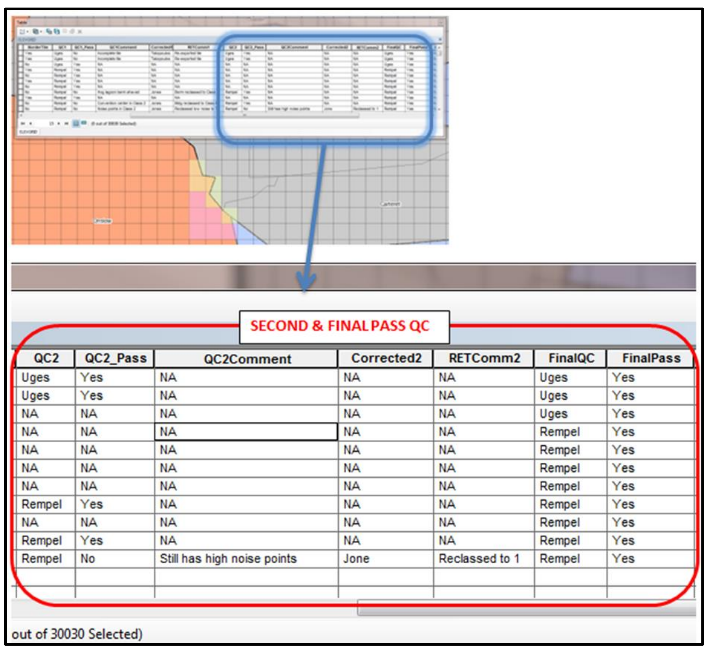
Figures 20 and 21 demonstrate this tracking system using a sample attribute table based on the State tile layout.

Figure 20: First pass QA/QC tracking



BorderTile	QC1	QC1_Pass	QC1Comment	Corrected1	RETComm1
Yes	Uges	No	Incomplete tile	Takopoulos	Re-exported tile
Yes	Uges	No	Incomplete tile	Takopoulos	Re-exported tile
No	Uges	Yes	NA	NA	NA
Yes	Rempel	Yes	NA	NA	NA
No	Rempel	Yes	NA	NA	NA
Yes	Rempel	Yes	NA	NA	NA
No	Rempel	Yes	NA	NA	NA
No	Rempel	No	Hog lagoon berm shaved	Jones	Berm reclassed to Class 2
Yes	Rempel	Yes	NA	NA	NA
No	Rempel	No	Convention center in Class 2	Jones	Bldg reclassed to Class 6
No	Rempel	No	Noise points in Class 2	Jones	Reclassed low noise to 7

Figure 21: Second and final pass QA/QC tracking



QC2	QC2_Pass	QC2Comment	Corrected2	RETComm2	FinalQC	FinalPass
Uges	Yes	NA	NA	NA	Uges	Yes
Uges	Yes	NA	NA	NA	Uges	Yes
NA	NA	NA	NA	NA	Uges	Yes
NA	NA	NA	NA	NA	Rempel	Yes
NA	NA	NA	NA	NA	Rempel	Yes
NA	NA	NA	NA	NA	Rempel	Yes
NA	NA	NA	NA	NA	Rempel	Yes
Rempel	Yes	NA	NA	NA	Rempel	Yes
NA	NA	NA	NA	NA	Rempel	Yes
Rempel	Yes	NA	NA	NA	Rempel	Yes
Rempel	No	Still has high noise points	Jone	Reclassed to 1	Rempel	Yes

By tracking the QA/QC issues and corrections, ESP will be able to document quality metrics such as:

1) Percentage of tiles passing the first pass QC (“First Time Right”)
2) Types and distribution of issues
3) Trends and/or systemic errors

As a product of this process, any information of import will be incorporated into the "Lessons Learned" portion of the relevant report (Collection Report, Processing Report, etc.) and will be used to continually improve QA/QC methodology.

Third Party and State QC Response Process

ESP's QA/QC workflow will incorporate visual and semi-automated QA/QC methods used by the State and NCDOT during Phases 1-3. These improvements and considerations will be based on Issue Paper number L15_04: Visual Quality Control for LiDAR 2015. ESP further understands that the State will provide ESP with tools identical to those used by the State and NCDOT for QA in order to ensure that all project stakeholders are reviewing the data in the same manner.

The QA/QC tool in ESP Analyst will be used to facilitate tracking and status of QA/QC calls from internal and external project stakeholders. This tool was developed during Phase 2 efforts as part of ESP's internal lessons learned review. The tool allows the technician or reviewing to reference in the QA shapfile and "drive" to each call automatically in the LiDAR. This significantly reduces the time needed to navigate to each QA call.

All QA/QC files will contain return comments denoting whether a call was addressed or outlining a reason for not addressing a call such as the identification of a false positive flag.

Changes to QA/QC items per Issue Paper L15_04 are outlined within each relevant section below.

Task 9a: LiDAR Data Acquisition QA/QC

Overview

The QA/QC workflow for Task 9a is broken into three distinct phases to ensure that quality is monitored throughout the task:

1) Pre-flight Planning QA/QC
2) Data Acquisition QA/QC
3) Post-Data Acquisition Reporting QA/QC

There are no changes to QA/QC methodology for Task 9a as a result of Issue Paper L15_04.

Pre-flight Planning QA/QC

Flight operations for data acquisition will not commence until the team has reviewed and obtained approval for the data acquisition plan for the Phase 4 counties that will be collected. To facilitate the QA/QC, ESP has established guidelines for pre-flight documentation that shall be submitted to the quality control manager for approval. This documentation consists of an Operations Plan along with the associated files covering sensor calibration information, ground survey control plan, flight plans, planned GPS base stations, and project boundaries.

ESP's internal guidelines for pre-flight documentation were tested and refined during Phase 2 and will be used for Phase 4 operations and included in our Operations Plan. Table 5 outlines our minimal content for the team's Operations Plan:

Table 5: Minimum content for Operations Plan

Operations Plan Contents	
• Planned flight lines • Planned GPS stations Planned control • Planned airport locations • Calibration plans • Quality procedures for flight crew (project-related for pilot and operator) • Planned scanset (sensor settings and altitude) • Type of aircraft • Procedure for tracking, executing, and checking reflights	• Considerations for terrain, cover, and weather in project • Communications matrix (survey & flight crews, QA/QC and flight managers) • Contingency plan • Anticipated airspace constraints • Sensor calibration information • Project boundaries and buffers • Data transfer procedure • Daily reporting procedure • Intensity gain settings

ESP's quality control manager will ensure that the Operations Plan and any associated files are reviewed to verify that the project design meets or exceeds the technical requirements of the project and that the proper controls are established prior to data acquisition commencing. Upon review of the initial submittal, the quality control manager will hold a feedback meeting with the data acquisition team to discuss any potential issues with the plan and to provide feedback. Once any issues and/or feedback have been addressed, the plan will be submitted to the NCFMP program manager.

If the NCFMP program manager requires any revision to the plan, the revision will be incorporated and the plan resubmitted for approval prior to data acquisition activities. As part of this approval process, the project boundary and associated buffer shall be submitted as a digital file for final approval and verification.

Data Acquisition QA/QC

During Operations

QA/QC during data acquisition operations begins in the field with the personnel executing the task. These personnel represent the first line of defense against potential issues and will follow in-field QA/QC procedures on a daily basis to ensure that each day of collection meets the specifications of the project. In-field QA/QC procedures include, but are not limited to:

1) Pre-flight aircraft and equipment checklists
2) Pre- and post-flight initializations of ABGPS
3) Review of sensor logs for each flight

4) Monitoring of ABGPS and sensor during flight
5) Review of in-air IMU alignments
6) Initial completeness check of each flight's data prior to shipping to office

Once each day's collection is shipped overnight to the office, it immediately undergoes the QA/QC outlined in the Data Coverage Verification section of this proposal.

ESP understands that strong coordination between flight crews, survey crews, and managers is critical to the success of this phase and has established internal daily reporting requirements for data acquisition operations. This ensures that data acquisition and quality managers are continuously aware of any potential issues that could arise. These requirements include delivering flight logs, Activity Reports, sensor logs, and trajectory files for review on a daily basis. The flight logs to be used by the team shall include information that will allow for the initial verification of the flights against plan and to ensure that a level of redundancy is present in the QA/QC process.

The ESP Daily Activity Reports will be consolidated as needed to compile an Acquisition Report (acquisition status) that will be distributed to the project stakeholders by the ESP project manager. The content and frequency of the Acquisition Report will be determined by the project kick off meeting. During Phase 2 it was found that a weekly report sufficed and ESP recommends the same for Phase 4. At a minimum, ESP shall include the following items in the report:

1) ESRI shapefile representing the geographic extent of the acquired data during the relevant reporting period
2) Graphic of the above to facilitate presentation of the status to non-ESRI users
3) Anticipated progress for the next reporting period
4) Any issues encountered
5) Progress against the baseline schedule

ESP has established minimum content for flight logs that will be used for the project. This minimum content was used during Phase 2 and worked well in terms of tracking flights and refights. This information was critical for our internal QA process. Table 6 outlines the team's minimum flight log content.

Table 6: Minimum flight log content

ESP Team Flight Log Contents	
• Job # / name • Lift # • Block or AOI designator • Date • Aircraft tail number, type • Flight line, line #, direction, start/stop, altitude, scan angle/rate, speed, conditions, comments • Pilot name • Operator name	• Sensor name/type • Sensor serial number • Intensity settings • Laser pulse rate • Mirror rate • Field of view • Airport of operations • GPS base station names/numbers

During the data acquisition phase, the quality control manager will coordinate closely with the Harris' aerial acquisition manager to continuously monitor operations and review all internal and external reports for content and compliance with the project specifications.

Post-Acquisition Data QA/QC

The post-acquisition data QA/QC begins immediately upon receipt of a day's flight data. In order to identify potential issues as early as possible, the goal is to review and approve each day's flight within 24 hours or less. This ensures that potential re-flights are identified prior to the aerial assets demobilizing from any particular area. This phase of the project QA/QC workflow is conducted using visual and qualitative inspection methods designed to verify that each day's collection will support the specifications and final accuracies of the project. They are conducted as follows:

1) ***Visual inspections*** – will verify coverage, resolution of LiDAR, data irregularities (e.g., unusual data voids, extreme vertical/horizontal misalignments, and other anomalies).

2) ***Quality inspections*** – GPS and IMU data are processed to a preliminary stage sufficient to complete a quantitative location and quality analysis of the data collected. Dilution of Precision (DOP), combined separation, and other quality GPS/inertial metrics reviewed to ensure trajectory solutions will support final accuracies. LAS files are generated to visually compare against the project's boundary. For any data gaps or other identified data problems, new flight lines are generated to cover the problem areas and sent electronically to the sensor operator on-site.

In accordance with the NC LiDAR Standard and internal processes used by the team, the following detailed QA/QC steps (Table 7) are taken to verify that the data is ready for production and that there are no issues with the data that would trigger a re-flight:

Table 7: Post-Acquisition QA/QC Matrix

QA/QC Step	Comments	Corresponding Standard/Specification
1. Data completeness	Deliverable media is readable; all files for flight are present, no gross gaps, cross flights are present	Internal
2. Check against flight plan	Trajectory files are reviewed to ensure flight plan was followed	Internal
3. Flight parameters	Sensor settings and flight reflect the approved project design	Internal
4. Data coverage	Data covers planned collection; areas along project boundary and 100' buffer are adequately covered	Contractual
5. Data voids	Do not exceed 4*Nominal Pulse Spacing (NPS) except where caused by water bodies, low reflectivity, or is filled in by another swath/lift	NC LiDAR Standard, Section 5.01.4
6. GPS & IMU	Reviewed to ensure proper operation/coverage/quality (includes base stations)	Internal and NC LiDAR Standards, Sections 5.02.4 and 6
7. Density	Review of density to verify proper operation of sensors and flight execution. Nominal pulse spacing (NPS) is 0.7 meter or better	Contractual
8. Intensity	Intensity values are present and consistent in range	NC LiDAR Standard, Section 5.01.2
9. Overlap	Overlap between adjacent lines is 20% or better	*See exemption request*
10. Signal returns	Multiple returns are present	NC LiDAR Standard, Section 5.01.1

Post-Acquisition Reporting QA/QC

The final QA/QC step for Task 9a is the review of the final reports from this task (which includes the Collections Report and Survey Report) to provide a final verification of the executed task against plan. This ensures that the reports meet the minimum content requirements of the NC LiDAR Standards our internal requirements outlined below in Table 8.

Table 8: Post Collections Report minimum content

Post-Acquisition Report Content	

• GPS base station information:
  ○ Base station name
  ○ Latitude/Longitude (ddd-mm-ss.sss)
  ○ Base height (Ellipsoidal meters)
  ○ Maximum Position Dilution of Precision PDOP
• Map of locations
• GPS/IMU processing summary:
  ○ Max Horizontal GPS Variance (cm)
  ○ Max Vertical GPS Variance (cm)
  ○ Notes on GPS quality (High, Good, etc.)
  ○ GPS separation plot
  ○ GPS altitude plot
  ○ PDOP plot
  ○ Plot of GPS distance from base station/s
• Mission planning detail
• Flight logs
	• Project overview
	• Description and resolution of issues encountered (if applicable)
	• Lessons learned
	• Recommendations for future projects
	• Coverage – verification of data coverage
	• Flights:
	• As-flown trajectories
	• Calibration lines
	• Flight logs (incorporated as an Appendix)
	• Control – control and base station layouts
	• Data verification/QC:
	• Description of data verification/QC process
	• Results of the verification and QC steps

The Survey Report shall be reviewed and quality controlled to ensure that it meets the requirements outlined in Sections 9.01 and 9.03 of the NC LiDAR Standard and internal quality requirements:

1) The report shall be prepared under the supervision of a North Carolina Professional Land Surveyor and certified and sealed by the surveyor in responsible charge in accordance with North Carolina Surveying Law N.C. G.S. 89C.

2) The report shall contain details outlining the collection of the control and reference points used for calibration and QA/QC.

3) Survey points are verified to ensure that they were collected per standard operating procedures for LiDAR control.

The quality control and acquisition managers will review the Collection Report and Survey Report for content and accuracy prior to the submittal of the reports to the NCFMP program manager.

Task 9b: LiDAR Calibration QA/QC

Process Overview

The QA/QC workflow for Task 10b of this project consists of verifying the results of the data calibration via visual inspection and accuracy testing (positional and relative). Because the LiDAR calibration process adjusts the data, some of the initial quality checks from the data acquisition phase (Task 1) are repeated. The quality checks that are repeated after calibration include:

1) Data coverage and void check
2) Review of ABGPS and IMU data
3) Data integrity checks (to verify no change in returns present, intensity quality, etc.)

A residuals report, similar to those contained in aerotriangulation reports, will be generated from the match point registration process for the relative accuracy reporting. This will be provided by team member Harris and reviewed by ESP's photogrammetrists.

Vertical Accuracy Assessment

During Task 1, only the Fundamental Vertical Accuracy (FVA) will be calculated to assess vertical accuracy as FVA is determined by a comparison against vertical checkpoints in open terrain and the LiDAR data have not undergone automated and manual classification yet. Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA) will be assessed on the final deliverable LiDAR data once the point classification has been conducted.

In accordance with Section 5.01.8 of the NC LiDAR Standard, FVA shall be assessed and reported per the NDEP Elevation Guidelines. For this project, the project design ensures that the LiDAR is suitable for a 1 foot contour product, or a threshold of ≤ 9.25cm $RMSE_z$ (18.13 Accuracy at the 95 percent confidence level). It is our understanding that the data will be independently tested after delivery by a third party, therefore ESP's vertical accuracy test will utilize the project control and shall provide the following statement regarding FVA:

> *"Compiled to meet ≤ 18.13cm Fundamental Vertical Accuracy at the 95 percent confidence level in open terrain using $RMSE_z$ * 1.9600".*

The internal calculated value for FVA will also be provided.

Task 9c: LiDAR Classification QA/QC

Process Overview

The QA/QC workflow for Task 9c encompasses a series of automated and manual review processes designed to identify potential issues throughout the task as early as possible. During production, technicians will utilize peer review and lead technician reviews to ensure that quality is maintained throughout the classification process. When the classification process is completed, the data will undergo what is commonly known in the industry as "macro" and "micro" QA/QC. These processes are described in further detail below.

This QA/QC procedure contains changes as a result of Issue Paper L15_04.

Peer and Lead Technician Review
Some of the common issues encountered during the LiDAR classification phase include:

1) Blunders caused by automated classification routines
2) Blunders caused by a misinterpretation by the technician during editing
3) Lack of homogeneity across tiles and blocks due to different work methods, quality, or technicians

ESP's strong production QA/QC process is designed to catch such problems during production to prevent errors from propagating into other products and final deliverables. During the peer review process, technicians working on editing the LiDAR tiles will check each other's work. This ensures that every tile will be reviewed by more than one individual and that teams of individuals are executing the editing in the same manner.

Lead technicians on the production floor will be responsible for ensuring that the tiles and blocks completed by the production teams are consistent in quality and appearance. They will also be responsible for ensuring that processes and procedures are being followed. Once thoroughly reviewed by the lead technician, LiDAR tiles will be submitted to the QA/QC technicians.

Macro QA/QC Checks
Macro checks are executed via automated methods and quick visual QCs, allowing the reviewers to quickly identify potential systemic or gross errors in the product. Gross or systemic errors can often be caught with a macro check, ensuring that the product is rejected internally prior to the micro checks occurring. The macro checks for Task 3 include the following items shown in Table 9.

Table 9: Macro QA/QC checks

QA/QC Step	Comments	Corresponding Standard/Specification
1. Verify completeness	Files are readable, correctly named	Naming convention – NC LiDAR Standard, Sections 1.05 and 5.04.2
2. Verify projection	Checked against project system – NC SPCS NAD83 (2011), NAVD88, Geoid 12A, US Feet	Request for Delivery Order, DO 22
3. Review overall classification	No classifications in unused bins, variable length records present, min/max x, y, z ranges appropriate	Internal, contractual, and NC LiDAR Standard, Section 5.03.3
4. Check coverage	Data clipped correctly to tiles, project area and buffer covered	Contractual

QA/QC Step	Comments	Corresponding Standard/Specification
5. Check for voids	Do not exceed 4*Nominal Pulse Spacing (NPS) except where caused by water bodies, low reflectivity, or is filled in by another swath/lift	NC LiDAR Standard, Section 5.01.4
6. Check format	Tiles are in correct, deliverable format	LAS 1.4 per Request for Delivery Order, DO 22
7. Check density	Nominal pulse spacing (NPS) is 0.7 meter or better	Contractual

Micro QA/QC Checks

The micro checks consist of a detailed review, tile by tile, of the LAS product to ensure that the product meets the State's expectations in terms of the accuracy and consistency of the point classification. Per Section 5.03.3 of the NC LiDAR Standard, the classification accuracy of the LiDAR data shall meet or exceed the following test:

- Within any 1km x 1km area, no more than 2% of non-withheld points will possess a demonstrably erroneous classification value (including Classes 0 and 1)

A thorough manual review of the data, tile-by-tile, facilitates this check. QA/QC technicians use a variety of methods to conduct this review using a combination of commercial off-the-shelf software (COTS), ancillary data (such as aerial imagery and GIS layers), and proprietary software. During this review, the technicians are inspecting the LAS product for:

1) Overly-aggressive editing
2) Vegetation or other above-ground features classified as ground
3) Ground points in water bodies
4) Proper depiction of roads, drainage patterns, and terrain
5) Bridges and buildings classified correctly
6) Water classifications match other products such as the hydro-flattening breakline layer

Please note that the following information is provided for clarification for items related to this delivery order:

1) For this project, the building and vegetation classifications are designed to meet a95% classification accuracy.
2) LAS tiles will not be finalized for delivery until the associated hydro-flattening lines have been used to classify water points in the LAS so that the two products match.

The following changes in this procedure are as a result of Issue Paper L15_04:

1) Building classifications will be checked against ancillary building layer from State as additional reference.
2) Minimum classified building size is 800 square feet
3) All large structures should also be classed as building with no other classification within the structure. The one exception is courtyards that could be classified as ground.
4) In areas or high urbanization the 90% rule will be used. Single random Residential structures that are missed will be ignored. If there are a large number of buildings that are incorrectly classified as anything else they will be expected to be corrected.
5) Small structures and buildings in back yards that are assumed non-residential should not be called as missed.
6) Vegetation classification errors that are acceptable include pools, fences, sheds, cell towers, power lines, cars and truck in the low and medium classifications, and isolated building roof points. Bleachers should be left in the vegetation classification
7) Constructed Dam structures that are large scale and are above the terrain surface should also be classified as building.
8) Sporting structures such as bleachers should be classed as vegetation
9) Lots of trucks or other box like movable structures that are classified as building should be classed as veg.
10) This will only be called if it is a large scale issue. If there are a few that are classed incorrectly it will be accepted

Final Accuracy Assessment
After the LAS QA/QC is completed for a particular block, a final accuracy assessment incorporating calculations for SVA and CVA will be conducted in accordance with the specifications in Sections 6.02.6 through 6.02.9 of the NC LiDAR Standard and in accordance with NDEP reporting guidelines.

As mentioned earlier in the proposal, ESP understands that a third-party accuracy assessment will be commissioned by the State. Therefore, ESP will be testing the LiDAR internally against the project control and will only provide "Compiled to meet" statements for FVA, SVA, and CVA.

- FVA Statement: "Compiled to meet ≤ 19.6cm Fundamental Vertical Accuracy at the 95 percent confidence level in open terrain using $RMSE_z$ * 1.9600."
- CVA Statement: "Compiled to meet 26.9cm Consolidated Vertical Accuracy at 95th percentile in open terrain, (insert other land cover categories tested)."
- SVA Statement: "Compiled to meet 26.9cm Supplemental Vertical Accuracy at 95th percentile in (insert land cover category tested)."

The internal, calculated values for FVA, SVA, and CVA will also be provided.

Task 9d: Hydro-Flattening Breaklines QA/QC

Process Overview
For Task 9d the QA/QC workflow will consist of reviewing the hydro-flattening breaklines visually and by comparing the line work to ancillary data and the LiDAR surface. The visual QC will ensure that there are no issues with the original horizontal placement of the line work and that the minimum features have been collected in accordance with USGS and State standards:

1) Islands ≥ 1 acre
2) Water bodies ≥ 2 acres
3) Rivers of 100 feet in width or greater

Other quality control checks, such as spot-checking monotonicity of flowing water features and the elevations of closed water bodies, will be conducted to ensure that the software-assisted portion of the collection is performing as planned.

All hydro-flattening breaklines will be checked against the specifications prior to being approved for use in the generation of the DEM product.

The following changes in this procedure are as a result of Issue Paper L15_04:

1) Hydro Files will be checked for completeness within each tile
2) Hydro Files will be checked for edge-matching between teams and between existing deliverables
3) Line should connect with existing lines between years. Steps in elevation are acceptable if tying to a previous year of LIDAR.
4) Islands will be checked for 1 acre limit
5) Hydro will be solely based on las files and not on imagery
6) There should be no buildings in Water. All Boat houses, structures on decks, etc.... should be removed from within water files.

Task 9e: DEM Generation QA/QC

Process Overview
The DEM product produced under Task 9e will undergo a manual review to ensure that the product meets the requirements outlined in Section 9.13.1 through 9.13.6 of the NC LiDAR Standard:

1) Bare earth points in close proximity to breaklines were removed prior to generating the DEM
2) Above-ground artifacts are not present in the surface

3) The resolution and format of the DEMs meet the project requirements (GIS-compatible, 32-bit floating point raster format with a cell size no greater than 3ms and no less than the design NPS of 0.7m)
4) Geo-reference information is included in the raster file
5) Tiled delivery without overlap
6) Void areas coded with a 'NODATA" value
7) Project area is covered

Task 9f: ESRI Terrain Dataset QA/QC

Process Overview

The QA/QC process for Task 9f will be used as each county-level terrain dataset is completed. The QA/QC will involve opening the geodatabase created for each county in ArcMap version 10.0 or later and visually inspecting the database for compliance with the requirements. The file will be visually inspected to verify that:

1) Multipoint features will be stored as the Surface Feature Type (SFType) "mass points" and are embedded into the terrain.
2) Breaklines developed as part of the project are included within the terrain and have the appropriate SFType assigned based on the type of input feature.
3) The Pyramid Type was set to the Z Tolerance setting and the Pyramid Properties and Levels were calculated using the Calculate Pyramid Properties dialog within the ESRI Terrain development tool.

Task 9g: LiDAR Intensity Image QA/QC

Process Overview

The QA/QC process for Task 10g involves the manual review of the files over the entire project area to ensure that there are no gaps caused by processing and to review the product for the desired appearance. File format and naming convention for this deliverable will also be verified as a final check prior to delivery.

Task 9h: Road and Bridge Classification QA/QC

Process Overview

The QA/QC process for Task 9h involves the following based on experience from prior phases and items outlined in Issue Paper L15_04.

1) Roads shall be verified against the NCDOT LRS GIS road centerline seed file. Using the automated process provided by the state, areas to check will be flagged in a shapefile. These points will be checked for appropriate classification. Only flag if points are not classified and

the road centerline exists. There will be exceptions to this rule. If there are large roads that are not in the seed file these will be flagged for collection.

2) New construction exception - if there are areas that are new construction between the imagery available and the LIDAR the road will not be classified in these areas. The areas will be marked in a shapefile for QC and will be marked as under construction.

3) Roads will be checked for $delta_z$ in the programmable checks however there will be instances where noisy roads may be called.

4) Road points that fall parallel to the bridge deck and are not part of the bridge should be corrected

5) Intensity will not be solely used to derive roads. This is a visual creation from the intensity imagery, RGB imagery, and LiDAR. Intensity often takes more areas into consideration such as shoulders.

6) Bridges will be checked to ensure that they are classified. (The inclusion of additional bridges not in the GIS file: (Railroad bridges, foot bridges, etc.) is encouraged

7) Bridge classification will be checked against the latest NCDOT Bridge Inventory file by referencing the shapefile into ESP Analyst

8) The NCDOT bridge file holds Typ_N if the type is Bridge, City Bridge, Federal Bridge, Pavement of Piles, Railroad, or Vehicular Underpass it will be classified as a bridge. All others will not be required to be classified as Bridge

Expected Tools and Inputs from the State

ESP understands that the following tools, methodology, and files will be made available by the State for use in our internal QA/QC processes.

1) Breakline proximity point checks

2) Building classification check methodology using ArcGIS tools

3) Road classification checks for elevation range (methodology)

4) Bridge classification checks for elevation range (methodology)

5) Files:

   a. Roman LRS Road centerlines

   b. Latest NCDOT bridge file

   c. Any other ancillary data being used by the State or NCDOT for QA/QC

These processes, tools, and files will supplement the existing QA/QC processes used by ESP. Use of these tools and processes and the expectations of the State for reporting will be discussed at the project kick off meeting. If new or additional methods are used by the State or NCDOT during the course of the project, ESP requests that these be shared to avoid potential delays and issues caused by false positive flags and other calls not meeting specifications or affecting the quality of the product.

Task 9i: Building Footprint QA/QC

Process Overview

The QA/QC process for Task 10i involves the compilation of the acquired LiDAR intensity images into mosaic datasets for each individual county. The locations of change within the building change analysis will then be manually reviewed in conjunction with the intensity dataset. This will provide the source of human judgment to maintain consistent data validation across the entire study area.

Task 10: Preparation of Project Reports

ESP will prepare the appropriate project reports as detailed in the North Carolina Specifications for LiDAR Base Mapping and be available to attend the necessary meetings. The following is a summary of the technical approach and scope of services for Task 10.

Task10a: Project Reporting

Overview

ESP will attend and prepare for weekly meetings throughout the life cycle of the project. At each of these meetings, ESP will deliver a weekly status report detailing acquisition, calibration, processing, and any other current actions of the project. In addition, ESP will prepare the following list of reports as detailed in the North Carolina Specifications for LiDAR Base Mapping and each of these reports will be delivered, including the appropriate professional seals, within five (5) days of the completion of the task to the North Carolina GTM SharePoint site: Collection Report, Survey Report, Processing Report, and Quality Assurance/Quality Control (QA/QC) Report.

The Collection Report will detail the mission planning and flight plan logs associated with the LiDAR Data Acquisition phase of the project, also known as Task 1 of this Technical Proposal. A Survey Report will be prepared, along with North Carolina Professional Land Surveyor (NCPLS) certification and seal that will detail the collection of control and reference points used for the calibration and QA/QC of the acquired LiDAR data. The Processing Report will provide detailed information on the calibration, classification, and product generations procedures including methodology used for breakline extraction and hydro-flattening. During the entire course of the project there will be an ongoing QA/QC component for each phase and subsequent deliverable. All of this quality control information will be formatted into a QA/QC Report that will provide a detail analysis, accuracy assessment and validation of the LiDAR point data (absolute, within and between swaths), bare earth surface (absolute), and the other deliverable products stated within this Technical Proposal.

Task 11: Metadata

ESP will develop FGDC compliant metadata. The following is a summary of the technical approach and scope of services for Task 11.

Task 11a: Metadata Generation

Overview
ESP will generate metadata to all appropriate deliverables that are FGDC compliant and in XML format. A single metadata file will be generated for each project, lift, and tiled deliverable product group. For the purposes of this technical proposal, a tiled deliverable product group refers to the classified point cloud data, hydro-flattened DEMs, ESRI terrain datasets, and intensity images. It is not anticipated that individual metadata files for each tile will be required. All deliverable metadata files will pass the USGS metadata parser with no errors or warnings. Please note that newer version of ESRI releases contain additional superfluous lines and text that may generate errors in the USGS parser that are listed as a Severity of "0". ESP will limit the number of these instances where possible.

Metadata content will follow the metadata content developed during Phase 2 and will be submitted to the State for approval prior to finalizing the deliverable of Task 11: Preparation of Project Reports.

Task 12: Spatial Data Download Enhancements

ESP will enhance the existing spatial data download tool to accommodate the new LiDAR density and additional functionaility.

Task 12a: Spatial Data Download Enhancements

Overview
The spatial data download tool allows interactive clipping of LiDAR and GIS datasets. Under this task ESP will enhance the tool to include the following:

1) The spatial data download will be enhanced to allow for download of 8ppm Phase 4 LiDAR.
    a. These .las files will be stored in the same manner as the QL2, but will have more tiles, bigger datasets and slightly different naming conventions.
    b. The LidarServer.exe will be updated to clip single tile, area and rectangle areas of interest.
    c. The notification and logging of the requests will remain the same as QL2 download.

2) Allow download of metadata for each county and LiDAR type (Legacy, QL2, Phase 4)

3) For GIS Services, update the administrator page to automatically pull the list of layers from the service REST endpoint to eliminate the need to enter these manually.

4) Allow the user to view pending jobs and update basic account information.

5) Update the Home page of the Spatial Data Download to reflect new dataset options

6) Update the Administrator Configuration Services page to include help tips showing where each field will be used.

7) For GIS datasets, allow the administrator to include a link and message for countywide GIS datasets (e.g. Links to FRIS, etc.)

8) For elevation downloads, include a summary of the contents

9) Update the SQL Server email functions to provide a single location for all links that need to be changed (signature, application link, etc.).

10) The Application Delivery Checklist will be updated to add the DEM Downloader and Phase 4 LiDAR updates

11) Develop a new administrator report that shows data requested by date range and jurisdiction. This report will leverage the LidarTile to Jurisdiction roll up table

ESP will provide two knowledge transfer sessions with NCEM staff to review the updates and assist in installation of the updates on the NCEM staging server.

Project Deliverables

The following table summarizes the anticipated deliverables for each task:

Task	Deliverables
Task 1: LiDAR Data Acquisition	• Project boundary GIS file and map (State 2,500ft X 2,500ft tiling scheme with 100 meter buffer) • Flight line layout GIS file and map • Ground control GIS file and map • Adjacent Contractor Coordination Agreement • GPS ground control survey points (approximately 390)
Task 2: Ground Survey and Support for Acquisition	• Signed and sealed ground survey report
Task 3: Classification of LiDAR Points	• ASPRS LAS 1.4 (using WKT VLR for projection) classified LiDAR point clouds (full tiles of the State's 5K tiling scheme; approximately 14,400 tiles) • Fundamental Accuracy Control Report
Task 4: Development of DEMS in ESRI Grid Format	• 3.125 feet cell size Hydro-flattened ESRI raster datasets • 10 feet cell size Hydro-flattened ESRI raster datasets • 20 feet cell size Hydro-flattened ESRI raster datasets • 3D breakline files • *All datasets will be on the same tile scheme as the Classified LiDAR LAS files*
Task 5: Terrain Datasets by County	• Individual countywide terrain datasets within a file geodatabase
Task 6: High Detail Road and Bridge Classifications	• Incorporated into deliverable for Task 2 • Collected road polygons in ESRI GDB format
Task 7: Intensity Images	• Intensity image files (8-bit, GeoTiff, 5 foot raster cell size) • *All datasets will be on the same tile scheme as the classified LiDAR LAS files*
Task 8: Building Change Detection	• Building footprint and change detection update maps in ESRI file geodatabase
Task 9: Quality Assurance/Quality Control Plan	• QA/QC Report
Task 10: Preparation of Project Reports	• Weekly Status Reports • Collection Report (mission planning and flight logs) • Survey Report (survey and calibration) • Processing Report (product generation and methodology)
Task 11: Metadata	• FGDC compliant metadata for classified LAS point clouds • FGDC compliant metadata for 3.125, 10, 20, and 50 feet Hydro-flattened raster datasets • FGDC compliant metadata for ESRI Terrain Datasets • FGDC compliant metadata for Intensity Images

Project Schedule

The following table summarizes the anticipated delivery schedule for each task:

Task	Completion/Submission Date
Task 1: LiDAR Data Acquisition	05/02/2016
Task 2: Ground Survey and Support for Acquisition	04/15/16
Task 3: Classification of LiDAR Points	08/08/2016
Task 4: Development of DEMS in ESRI Grid Format	09/19/2016
Task 5: Terrain Datasets by County	10/3/2016
Task 6: High Detail Road and Bridge Classifications	08/082016
Task 7: Intensity Images	10/3/2016
Task 8: Building Footprints & Change Detection	10/08/2016
Task 9: Quality Assurance/Quality Control Plan	12/07/2016
Task 10: Preparation of Project Reports	**Submitted with corresponding deliverable*
Task 11: Metadata	**Submitted with corresponding deliverable*

Data Rights

As requested by the State and per the meeting of February 16th, 2016 between the State and ESP, the team understands and will adhere to the following requirements concerning raw data ownership for this project:

1) The State shall receive prior notice of any products derived from the stored raw data for this project or value added services provided through use of the raw data or derivatives
2) The State shall receive an Annual Report listing any data buy ups or other value-added services provided from the stored raw data to include a brief project and product summary, approximate value, square miles, and category of client
3) The ESP team shall retain the rights to the raw data being stored by the team under this project.
4) The State has total ownership and control of the 8ppsm LiDAR files and deliverables derived from those files for this project.

Optional Tasks

As requested by the State, the team is pleased to offer the following options for data buy ups and utility sector products that can be derived from the source LiDAR point cloud. The tasks related to the utility sector outlined below are based on the limited information available as to the needs and specifications of any potential stakeholder that may be involved in the project. These tasks outline ESP's preliminary approach and scope as well as any assumptions.

Should the below options be exercised by the State, a scoping meeting with relevant stakeholders will occur to determine the specifications needed for the options exercised. Such a meeting may or may not yield additional requirements that would necessitate revising the task as well as the task budget. The ESP team will work closely with any stakeholders to ensure that the below options meet their needs.

The corresponding budget numbers provided in our Business Proposal are based on research conducted by ESP on the extent of the transmission and distribution line holdings in NC as well as a polygon file of existing ash pond holdings. Any clarification from project stakeholders on their actual holdings may result in a decrease or increase in budget and/or scope.

Task numbers for each option mirror the numbers used in our submitted Business Proposal for this project.

Optional Task 17: NC Ash Pond Air Space Volume

Scope
The team, under this optional task, would conduct topographic mapping of ash pond sites providing only above water/ash deposit surfaces for volume (air space) calculations and topographic information up to the edge of ponds. This task **does not** include acoustic soundings to determine volumes of the pond feature below the bank edges.

The team will generate a topographic grid, breaklines, and surface derived from the aerial LiDAR and conventional topographic survey methods, contours, and above-pond surface volumes. This approach will allow access to restricted or unsafe areas by virtue of using the aerial LIDAR.

This task would include the establishment of semi-permanent bench marks on-site to be used for future pond monitoring by ESP and others.

Should stakeholders require it, the scope can be revised (along with an increase in budget) to add hydrographic surveys to determine the characteristics of the ponds below surface. This would require a case-by-case assessment of each individual site.

Assumptions
The following assumptions apply to this optional task:

- Hydrographic survey will not be required

- Stakeholders will provide access to sites
- Stakeholders will provide information relevant to site identification such as site boundaries and any existing mapping

Optional Task 18: Extracted Transmission Unclassified 30ppsm Point Cloud

Scope
Under this option the team would utilize existing transmission corridor information from project stakeholders to develop corridor data extraction polygons. The polygons will be based on the desired corridor width for a given transmission line type or vegetation analysis need.

The polygons would then be used as project bounds to clip calibrated data to the extents along with a small buffer to ensure coverage. This process will create manageable, 30ppsm LiDAR files (unclassified) along the transmission routes to be used for any transmission products selected under other tasks. This task is required for the team to be able to access the data for use in Optional Task 20, and any other potential transmission products of interest to the stakeholders.

Format of the unclassified point clouds will be LAS 1.3 or 1.4 depending the stakeholder's software needs.

Assumptions
The team assumes that the following would be made available by project stakeholders for this option:

- Existing Right-of-Way (ROW) information for all transmission lines
- Information concerning the stakeholders specific corridor mapping limits (i.e. 250 foot corridor centered on the lines for a particular kV rating)

Optional Task 19: Transmission Classified Point Cloud

Scope
Under this task the team would conduct automated and manual classifications for transmission lines only using the stakeholder-provided point cloud schema. The classifications anticipated for this task are as follows:

- Poles/towers
- Vegetation
- Ground
- Wires
- Buildings
- Vegetation encroachment polygons using stakeholder-provided PLSCADD models (product includes change detection)

Format of the classified point clouds will be LAS 1.3 or 1.4 depending the stakeholder's software needs.

Assumptions
The team assumes the following for this option:

- Stakeholders will provide existing PLSCADD models for use in generating the vegetation encroachments
- Additional point classifications beyond the ones listed under this optional task would require a revision to the scope and potentially an increase to the budget allotted for this task
- Information on the vegetation encroachment criteria specific to the stakeholder
- Execution of Optional Task 18

Optional Task 20: Transmission PLSCADD Model (Method 1)

Scope
Under this optional task the team would produce PLSCADD models (Method 1) using a hybrid approach to obtain weather information for the dates of flight over any particular area. This approach is necessary as the data flights will have occurred as part of the Phase 4 data collection and the placement of weather stations along transmission routes is neither feasible during nor required by the base contract acquisition specifications.

Weather data will be derived from various sources to determine the best approximation of conditions during the flight time over a particular line.

The team will meet with stakeholders to determine stakeholder-specific requirements for the models.

Assumptions
The team assumes the following for this option:

- Stakeholders will provide existing PLSCADD models where available
- Stakeholders will provide specification and guidelines specific to their workflow for PLSCADD models
- Information on the vegetation encroachment criteria specific to the stakeholder
- Execution of Optional Task 18

Optional Task 21: Oblique Aerial Photography for Transmission

Scope
This optional task would entail the use of an airborne digital camera platform to obtain color high resolution, oblique photography at a sufficient resolution to identify details of transmission line structures along a given line. The digital oblique imagery will be acquired at a resolution of 11 megapixels or greater and provided in JPEG format with a corresponding Microsoft Excel

spreadsheet contain image file names, image file paths, and the latitude and longitude of image capture location.

Assumptions
The following assumptions are related to this optional task:

- Stakeholders will provide existing information on the locations of lines and assets to be imaged

Optional Task 22: Classification of Distribution Network

Scope
This option would provide limited classification of the stakeholder's distribution network using the 30ppsm LiDAR point cloud files. The classifications that will be present in the classified LiDAR point cloud files are:

- Poles
- Vegetation
- Ground
- Wires
- Buildings

Assumptions
The team assumes the following for this option:

- Stakeholders will provide any existing information on their distribution network that can assist the team in identifying areas where holdings exist
- Additional point classifications beyond the ones listed under this optional task (if possible from 30ppsm) would require a revision to the scope and potentially an increase to the budget allotted for this task

Optional Task 23: Geiger Data Storage – 3 Years

Scope
Team member Harris Corporation will store the raw and calibrated data files for Phase 4, for a period of 3 years to provide near-term access to the data. The team will develop a data request process for the State to use for any requests that require the retrieval of data from storage. Data buy ups that necessitate a re-calibration and processing of data (such as a request for a different density) will be subject to the Reprocessing and Calibration Fees table in the team's business proposal.

The current storage plan does not involve online or cloud storage, or a "clip and ship" type of service.

Assumptions
There are no assumptions for this option.

Delivery Order No. 22

Appendixes

Appendix A: Requested Technical Specification Exemptions

In accordance with the North Carolina Technical Specifications for LiDAR Base Mapping, dated 2/15/2012, and this Delivery Order, ESP is requesting Specification Exemption for the items listed below.

Section 3.01.4 – *North Carolina Technical Specifications for LiDAR Base Mapping*

- **Buffering**
  - **Specification**
    - Project boundary shall be buffered by a minimum of 2,000 feet. Buffer areas may be adjusted by Contracting Officer.
  - **ESP Recommendation**
    - Update the Buffering specification to extend 100 Meters beyond all 2,500 feet by 2,500 feet tiles that intersect the political boundaries of the counties within the project area.
    - Please refer to *Task 1a – Project Boundary and Buffer*, for supporting details

Section 4.03 – *North Carolina Technical Specifications for LiDAR Base Mapping*

- **Daily Calibration Survey**
  - **Specification**
    - A daily calibration test course shall be established by the contractor within the project area. Daily calibration survey data will be collected by each sensor over this course at the start and end of each flight mission. The calibration sites must be established by ground surveying prior to the collection of any aerial LiDAR data for the projects. GPS base stations and surrounding High Accuracy Reference Network (HARN) points should be used to control redundant RTK GPS surveys and conventional surveys to approximately 8 to 10 calibration points at each site. The calibration site should be selected in an open flat area where elevation ground truth can be unambiguously established. Elevation points should be on smooth, unpainted or bare natural surfaces. Static initialization of the airborne GPS should be performed prior to take-off and upon landing. At minimum three flight lines shall be flown over the calibration site for the detection of systematic errors in the airborne GPS/IMU and LiDAR system data. The flight pattern is flown over the test area in two opposing directions and a cross-flight at 90 degrees to the former. A report of the daily calibration results and documentation of calibration points used will be furnished to the Contracting Officer and the quality control team. Any corrective action taken as a result of the daily calibrations shall be included in the report.
  - **ESP Recommendation**
    - Waive the Daily Calibration Survey requirement and adopt ESP's proposed Calibration Methodology.
    - Please refer to *Task 1c – Calibration* for supporting details.

Appendix B: Project Equipment List

The following equipment is available and is planned for use with this delivery order from the ESP team.

Aircraft *(planned aircraft for use; tail numbers to be provided in Operations Plan)*

- King Air 200
- Cessna 402C

LiDAR System

- Harris Geiger Mode

Internal Measurement Unit (IMU)

- Leica IPAS GNSS-IMU

Processing Software

- Harris Geiger Mode Enterprise Rainer Baseline V
- ESRI ArcGIS 10.x
- QT Modeler
- ESP Analyst
- Terrasolid Product Suite
  - TerraModeler
  - TerraMatch
  - TerraPhoto
  - TerraScan
  - TerraSlave

Ground Control Survey

- Trimble GPS Receivers
  - R8 GNSS
  - R10 GNSS
- Trimble Data Collectors
  - TSC-3