Amendment 8
to
Agency-Specific Price Agreement 7525

This is Amendment No. 08 ("Amendment") is to the LIDAR Data Acquisition Price Agreement 7525 ("Agreement"), originally effective May 12, 2008 between the State of Oregon acting by and through the State Procurement Office of the Department of Administrative Services ("SPO") Procurement Services on behalf of the Oregon Department of Geology and Mineral Industries ("Authorized Purchaser") and Quantum Spatial, Inc., a Wisconsin corporation registered in Oregon ("Contractor"). The State and the Contractor individually known as "Party", shall together to be known as "Parties". This Amendment is effective on the date it has been signed by the parties and approved in accordance with applicable law.

Background and Prior amendments.
The parties previously amended the Agreement as follows:

* Amendment 1 extended the termination date from March 18, 2010 until March 18, 2011.
* Amendment 2 extended the termination date from March 18, 2011 until March 18, 2012.
* Amendment 3 extended the termination date from March 18, 2012 until March 18, 2013.
* Amendment 4 extended the termination date to June 30, 2014 and added services.
* Amendment 5 extended the termination date to June 30, 2017 and replaced two exhibits.
* Amendment 6 made changes to the technical specifications.
* Assignment and Assumption Agreement substituted Quantum Spatial, Inc. for Watershed Sciences, Inc. The Agreement number changed from 8865 to 7525.
* Amendment 7 extended the termination date to June 30, 2020 and updated or revised technical specifications and services.

Purposes of Amendment 8.
The purposes of this Amendment are to:

(1) Extend the term of the Agreement defined in ***Section 4.0 TERM OF THE PRICE AGREEMENT to June 30, 2024***,

(2) Replace existing ***Exhibit A*** **DESCRIPTION AND SPECIFICATION OF THE SERVICES** with the ***Exhibit A*** **DESCRIPTION AND SPECIFICATION OF THE SERVICES** attached to this Amendment no. 08 to update the technical specifications and project deliverables, and

(3) Include ***APPENDIX 1 to Exhibit A*** as additional reference materials for lidar specifications.

APPROVED, the **Parties** have executed this Amendment No. 08 as of the dates set forth below.

(Authorized Purchaser) STATE OF OREGON acting by and through its **Oregon Department of Geology and Mineral Industries**

Dania Ballard 5/11/2020

Dania Ballard, CFO Date

(SPO) STATE OF OREGON acting by and through its Oregon **State Procurement Office Department of Administrative Services,**

21 MAY 2020

(Name), (Title) Date

(Contractor) Quantum Spatial, Inc.,

Robert Vander Meer, Vice President May 11, 2020

(Name), (Title) Date

Approved pursuant to ORS 291.047
Approved by: Exempt Per email dated: n/a

EXHIBIT A
DESCRIPTION AND SPECIFICATION OF THE SERVICES

1. Specifications of the Services

Contractor shall provide the lidar ("light radar," or airborne laser swath mapping) data services (the "Services") that meet or exceed the specifications in this Exhibit A.

- The Services will be provided for lidar data collection projects, which may be ordered by written or electronic Purchase Orders issued by DOGAMI.
    - Standard lidar deliverables are described in Section 2.2 and standard cost for those products are listed in Table 1.
- Defined terms used but not defined in this exhibit have the meaning provided in the Agreement.

2. Lidar Services

Contractor's obligation to perform the Services includes providing all facilities, components, personnel, and equipment required to provide the Services, including without limitation aircraft services.

- The minimum accepted Quality Level (QL) for lidar services is QL1 as defined in this document and as published by the National Geospatial Program's Lidar Base Specification version at time of purchase order.
    - See Tables 2-8 in Appendix for details on quality level requirements.
    - Optional Services (Section 2.6) will meet QL1 standards unless specifically detailed in the Optional Service product description sub-section or specifically requested by DOGAMI in the purchase order.

2.1 Acquisition and Project Design Specifications

2.1(a) Lidar Sensor Requirements

Contractor's lidar sensor used for Services must meet the following requirements:

- Sensor Type:
    - Contractor will provide sensor information to DOGAMI and DOGAMI will provide approval prior to purchase order submission.
- Laser Spot Diameter:
    - Lidar sensor will produce an on-ground laser spot diameter no less than **15 centimeters (cm)** and no greater than **50 cm** measured at 1/e.
    - 1/e is defined as the diameter at which the beam irradiance (intensity) has fallen to 36.5 percent of its peak value.
- Sensor Returns:
    - Deriving and delivering multiple discrete return are required in all conventional lidar data collection efforts.

  - Record a minimum of 4 returns per laser pulse, including first and last returns.
  - Full waveform collection is acceptable and is promoted however full waveform data is regarded as supplemental information.
- Overlap:
  - Contractor shall plan surveys with a minimum of 30 percent sidelap of adjacent swaths.
  - Sidelap may be increased in the case of areas of steep terrain to ensure full coverage.
- Density:
  - Aggregate Nominal Pulse Density (ANPD) and Aggregate Nominal Pulse Spacing (ANPS) shall meet the requirements of QL1 for lidar collections (Table 2).
  - ANPD and ANPS assessments are to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath.
- Intensity:
  - Intensity values are required for each multiple discrete return.
  - The intensity values recorded in the LAS files shall be scaled to 16-bit, as required by the LAS specification version 1.4–R13 (ASPRS, 2011).
  - Common image stretches (minimum-maximum, standard deviations, percent clip, histogram, and so forth) are expressly forbidden

2.1(b) Acquisition Area Design

DOGAMI and Contractor will adhere to the following requirements when designing collection projects:

- Area of interest (AOIs):
  - Each AOI designed by DOGAMI must be a contiguous area no smaller than **40 square miles and may range to in excess of 2,000 square miles**.
  - AOI cannot contain large internal gaps, and narrow extensions.
  - AOI must be at least 1.25 miles wide at the narrowest point and must not have a perimeter to area ratio greater than 2 miles per square mile.
  - AOI must include all land area within a survey and the area of all water bodies with minimum dimension less than one-half mile.
    - Larger water bodies, except for a 300-foot-wide seaward buffer along a shoreline, must be excluded from the calculation of the survey area, unless otherwise specified in a Purchase Order.
  - AOI shall be finalized by DOGAMI after consultation with Contractor.
- Defined Project Area (DPA):
  - DPA shall be the Area of Interest (AOI) plus a 100-meter buffer.
  - Data collection is required for the full extent of the DPA.
  - All Services delivered to DOGAMI shall be produced to the extent of the DPA.

- All products, including checkpoints, shall be located within or otherwise clipped to DPA extents.

2.1(c) Collection Conditions

Contractor must consult with DOGAMI if potentially adverse collection conditions such as snow, high water, or smoke exist, and may proceed only with written approval. Contractor will only acquire data when the following conditions have been met:

- Atmospheric Conditions:
  - Collection area shall be cloud and fog free between the aircraft and ground during all collection operations.
- Ground Conditions:
  - Lidar laser penetration to the ground shall be adequate to produce an accurate and reliable bare-earth surface that meets QL standards (Tables 2-9).
  - Collection area shall be free of extensive flooding or any other type of inundation.
  - Ground conditions will be snow free.
    - Very light, undrifted snow may be acceptable with prior approval.
- Special Acquisition Request:
  - If data acquisition during specific dates, tide levels, stream or reservoir levels, is required, DOGAMI and Contractor may negotiate a price supplement to compensate Contractor for the additional cost of the special request.
    - If specific acquisition conditions are needed, Contractor will provide a written description to DOGAMI of the additional cost required to meet the conditions and shall explain the basis for the added cost.
    - If DOGAMI wishes to proceed, the costs will be included in the Purchase Order, and the written cost description will be attached to the Purchase Order.
- Recollection:
  - Contractor will recollect lidar in areas of data voids if the following conditions are met:
    - A data void is any area greater than or equal to (4 × Aggregate Nominal Pulse Spacing) ^{2}, which is measured using first returns only.
    - Data voids within a single swath are not acceptable, except in the following circumstances:
      - Where caused by waterbodies.
      - Where caused by areas of low near infrared reflectivity, such as asphalt or composition roofing.
      - Where caused by lidar shadowing from buildings or other features.
      - Where appropriately filled in by another swath.

2.1 (d) GPS Procedures for Collection and Calibration

Contractor will follow these Global Positioning System (GPS) procedures during lidar collection and calibration:

- GPS Time:
  - GPS data shall be recorded as Adjusted GPS Time (Standard satellite GPS time minus 1*109) at a precision sufficient to allow unique timestamps for each pulse.
- PDOP:
  - All GPS measurements must be made during periods with Positional Dilution of Precision (PDOP) less than or equal to 3.0 and with at least 6 satellites in common view of both a stationary reference receiver and the roving receiver.
  - Contractor shall make all GPS measurements with dual frequency L1-L2 receivers with carrier-phase correction.
  - At least two GPS reference receivers must be in operation during all lidar data collection, sampling positions at greater than or equal to 1 hertz (Hz). The roving GPS receiver in the aircraft must sample positions at greater than or equal to 2.0 Hz. Differential GPS baseline lengths shall be no longer than 30 km.
  - Use of PPRTX, ORG Network and CORS stations which are equal to or exceed the before mentioned methods for accuracy are also acceptable.
- GPS Control Points
  - Control points used in the calibration process for data acquisition shall not be used as check points.

2.1 (e) GPS Procedures for Accuracy Assessment

Contractor must meet all specifications and requirements in the American Society for Photogrammetry and Remote Sensing (ASPRS) "Positional Accuracy Standards for Digital Geospatial Data (ASPRS 2014). Hyperlink to PDF:
https://www.asprs.org/a/society/committees/standards/Positional_Accuracy_Standards.pdf

- Ground Check Points (GCPs):
  - Independent set of surveyed points used for the sole purpose of assessing vertical accuracy.
    - The unclassified point data shall meet the required NVA for QL1 before further classification and processing of the lidar products.
  - The same GCPs may be used for Nonvegetative Vertical Analysis (NVA) assessment of the point data and surface rasters.
  - Check points will be located in areas having a minimum homogeneous area of Aggregate Nominal Pulse Spacing (ANPS) *5) ^{2}, with less than one-third of the required vertical root mean square error in the z direction (RMSEz) deviation from a low-slope (<10 degree) plane.
  - All tested locations will be photographed showing the position of the survey tripod and the ground condition of the surrounding area.

- Nonvegetative Vertical Analysis (NVA) Check Points:
    - GCPs for NVA assessments shall be surveyed in clear, open areas (which typically produce only single lidar returns) devoid of vegetation and other vertical artifacts (such as boulders, large riser pipes, and vehicles) (Table 4).
    - Check points shall not be located on ground that has been plowed or otherwise disturbed.
- Vegetative Vertical Analysis (VVA) Check Points:
    - Check points for VVA shall be surveyed in vegetated areas (typically characterized by multiple return lidar) (Table 4).
    - In land covers other than forested and dense urban, the tested check point will have no obstructions above 15 degrees over the horizon.
- Check Point Quantity and Distribution:
    - The quantity and location of check points shall meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (ASPRS 2014).
    - Minimum number of survey points shall follow ASPRS and USGS current guidelines at time of purchase order (Table 5).
    - Within each assessment type, check points will be well-distributed among all constituent land cover types (Table 4) in approximate proportion to the areas of those land cover types (ASPRS, 2014).
        - A survey plan will be agreed upon by DOGAMI and Contractor for areas with limited project area access.

2.1 (f) Coordinate Reference System and Datums

DOGAMI and Contractor will agree to and specify the spatial reference framework and the Coordinate Reference System (CRS) within the purchase order. All Services shall be processed and delivered in a single CRS. Contractor will collect all remote sensing data using the information below:

- Horizontal Datum:
    - The horizontal datum for latitude and longitude and ellipsoid heights will be the North American Datum of 1983 (NAD 83) using the most recent National Geodetic Survey (NGS) published adjustment.
    - Currently, the most recent NGS adjustment is NAD 83, epoch 2010.00, realization of 2011.
- Vertical Datum:
    - The vertical datum for orthometric heights will be the North American Vertical Datum of 1988 (NAVD 88). Using the most recent NGS published adjustment.
    - The geoid model used to convert between ellipsoid heights and orthometric heights will be the latest hybrid geoid model of NGS, supporting the latest realization of NAD (83).

    - Currently, the most recent geoid model is Geoid12B.
- Coordinate Reference System (CRS):
    - The complete CRS definition and its WKT representation, both horizontal and vertical, shall be documented as part of the agreement
    - All references to the units of measure "Feet" and "Foot" shall specify "International," "Intl," "U.S. Survey," or "US."
    - DOGAMI's preferred CRS is Oregon Lambert NAD (83) International Feet.
        - Currently the most recent version is European Petroleum Survey Group (EPSG) WKID #6557
        - Specific details on the Oregon Lambert projection are available at the following web link: http://www.oregon.gov/geo/pages/projections.aspx
    - DOGAMI may request the use of different CRS.

2.1 (g) Point Source Identification

Contractor will collect all lidar data using the file and point source identification requirements below:

- File Source ID:
    - At the time of its creation and prior to any further processing each swath shall be assigned a unique file source ID.
- Point Source ID:
    - Each point within the swath shall be assigned a point source ID equal to the File Source ID.
    - The point source ID on each point shall be consistent, unchanged throughout all processing and delivery.

2.1(h) Project Tilling Scheme

A single nonoverlapping project tilling scheme will be established and agreed upon by DOGAMI and Contractor before collection. Contractor will also deliver mosaiced project deliverables based on the project tilling scheme.

- Project Tilling Scheme:
    - The tilling scheme shall use the same Coordinate Reference System and units defined in purchase order and will meet requirements of Section 2.1 (f).
    - The tile size shall be an integer multiple of the cell size for raster deliverables.
    - The tiled project deliverables shall edge-match seamlessly and without gaps.
    - The tiled project deliverables shall conform to the project tilling scheme without added overlap.
- Naming convention:
    - Last 4 digits of the X and Y of the lower left coordinate
- Mosaiced Deliverables:
    - Contractor will mosaic project deliverables based on the project tilling scheme.

- The mosaic deliverables shall use the same Coordinate Reference System and units as the data - Section 2.1 (f).
- The mosaic deliverables shall edge-match seamlessly and without gaps.
- The maximum size of mosaic deliverables will be 64 gigabytes (GB).
  - Any mosaiced project deliverables larger than 64 GB will be divided into multiple pieces.

2.2 Standard Project Deliverables

Contractor shall provide to DOGAMI the following standard services as project deliverables. All standard project deliverables will meet requirements in Section 2.1 - Acquisition and Project Design Specifications. Each standard project deliverable has a set of requirements that must be met.

- Cost for standard project deliverables are provided in Table 1, Row: Section 2.2 in the Appendix.
- Contractor shall reformat and re-deliver any data that:
  - Fails to meet format specifications.
  - Contain inconsistent or unreadable internal formats.
  - Contains incomplete or incorrect associated projection files.

2.2(a) Classified Point Data

All project swaths, returns, and collected points shall be fully calibrated, adjusted to ground, classified, and segmented into tiles. Project swaths exclude calibration swaths, cross-ties, and other swaths not used, and not intended to be used, for product generation.

- LAS Format:
  - All point deliverables shall be in LAS format, version 1.4 using Point Data Record Format 6,7,8,9 or 10. LAS Specification version 1.4 – R13 (ASPRS, 2011).
  - LAS file naming convention will match the tilling scheme naming convention (Section 2.1 (h)).
- GPS Time:
  - GPS data shall be recorded as Adjusted GPS Time, at a precision to allow unique timestamps for each pulse.
  - The encoding tag (for GPS time) in the LAS header shall be properly set.
- Point Source ID:
  - Each point within a swath shall be assigned a point source ID equal to the file source ID.
  - The point source ID on each point shall be consistent unchanged throughout all processing and delivery.

  - The file source ID for tiled LAS files shall be set to '0' (see LAS specification version 1.4–R13 [ASPRS, 2011]).
- Overage Points:
  - If it is necessary to identify overage points in overlap areas, the overage points shall be identified using the overlap bit flag as defined in LAS Specification Version 1.2-R13 (ASPRS, 2011).
  - Overage (Overlap) and Withheld flags shall set as appropriate.
- Point Classification:
  - All points that fall within the minimum classification scheme (Table 7) and not flagged as withheld shall be properly classified.
  - No points in the classified LAS deliverable may remain assigned to Class 0.
- LAS File Headers:
  - Correct and properly formatted georeferenced information as Well Known Text (WKT) shall be included in all LAS file headers.
  - The Coordinate Reference System (CRS) information may be recorded in either a variable length record (VLR) or an extended variable length record (EVLR) at the discretion of the data producer.
  - The CRS record shall contain no whitespace unless enclosed within double quotation marks.
  - The CRS record shall contain no carriage returns (CRs), line feeds (LFs), or new lines (NLs), or any other special, control, or nonprintable characters.
- Duplication:
  - Duplication of lidar points (x, y, z, and timestamp) within the project is not acceptable.
  - LAS files containing duplicated points will be rejected.
  - Near duplication (that is, a group of points duplicated but with a slight but consistent spatial offset) will be regarded as duplication.
- Intensity Values:
  - Intensity values shall be normalized to 16-bit.
- RGB Attribution:
  - Red, Green, Blue (RGB) values must be attributed with co-acquired orthoimagery or latest NAIP imagery when applicable.

2.2(b) Bare-Earth Digital Elevation Models (DEMs):

Bare-Earth Digital Elevation Model (DEM) is defined as a raster of ground surface interpolated via triangulated irregular network from identified LAS ground points (classification 2).

- Extent and Coverage:
  - Bare-Earth DEMs shall be generated to the limits of the DPA.
  - Bare Earth DEMs must not have tiling artifacts or gaps at tile boundaries, or artifacts such as pits, birds, striping or aliasing.
    - Bridges removed from the surface.
    - Road or other travel ways over culverts remain intact in the surface.
- Resolution:
  - Bare-Earth DEM resolution is 3-foot (1 meter if UTM projection specified) cell size, snapped to center of cell (0,0) of the project tilling scheme (Table 8).
- Format:
  - 32-bit floating point GeoTiff raster format.
  - The NODATA value of '-9999999' shall be defined in GDAL_NODATA tag #42113.
- Projection:
  - Bare-Earth DEMs shall have the same CRS as the other project deliverables.
    - This information shall include both horizontal and vertical systems; the vertical system name shall include the geoid model used to convert from ellipsoid heights to orthometric heights.

2.2(c) Highest-Hit Digital Surface Models (DSMs)

Highest Hit Digital Surface Model (DSM) is defined as raster of first-return surface, interpolated via triangulated irregular network from identified highest, first returns within a cell.

- Extent and Coverage:
  - Highest-Hit DSMs shall be generated to the limits of the DPA.
  - Highest-Hit DSMs must not have tiling artifacts or gaps at tile boundaries, or artifacts such as pits, birds, striping or aliasing.
- Resolution:
  - Highest-Hit DSM resolution is 3-foot (1 meter if UTM projection specified) cell size, snapped to center of cell (0,0) of the project tilling scheme (Table 8).
- Format:
  - 32-bit floating point GeoTiff raster format.
  - The NODATA value of '-9999999' shall be defined in GDAL_NODATA tag #42113.
- Projection:
  - Highest-Hit DSMs shall have the same CRS as the other project deliverables.
    - This information shall include both horizontal and vertical systems; the vertical system name shall include the geoid model used to convert from ellipsoid heights to orthometric heights.

2.2(d) Intensity Images

Lidar intensity image is defined as the return strength of the laser pulse measured when the laser scanner produces a lidar point. Intensity images rasters are interpolated via triangulated irregular network.

- Extent and Coverage:
  - Intensity images generated to the limits of the DPA
  - Intensity images must not have tiling artifacts or gaps at tile boundaries.
- Resolution:
  - Intensity image resolution is 1.5-foot (0.5 meter if UTM projection specified) pixel size, snapped to center cell (0,0), of the project tilling scheme.
- Format:
  - 16-bit pixel depth grayscale GeoTiff raster format.
  - Intensity will be scaled to 16-bit as referenced Section 2.1 (a)).
- Projection:
  - Intensity images shall have the same CRS as the other project deliverables.
    - This information shall include both horizontal and vertical systems; the vertical system name shall include the geoid model used to convert from ellipsoid heights to orthometric heights.

2.2(e) Vector Files

Contractor will provide georeferenced Esri® shapefiles in order to show polygonal representation of the detailed extent of certain project deliverables. Contractor will provide the following deliverables in Esri® polygon shapefile format:

- Project Area: Extent of the DPA for the project.
- Tile Index: Tilling scheme used for all project deliverables.
- Control Layers:
  - Ground control points used to calibrate and process the lidar.
  - NVA ground check points (GCP) used to validate the lidar point data and raster products.
  - VVA ground check points (GCP) used to validate the raster products.
  - Monuments: Location of the NGS markers, if used, occupied by the Contractor's stationary reference receivers when acquiring control points or check points.
    - Any NGS monument Contractor establishes will be included in this vector file.

- Lidar Swath: detailed extent of each lidar swath collected as a set of polygons that define the area actually covered by the swaths, not merely the points collected in the swaths. Each swath polygon shall be attributed with the following:
  - Project name.
  - Start date and Time of swath.
  - End date and Time of swath.
  - Lift's unique ID.
  - Unique file source ID of the swath.
  - Swath Type: "Cross-tie", "Fill-in", "Calibration" or "Other."

- Trajectory Files:
  - Recorded aircraft trajectory data (Smoothed Best Estimate of Trajectory (SBET) files) attributed with the following information:
    - Project name.
    - Point Source ID # that is associated with LAS point header information.
    - Date of acquisition.
    - Aircraft position (easting, northing, elevation).
    - Attitude (heading, pitch, roll).
    - GPS time recorded at regular intervals of 1 second or less.
    - The data files may include additional attributes, such as temperature and humidity.

2.2 (f) Survey Report

Contractor's survey report describes lidar project information, acquisition summary, calibration process, classification method, methodology for ground survey data, the Quality Assurance/ Quality Control (QA/QC) process and accuracy assessment for all project deliverables. If Optional services (Section 2.5) are requested, a full report is required for each additional optional service.

- Acquisition:
  - Project name, location map, Purchase Order date, delivery date, project AOI, project DPA, specified datum, CRS, epoch of adjustment, geoid and units.
  - Map of flight lines indicating dates of collection, table of acquisition parameters including information about the aircraft, sensor, acquisition settings, flight elevation.
  - Detailed flight logs. Flight logs are expected to include:
    - Aircraft make, model and tail number
    - Take-off and landing times of each lift
    - Instrument manufacturer, model and serial number
      - Date of the instrument's most recent factory inspection/calibration
    - General weather conditions
    - General observed ground conditions
    - Inflight disturbances and notable head/tail/crosswinds.

        - Inflight instrument anomalies and any inflight changes in settings
- Project Deliverables:
    - List of deliverables, file formats used for deliverables and total number and data volume of each deliverable.
    - Standardized description of the data tiling scheme.
- Calibration:
    - Contractor shall fully describe all steps taken to calibrate each aircraft's onboard inertial measurement unit (IMU) and sensor offsets and settings.
    - Contractor shall provide information related to the control points used to calibrate and process the unclassified lidar data.
- Classification:
    - Methodology for classifying lidar data.
- Ground Survey Report:
    - The report must describe the survey technique(s) used to establish, collect and process GCPs for the purposes of undertaking lidar data quality control (QC) used by Contractor and document the positions and residuals of all GCPs used to evaluate survey accuracy.
    - The documentation must include the identity, published position, and measured position of all existing NGS marks used for reference stations.
    - If applicable, the locations of new marks must be described, along with their measured positions and the identity and published positions of CORS to which their locations were tied.
    - Contractor shall document the positions of all GCPs used to evaluate survey accuracy and provide a map showing the locations of all GCPs used to validate lidar point data or surface derivatives.
- QA/QC Process:
    - Methodology of Contractor's QA/QC process.
        - Expected horizontal accuracy of the lidar data.
        - Assessed relative accuracy of the point data.
    - Assessed (NVA) and (VVA) of the bare earth surface in accordance with the guidelines. (ASPRS 2014).
    - Pulse Desnity
        - Contractor's assessment of pulse density over the project area, including maps showing design pulse density, by tilling scheme, and histogram of density parameters and statistics for percentage of populated cells (as described in Section 2.1 (a)).
- Report for Additional Services (Optional) if requested by DOGAMI:
    - Additional Services will require an additional section in the Survey Report detailing the collection, calibration, processing, QA/QC methodology and project deliverables.

2.2(g) Formal Metadata:

Contractor shall deliver one extensible markup language (XML) metadata file for each standard product deliverable. DOGAMI will provide Contractor a standardized metadata document for creating XML files.

- Compliance:
  - FGDC-compliant metadata shall pass the USGS Metadata Parser (MP) without errors.
  - A block of lidar-related metadata tags specified by the USGS shall be included in the CSDGM (FGDC, 1998) metadata files for all lidar data deliverables. All tags are required.
    - Tags requiring a numeric value shall not contain text.
- Metadata Requirements:
  - One XML metadata file for the following list of high-level lidar products that are standard project deliverables:
    - Classified point data.
    - Bare-Earth DEMs.
    - Highest-Hit DSMs.
    - Intensity Images.
    - Vector files.
      - Each vector file requires a unique metadata file.

2.3 Data Quality

Services must meet or exceed the requirements described in this Exhibit A for lidar project deliverables. All project deliverables must meet QL1 as defined in this document (See Tables 2-8 in the Appendix for details on QL requirements.) DOGAMI may reject data if the data does not meet specifications that are detailed in this section. DOGAMI may, in its discretion, either require Contractor to rework rejected data (including re-acquisition if necessary) or refuse payment. At DOGAMI's discretion, it may agree to partial payment for partially satisfactory data. Contractor shall not charge, and DOGAMI will not pay, any additional costs for any re-acquisition arising because the data does not meet these specifications.

2.3 (a) Completeness of Data.

All project deliverables will be reviewed by DOGAMI to ensure that the data coverage and spatial extent is accurate.

- All products delivered to DOGAMI shall be produced to the extent of the DPA.
- A data void is considered any area greater than or equal to $(4 \times \text{ANPS})^2$, which is measured using first returns lidar points only (Section 2.1 (c)).
  - No voids between swaths.
  - Less than or equal to 10% no-overlap area per project area.

2.3(b) Positional Accuracy Validation

Prior to classification and development of derivative products from the point data, the absolute and relative vertical accuracy of the point data shall be verified. A detailed report of the validation processes used shall be delivered as part of the Survey Report.

2.3(c) Absolute Horizontal Accuracy

Horizontal error in lidar derived elevation data is largely a function of positional error as derived from the Global Navigation Satellite System (GNSS), attitude (angular orientation) error (as derived from the INS) and flying altitude; and can be estimated based on these parameters.

- Contractor will provide the calculated horizontal accuracy for the lidar sensor based on the ASPRS Horizontal Accuracy Requirements for Elevation Data (ASPRS 2014)

2.3(d) Relative Vertical Accuracy

Relative vertical accuracy refers to the internal geometric quality of a lidar dataset without regard to surveyed ground control. Two primary factors need to be considered in lidar data relative vertical accuracy:

2.3(d1) Intraswath Precision (Smooth Surface Precision)

Intraswath Precision is defined as "longitudinal and along-track planarity of elevations for a single swath across a uniform, flat surface, and is a measure of sensor and inertial motion unit system calibration and stability."

- Sample areas for assessment of precision will be approximately 100 pixels.
- To the degree allowed by the data and the project environment, multiple sample areas representing the full width of the swath(s) (left, center, and right) will be examined.
    - Multiple single swaths from a single lift may be used if needed to sample the full swath width.
- At a minimum, precision shall be assessed against for each lift of each aircraft/instrument combination used on the project.
    - Each test area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cell size = CEILING(ANPS)×2).
    - The difference rasters will be statistically summarized to verify that root mean square difference in the z direction (RMSDz) values do not exceed the limits set forth in Table 2 for the QL of information that is being collected.
- Precision shall be reported by way of a polygon shapefile delineating the sample areas checked and, using the cells within each polygon as sample values, attributed with:

- minimum slope-corrected range (numeric),
- maximum slope-corrected range (numeric), and
- RMSDz of the slope-corrected range (numeric).

2.3(d2) Interswath (Overlap) Consistency

Interswath consistency is defined as overlap consistency of swaths.

- This consistency is assessed at multiple overlap areas that are nonvegetative in nature and have slopes of less than 10 degrees.
- The overlap areas that will be tested are those between the following:
  - adjacent, overlapping parallel swaths within a project;
  - cross-tie swaths and a sample of intersecting project swaths in both flight directions; and adjacent, overlapping lifts.
- Each overlap area will be evaluated using a difference raster (Dz Orthos).
  - Dz Orthos are defined as a triangulated irregular network constructed raster with binary values representing the difference between adjacent flightlines using a threshold of +/- 8cm to indicate where flightline offsets occur within a given project area.
    - Values are determined from all spatially valid points within the lidar point cloud and modulated using intensity values. Lidar points flagged as withheld will be excluded from the analysis.
    - The cell size of Dz Ortho rasters equal to the ANPS, rounded up to the next integer, then doubled (Cell size = CEILING(ANPS)×2).
  - DZ Orthos represent the quality of flightline-to-flightline offsets within the project area.
  - The Dz Orthos will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in Table 2 for the Quality Level of information that is being collected.
  - Dz Orthos are to be delivered in TIFF or JPEG format and must contain georeferencing information aligned with the project coordinate system."

2.3(e) Absolute Vertical Accuracy of Lidar Point Data

Contractor shall calculate absolute vertical accuracy of the lidar point data by comparing Ground Check Points (GCPs) surveyed in clear, open, non-vegetated areas (which typically produce only single lidar returns) to a triangulated irregular network (TIN) constructed from the single return lidar points in those areas (Section 2.1 (e)).

- The minimum NVA requirements for the lidar point data, using the ASPRS methodology, are listed in Table 5.

- If the absolute vertical accuracy of the point data fails to meet the specification, Contractor and DOGAMI will investigate all statistics and distribution of ground control points to assess the nature and causes of outliers influencing the overall accuracy of the data.

2.3(f) Absolute Vertical Accuracy of Bare-Earth DEMs.

Contractor shall calculate vertical accuracy for the lidar point data by comparing GCPs surveyed in clear, open, non-vegetated areas (which typically produce only single lidar returns) to a triangulated irregular network (TIN) constructed from the single return lidar points in those areas (Section 2.1 (e)).

- NVA and VVA for the Bare-Earth DEMs are assessed by comparing GCPs to the final bare-earth DEMs.
- The minimum NVA and VVA requirements for bare-earth DEMs, using the ASPRS methodology, are listed in Table 5.
    - Both the NVA and VVA recommended values shall be met.
- If the absolute accuracy of the bare-earth DEMs fails to meet the specification, Contractor and DOGAMI will investigate all statistics and distribution of ground control points to assess the nature and causes of outliers influencing the overall accuracy of the data.

2.3(g) Lidar Pulse Density

Barring non-scattering areas (e.g. open water, wet asphalt) the lidar pulse density must meet the following requirements:

- Aggregate Nominal Pulse Density (ANPD) shall be no less than 8 points per square meter (QL1) (Table 2).
- Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.35 meters (QL1) (Table 2).
- ANPD and ANPS assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath.
- Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects.

2.3(h) DEM and DSM Surface Quality

The following requirements for raster quality must be met:

- There must be no tile-boundary artifacts or edge artifacts between tiles.
- No voids between tiled rasters.
- No avoidable misclassification of returns.

- Surface models must be free of other artifacts such as pits and spikes caused by anomalous high or low points and striping due to inadequate flight line calibration.
- A quilted appearance in the overall surface will be cause for rejection of the entire raster surface deliverables, whether the variations are caused by differences in processing quality or character among tiles, swaths, lifts, or other artificial divisions.

2.4 Delivery Schedule

The following are scheduling recommendations for Contractor:

- Contractor shall make final delivery no later than 110 business days from end of data acquisition.
- Contractor shall provide digital data to DOGAMI on new portable hard drives at Contractor's expense.
- DOGAMI will review and accept or reject lidar data within 30 business days of delivery.
    - Following a thorough quality control review by DOGAMI, data will be accepted or rejected based on specifications in this Exhibit A.
    - Contractor shall reprocess or re-fly problem areas without additional cost to DOGAMI if it is determined that the lidar data does not meet these specifications.

2.5 Data Ownership

All data delivered to DOGAMI under this Agreement shall be in the public domain. Contractor may resell the LIDAR data provided under this Agreement only with advanced written consent by DOGAMI, and only after the data has been made available to the public.

2.6 Optional Services.

The following additional lidar-related services, or specification changes may be requested by DOGAMI in a Purchase Order. Prices for these additional services are specified in Table 1 in Section 2.6. All optional services will adhere to acquisition and project design specifications in Section 2.1 unless specifically requested in Purchase Order.

2.6 (a) Collection of Higher Resolution Lidar

The designed aggregate nominal pulse density of the project must be greater than or equal to 15 pulses per square meter. The lidar services produced from higher resolution lidar collection will, at minimum, meet QL1 standards for acquisition design (Section 2.1), project deliverables (Section 2.2) and data quality (Section 2.3).

2.6 (b) Collection of Lower Resolution Lidar:

Lidar services must meet USGS Lidar Base Specification Quality Level 2 (QL2) data quality standards. QL2 quality metrics and requirements are listed in Tables 2-8 of the Appendix. The designed aggregate nominal pulse density of the project must be greater than or equal to 4 pulses per square meter.

2.6 (c) Bathymetric Lidar

Contractor must employ a green-wavelength (μ = 532 nanometer (nm)) bathymetric lidar system to collect simultaneous elevation data for a stream or lake bed and its adjacent shorelines. DOGAMI will provide a project AOI in Esri® shapefile format to Contractor. Contractor will provide a custom quote for bathymetric lidar services based on the unique characteristics of the AOI and expected performance of the bathymetric lidar survey. Bathymetric lidar services will meet the following requirements:

- Lidar Service Exceptions:
    - Bathymetric products must be the same as standard lidar services (Section 2.1) with the following exceptions:
        - Due to sensor limitations, data voids for stream and lake bed areas underwater are allowed where water depth and turbidity prevent the lidar pulses from reaching the bottom surface.
        - Corrections will be made for refraction.
        - Vertical accuracy standards for submerged topography will be relaxed to 30 cm RMSEz.
        - Pulse density requirements for submerged topography will be reduced to 5/m2.
- Deliverables:
    - Contractor will deliver standard lidar products (Section 2.2) with the following modifications:
        - Classified LAS files:
            - Classification of lidar returns will include classification of water.
        - Topobathymetric models:
            - Surface models that includes topography and bathymetry (DTM) in the same requested projections as other deliverables.
        - Ground density raster:
        - Vector files in Esri® polygon shapefile format:
            - Waterlines.
            - Submerged topography density (confidence intervals).

2.6 (d) Hydro-Flattened Bare-Earth DEMs

DOGAMI may choose to have hydro-flattened bare-earth DEMs created in which water bodies have been modified by Contractor. Hydro-flattening only pertains to the creation of derived DEMs and break lines. The methodology and products for hydro-flattening will meet current Lidar Base Specification requirements at the time of purchase order. Current Lidar Base Specification will be documented in the purchase order for reference.

- Cost:
    - 3DEP Hydro Flattening Cost: $1000 + ($4.50 x waterbody acres).
        - A $1000 minimum hydro flattening fee is added to an area rate of $4.50 per acre multiplied by total estimated waterbody acres.
        - DOGAMI will provide Contractor a single Esri® polygon shapefile for the total estimated waterbody acres.
            - This Esri® polygon shapefile will be reviewed by Contractor.
            - The final version of the Esri® polygon shapefile will be used to calculate cost.
    - A hydro flattening Esri® polygon shapefile will be submitted to Contractor with the Purchase Order.
- Processing:
    - Lidar Point modification:
        - Hydro-flattening makes no changes to the geometry of the originally computed lidar points.
        - Bare-Earth (Class 2) lidar points (serving as mass points) that are in close proximity to any breakline shall be classified as Ignored Ground (class 20) and shall be excluded from the DEM generation process when the breaklines are included.
            - This process prevents unnatural surface artifacts from being created between lidar points and breakline vertices.
        - The proximity threshold for reclassification as Ignored Ground is at the discretion of the data producer, but in general should not exceed twice the ANPS.
    - Bridge Decks:
        - Streams, rivers, and water bodies meeting the criteria for hydro-flattening shall be monotonically continuous where bridge decks have been removed.
            - When the identification of a structure as a bridge or culvert cannot be made definitively, the feature shall be regarded as a culvert.
        - Bridges in all their forms shall be removed from the DEM.
    - Inland Ponds and Lakes:
        - Waterbodies with a surface area of 0.8 hectare (ha; 2 acres) or greater (approximately equal to a round pond 100 m in diameter) at the time of collection shall be flattened.

- Flattened waterbodies shall present a flat and level water surface (a single elevation for every bank vertex defining the waterbody's perimeter).
- The entire water surface edge shall be at or below the immediately surrounding terrain (the presence of floating waterbodies will be cause for rejection of the deliverable).
- Long impoundments such as reservoirs, inlets, and fjords, whose water surface elevations decrease with downstream travel, shall be treated as streams or rivers.

- Inland Streams and Rivers:
  - Streams and rivers of a 30-m or greater nominal width shall be flattened.
  - Streams or rivers whose width varies above and below 30 m will not be broken into multiple segments.
  - Flattened streams and rivers shall present a flat and level water surface bank-to-bank (perpendicular to the apparent flow centerline).
  - Flattened streams and rivers shall present a gradient downhill water surface, following the immediately surrounding terrain.
  - In cases of sharp turns of rapidly moving water, where the natural water surface is notably not level bank-to-bank, the water surface will be represented as it exists while maintaining an aesthetic cartographic appearance.
  - The entire water surface edge shall be at or below the immediately surrounding terrain.
  - Stream channels shall break at culvert locations leaving the roadway over the culvert intact.
  - Streams shall be continuous at bridge locations.
- Non-Tidal Boundary Waterbodies:
  - Boundary waterbodies are waterbodies that contain some or all the DPA.
  - Boundary waterbodies may be any type of waterbody but are virtually always large in area or width
  - A boundary waterbody shall be represented as a polygon that follows the shore throughout the project and is then closed using arbitrary line segments as needed across the waterbody. Boundary waterbodies do not include the natural far shoreline.
  - The water surface shall be flat and level, as appropriate for the type of waterbody (level for lakes, gradient for rivers, and so forth). It is not expected that ponds <0.8 ha (2 acres) or streams <30 m in width would be used as boundary waterbodies, thus it is expected that all boundary waterbodies will be hydro-flattened.
  - All landward water surface edges shall be at or below the immediately surrounding terrain.

        - Unusual changes in the water surface elevation that may take place over the course of the collection (for example, different river stages due to increased or decreased discharge from an upstream dam) shall be documented in the project metadata.
            - Unusual changes in water surface elevation shall be handled as described in Tidal Waterbodies.
    - Tidal Waterbodies:
        - Tidal waterbodies are defined as any waterbody that is affected by tidal variations, including oceans, seas, gulfs, bays, inlets, salt marshes, and large lakes.
        - Tidal variations during data collection or between different data collections will result in lateral and vertical discontinuities along shorelines. It is the intent for the DEM to represent as much ground as the collected data permits.
            - Lidar ground points are not to be removed for the sake of adjusting a shoreline inland to match another shoreline.
            - It is recommended that, to the highest degree practical, collections are planned to minimize tidal differences at the land-water interface.
        - Within each tidal waterbody, the water surface shall be flat and level for each different water surface elevation.
        - Vertical discontinuities within a tidal waterbody resulting from tidal variations during the collection are considered normal and shall be retained in the final DEM.
        - Horizontal discontinuities along the shoreline of a tidal waterbody resulting from tidal variations during the collection are considered normal and shall be retained in the final DEM.
    - Islands:
        - Permanent islands 0.4 ha (1 acre) (approximately equal to a round island 72 m in diameter) or larger shall be delineated within all waterbodies.
- Deliverables:
    - LAS Points:
        - Delivery of updated LAS points based on hydro flattening processing.
        - LAS points will meet requirements in Section 2.2(a).
    - Hydro flattened Bare Earth DEMs:
        - Modified DEM raster files that have been hydro flattened.
        - Data products will meet requirements in Section 2.2 (b).
    - Breaklines:
        - Breaklines representing all hydro-flattened features in a project, regardless of the method used for hydro-flattening.
        - Breaklines shall be developed to the limit of the DPA.
        - Breaklines delivered in Esri® polygon shapefile format.

        - Each breakline feature class shall have properly formatted, accurate, and complete georeferenced information stored in the format's standard file system location.
    - Breakline data shall be in the same CRS as the lidar data.
        - All CRS information for 3-dimensional (3D) data shall include the vertical reference and identify the geoid model used to convert from the ellipsoid to orthometric heights.
    - Breakline metadata must be generated.
- Metadata and Reporting:
    - Hydro flattening process must be added to metadata files when applicable.
    - Hydro flattening methodology, processing and QA/QC must be documented in the survey report.

2.6 (e) Corridor Lidar

Contractor will provide corridor lidar services that meet QL1 standards for project deliverables (Section 2.2) and data quality (Section 2.3). DOGAMI will provide a project AOI in Esri® shapefile format to Contractor. Contractor will provide a custom quote for corridor lidar services based on the terrain and vegetation characteristics of the AOI. The following acquisition design requirements are required for corridor lidar:

- Acquisition Area Design:
    - AOI must be less than 1.25 miles wide at the widest point and must not have perimeter to area ratio greater than 2 miles per square mile.
    - AOI cannot contain large internal gaps, and narrow extensions.
    - AOI must include all land area within a survey and the area of all water bodies with minimum dimension less than one-half mile.
    - Larger water bodies, except for a 300-foot-wide seaward buffer along a shoreline, must be excluded from the calculation of the survey area, unless otherwise specified in a Purchase Order.
    - The Defined Project Area (DPA) shall be the Area of Interest (AOI) plus a 100-meter buffer.
        - Data collection is required for the full extent of the DPA.
        - All Services delivered to DOGAMI shall be produced to the extent of the DPA.
        - All products, including checkpoints, shall be located within or otherwise clipped to DPA extents.

2.6 (f) Hydro-Enforced Bare-Earth DEMs.

Hydro-enforced bare-earth DEMs allow for continuous downhill surface flow in such a way that the data can be utilized for advanced hydrologic and hydraulic modeling. Hydro-enforcement must be performed to produce the appropriate downhill gradient of stream and river centerlines. Bare-Earth DEMs are processed to remove obstructions from the natural flow of water, enabling an accurate depiction of continuous water flow throughout the drainage basin represented in the DEMs. DOGAMI will provide a project AOI in Esri® shapefile format to Contractor. Contractor will provide a custom quote for hydro-enforcement services based on the unique characteristics of the AOI. The following processing and deliverable requirements are required for hydro enforcement:

- Processing:
  - Common examples of artificial flow obstructions include road crossings over streams (culverts), which are represented as a solid ground surface in the Bare-Earth DEMs.
  - When flow is routed on the Bare-Earth DEMs, it will reach a point where a culvert exists, but is then forced to flow at an angle and follow the road side.
  - Similarly, artificial pits or sinks will prevent accurate flow modeling by retaining some of the flow artificially, rather than allowing it to travel downhill.
  - Some water networks such as elevated canals and transverse canal systems are unable to be enforced, and therefore Contractor is not required to hydro-enforce these structures.
  - The final hydro-enforced DEM shall have all culverts and obstructions removed, centerlines of streams and rivers which continuously flow downhill "burned" into the DEM, spurious pits or sinks filled, and water bodies such as lakes and reservoirs leveled according to hydro-flattened DEM standards as described in Exhibit A Section 2.5(c).
- Deliverables:
  - Hydro-enforced Bare-Earth DEMs
    - Products will meet requirements in Section 2.2 (b).
  - Bounding polygons of reservoirs and lakes
    - Delivered in Esri® file geodatabase with appropriate metadata (Section 2.2 (g)).
  - Stream and river centerlines
    - Delivered in Esri® file geodatabase with appropriate metadata (Section 2.2 (g)).

2.6 (g) 4-band Orthoimagery and Infusion of Imagery-Derived RGBI Values into Lidar Point Data.

Contractor shall collect four-band (color infrared, i.e. red-green-blue-near infrared) orthophotographic imagery utilizing a specialized camera designed for aerial surveys, as near in

time to the collection of the lidar data as feasible, and shall use that imagery as a source of color values with which to populate the RGB (red-green-blue) attributes of the lidar point cloud.

- Acquisition Specifications:
    - Sun is at least 30 degrees above the horizon.
    - Clear conditions with no cloud cover and less than 10% cloud shadow.
    - Orthoimagery flights will be planned with appropriate overlap to reduce parallax of buildings and trees, especially in areas of high relief.
    - Flight plans must be provided to DOGAMI upon request at any time to verify proper planning.
- Processing:
    - Contractor must use an orthophoto graphic workflow which incorporates camera specific external and interior orientation parameters and creates and applies aero triangulation solutions to aerial imagery.
    - Images must be calibrated by Contractor to specific geometric, gain and exposure settings associated with each captured image.
    - Photo position and orientation must be calculated by linking the time of image capture, the corresponding aircraft position and attitude, and the smoothed best estimate of trajectory (SBET) data.
    - Automated aerial triangulation must be performed to tie images together and adjust block to align with ground control.
    - Individual orthorectified tiff files must be blended together to remove seams and corrected for any remaining radiometric differences between images.
    - Orthophotography created by Contractor must be orthorectified using lidar derived elevation models collected to specifications in this Exhibit A, when possible.
        - In situations where the area of interest has been covered by lidar collected under this Agreement within the preceding five years, the orthoimagery may be collected without new lidar.
        - Adjusted images must then be draped upon a ground model and orthorectified.
    - Seam line artifacts between mosaiced orthorectified images must be adjusted to remove gross offsets between vertical features (i.e. bridges, buildings, etc.).
    - Seam lines must be offset in areas of forests.
- Tiling:
    - Orthorectified images must be mosaiced using tiling and naming scheme specified in Section 2.1.
    - Orthoimagery coverage within the project boundary must provide 100% coverage. There must be no obvious tile boundary artifacts between orthoimagery tiles.
- Data Quality

- The location of static features visible in both the orthoimagery and the corresponding lidar intensity imagery must match to within one-pixel dimension of the intensity image.
- Horizontal accuracy of the imagery will be RMSE XY less than or equal to 1-foot, and less than or equal to 2-foot at the 95% confidence level.
- In order to ensure the horizontal accuracy of the imagery, aerial targets must be installed by Contractor or identified (if permanent) by Contractor before the flight.
    - The use of photo identifiable points is also acceptable.
- Contractor's field crew must collect ground check points using GPS procedures described in Exhibit A Section 2.1(d) and meet the minimum check point requirement (Table 5).
    - For each aerial target, Contractor must collect one to five points per target, one for permanent Target Check Points (TCPs) and 5 for temporary TCPs. The expected accuracy of the TCPs is RMSE XYZ less than or equal to 1.5 cm (deviation from monument coordinates).

- Deliverables:
    - Orthoimagery will be collected and processed so that the delivered product has either a pixel size of 3 inches or less (7.6 cm or less), or 6 inches or less (15.2 cm or less), with the pixel size specified in a Purchase Order (under the pricing in Table 1 of Appendix).
    - The corrected images must be saved in 16-bit GeoTiff format for input into subsequent processes.
    - LAS File Attribution:
        - Contractor will populate the "user defined" (or most currently appropriate) field in the LAS file with the infrared values from the orthoimage.
    - The coordinates of the aerial targets must be included as Esri® polygon shapefile.
    - Survey report shall include a section describing the photo acquisition parameters, equipment, primary processing steps and software, and accuracy statistics.

2.6 (h) Thermal Infrared Imagery.

Contractor will acquire thermal infrared data (TIR) as closely in time as possible to a lidar collection. DOGAMI will provide a project AOI in Esri® shapefile format to Contractor. Contractor will provide a custom quote for collecting, processing and delivering thermal infrared imagery services based on the unique characteristics of the AOI. Detailed acquisition specifications and deliverables for the TIR data are as follows:

- Acquisition specifications:
    - Thermal infrared sensors must be scientific-grade and designed for aerial surveys.
    - Sensors must record at a minimum rate of one frame per second.

- On-board real-time GPS positioning and pre-planned navigation must be utilized throughout the flight.
- During any thermal infrared imagery survey, appropriate ground-based measurement must be taken in the form of submerged thermostats, heat blankets, and meteorological data collection.
  - This data must be used by Contractor to verify and calibrate the thermal imagery.
  - Thermal variance values will be converted to temperatures using standard Planck's radiation law and sensor calibration curves.
  - Thermal imagery will then be color-coded to assist with the visual inspection and interpretation of temperature variation.

Depending on the purpose of the thermal infrared survey, DOGAMI may order either of the following two options:

1. Thermal infrared imagery collected for the purpose of water temperature analysis of rivers and streams must be collected during peak summer temperatures, during the warmest time of the day, with weather conditions of 10% or less cloud cover and relatively low humidity (in the Pacific Northwest this is typically mid-July through early September from 1400 to 1800 hours). The survey is normally conducted in an upstream direction to ensure that headwaters with the highest temperature variability throughout the day are surveyed last, providing an accurate representation of the longitudinal temperature profile throughout the reach. The acquisition platform and corresponding speed and altitude must be tailored to the particular area with regards to valley configuration, stream or floodplain width, and sinuosity. Acquisition and processing must be performed based on the "airborne thermal remote sensing for water temperature assessment in rivers and streams" publication by Torgersen et.al. (2001).

2. Thermal infrared imagery may also be ordered for the purpose of large-scale thermal anomaly identification (such as geothermal activity or infrastructure analysis). Acquisition for these surveys must be conducted by fixed-wing aircraft only without restriction to flight pattern or direction. Depending on the anomaly of interest, night flights may be requested. Any seasonal or timeframe restrictions may be determined by DOGAMI and specified in a Purchase Order.

- Data Quality:
  - Contractor will collect the minimum number of check points for horizontal accuracy testing (Table 5).
    - Horizontal Accuracy will meet minimum requirements for project size (Table 5).
- Deliverables:
  - The TIR data must have a native spatial resolution of 0.5-1 meter (as specified in a Purchase Order) and a thermal resolution of 0.5 degrees Centigrade.
  - The TIR data must be orthorectified using the lidar data and delivered as GeoTiff in the same coordinate system as the lidar data.

- The coordinates of the aerial targets must be included as Esri® polygon shapefile.
- Survey report shall include a section describing the photo acquisition parameters, equipment, primary processing steps, software, quality control process and accuracy statistics.
- The coordinates of the aerial targets shall be included in a table or as a digital appendix.

2.6 (i) Hyperspectral imagery.

Contractor will acquire hyperspectral reflectance (HS) imagery as closely in time as possible to a lidar collection. DOGAMI will provide a project AOI in Esri® shapefile format to Contractor. Contractor will provide a custom quote for collecting, processing and delivering hyperspectral imagery services based on the unique characteristics of the AOI. Detailed acquisition, processing and delivery specifications for hyperspectral imagery are as follows:

- Collection:
  - The HS sensor will collect at least 200 spectral channels.
  - HS imagery must be collected during the optimum flight collection window of +/- 2 hours of solar noon or a time period with solar elevation angles greater than or equal to 40 degrees, whichever is longest.
  - During data collection, the signal will be optimized to ensure maximum attainable signal/noise ratio while minimizing data saturation of target materials.
  - In addition, areas within the survey or targets with known spectral signatures may be used in support of data validation when determined necessary. Acquisition must be planned to reduce saturation and bidirectional reflectance.
- Processing:
  - Image processing must consist of sensor calibration in accordance with industry best practices.
  - Data will be converted from radiance to reflectance using established atmospheric correction techniques and models.
  - Measured spectra will be checked to match known atmospheric absorption features.
  - Data will be processed in such a way that further analysis utilizing known spectral signatures can be performed.
  - The HS data must be geo-referenced using the lidar data.
- Data Quality:
  - Contractor will collect the minimum number of check points for horizontal accuracy testing (Table 5).
  - Horizontal Accuracy will meet minimum requirements for project size (Table 5).
- Deliverables:

- The HS data must have a spectral range of about 400-2450 nm, with a native spatial resolution of 0.6 meter per pixel or better, and at least a 12 bit image depth
- Calibrated and georectified reflectance data-cube of all bands in ENVI® data format and user defined single band thematic type layers delivered as a raster or vector datasets.
- User defined bands would be determined by project goals, such as forest stress analysis, precision agriculture, and, mineral maps determined by industry standard spectral signature databases.
- The coordinates of the aerial targets shall be included as Esri® polygon shapefile.
- Survey report shall include a section describing the photo acquisition parameters, equipment, primary processing steps and software, and accuracy statistics.

2.6 (j) Advanced Classification of Lidar Point Cloud.

DOGAMI will provide a project AOI in Esri® shapefile format to Contractor. Contractor will provide a custom quote for advanced classification of the lidar point cloud within the AOI. The cost of advanced lidar point classification is based on the unique characteristics of the AOI. The classification fields requested by DOGAMI and the cost for services will be included in the purchase order.

- Lidar Density:
  - Advanced lidar point cloud classifications may be dependent on lidar density and may require collection of higher resolution lidar (2.6 (a)).
- Classification:
  - Contractor must fully classify all lidar returns within the lidar point cloud.
  - Advanced classification of the lidar point cloud must be performed after the completion of data calibration and ground model creation.
- Above Ground Structures:
  - Buildings are defined as structures larger than 10 square meters.
  - Above-ground structures that are neither vegetation nor buildings must be classified as default points unless further classification is requested.
- Data Quality:
  - Quality assurance must be performed by Contractor using a random sample methodology and visual inspection with the assistance of available most recent associated imagery.
  - Classification accuracy must achieve the following standards:
    - No points shall be delivered as class 0 (never classified).
    - Within any 1 km x 1 km area no more than 2 % of points will demonstrate erroneous classification values, points remaining in class 1 that must be classified as other specified classes will be counted towards this 2 % threshold.

    - Point classification must be consistent throughout the dataset. Lidar classification shall follow "compiled to meet" standards as described in the current Lidar Base Specification Version at time of Purchase Order.
- Deliverables:
    - LAS point files with advanced classification fields.
    - LAS shapefile metadata will include classification procedure.
- Example of Advanced Classification fields:
    - Created, never classified
    - Unclassified
    - Ground
    - Low vegetation
    - Medium vegetation
    - High Vegetation
    - Building
    - Low noise
    - Model Key Points
    - Water

2.6 (j) Image Compression

DOGAMI may choose to order compression of digital imagery products. The cost of imagery compression is a custom quote, based on the services requested. The image compression services and associated costs will be listed in the purchase order.

2.6 (l) Building Footprints

DOGAMI may choose to purchase building footprints. The building footprint is defined as the visible first floor projection, at grade, to the edge of the built area. The built area includes conditioned and non-condition spaces: living area, above ground/raised decks and garages).

- Cost:
    - The price of building footprint creation is based on the designation of urban and rural areas of Oregon.
    - The urban and rural area delineation is based on the most recent US Census Block data and is defined by a shapefile available on request from DOGAMI.
    - The cost for building footprint in urban areas is $90 per square mile. The cost of building footprint in rural areas is $40 per square mile. There is a minimum $2,000 cost for this product (Table 1).
- Deliverable:
    - Esri® polygon shapefile of building footprints.

- Building footprint shapefile metadata will include footprint generation procedure.

2.7 Cost of Contractor Services and Deliverables.

Table 1 of the Appendix indicates the unit cost rate to be paid by DOGAMI to Contractor for the Services and deliverables purchased under this Agreement.

- These unit rates will be the basis for determining total cost of projects.
  - DOGAMI and Contractor may negotiate custom lidar costs that are below the standard unit rates in Table 1.
- DOGAMI will provide the following information to Contractor in a Purchase Order:
  - A shapefile of the area of interest.
  - Product deliverable resolution specifications and coordinate reference system required.
  - A list of optional services that are requested (if applicable).
  - Total cost to be paid by DOGAMI to Contractor
- Contractor will review the Purchase Order and address any question or clarifications.
  - If a revision is necessary, DOGAMI will submit a revised Purchase Order to Contractor.

3. Other Provisions

3.1 Inspection of Facilities.

Contractor shall make its facilities and equipment, including its aircraft and aircraft maintenance facilities, available for inspection at any time by DOGAMI.

3.2 Access to Land; Flight Plans; Other

Contractor shall determine land ownership encompassing project locations and, as required, obtain site access permission. Contractor shall notify landowners and coordinate with the appropriate personnel prior to on-site or over-site activities. Contractor shall be solely responsible for the requisite filing of flight plans and obtaining appropriate authority from the Federal Aviation Administration (FAA) and other agencies as necessary. Contractor shall be solely responsible for all aspects of aircraft operation, including but not limited to maintenance, safety and crew licensing and training.

3.3 Key Personnel.

Contractor and DOGAMI agree that each individual specified below (each, a "Key Person") is an individual whose special qualifications and involvement in Contractor's performance of services form part of the basis of agreement between the parties under this Agreement, and is an individual through whom Contractor shall provide to DOGAMI the expertise, experience, judgment, and personal attention required to perform services. Each of the following is a Key Person under this Contract:

Account Manager:	Melissa Christie	925-586-8301	mchristie@quantumspatial.com
Project Manager:	John English	503-505-5120	jenglish@quantumspatial.com
Land Surveyor:	Evon Silvia	541-752-1204	esilvia@quantumspatial.com
Acquisition Manager:	Ryan Lynch	503-505-5320	rlynch@quantumspatial.com

Neither Contractor nor any Key Person of Contractor shall delegate performance of services under this Agreement to others without first obtaining DOGAMI's written consent. Further, Contractor shall not, without first obtaining DOGAMI's prior written consent, re-assign or transfer any Key Person to other duties or positions so that the Key Person is no longer available to provide DOGAMI with that Key Person's expertise, experience, judgment, and personal attention. If Contractor requests DOGAMI to approve a re-assignment or transfer of a Key Person, DOGAMI has the right to interview, review the qualifications of, and approve or disapprove the proposed replacement(s) for the Key Person. Any individual DOGAMI approves as a replacement for a Key Person is deemed a Key Person under this Agreement.

3.4 Aircraft passengers.

Contractor shall not permit any persons, other than Contractor, employees of Contractor, or agents of Contractor, or DOGAMI personnel included under Contractor's insurance coverage required under Exhibit C to this Contract, in any aircraft being operated by or on behalf of Contractor in the performance of services under this Contract, without advance written consent from DOGAMI.

3.5 The Land Surveyor

The Land Surveyor, listed in Section 3.4 as a Key Person, must supervise and certify all services under this Agreement, and must be a State of Oregon registered and certified Professional Land Surveyor.

3.6 Sub-Contractor Agreement

Contractor may request the use of a sub-contractor for lidar processing tasks. Contractor must receive written approval from DOGAMI before the use of sub-contractor can begin. All work performed by the sub-contractor must take place within the United States of America. Data shall not be processed, accessed, or otherwise viewed by any persons, computers, or software outside the United States. At no time will data be viewed or shared via remote access or any other means with any persons, hardware, or software outside of the United States of America. QSI will provide DOGAMI with a copy of subcontractor services purchase order/contract in digital format (PDF).

4. Payment

4.1 Milestones

DOGAMI will pay Contractor all amounts due for Services completed and accepted by DOGAMI at the following milestones after its approval of Contractor's invoice for those Services. DOGAMI will send payment to Contractor at the address specified in the invoice.

	% of payment	Payment milestone
(a)	40%	initial payment upon collection of data.
(b)	30%	payment upon first data delivery for QC pass/fail exam by DOGAMI.
(c)	30%	payment upon final acceptance.

4.2 Payment Timeframe

DOGAMI will pay Contractor within thirty (30) days after the approval of an invoice by DOGAMI.

4.3 Overdue Payments

Contractor may assess overdue account charges per ORS 293.462.

4.4 Payment Responsibility

DOGAMI is solely responsible for the payment of all amounts due to the Contractor. Contractor shall look only to DOGAMI and not to any other state agency for payment.

4.5 Payment Contingency

Contractor understands and agrees that DOGAMI's payment of amounts under this Agreement is contingent on DOGAMI receiving funding, appropriations, limitations, allotments or other expenditure authority at levels sufficient to allow DOGAMI, in the exercise of its reasonable administrative discretion, to make payments under this Agreement.

5. Pricing.

Contractor is entitled to receive the full funding listed in the Purchase Order for its acceptable performance of the Services and deliverables.

6. Default and Termination.

DOGAMI will be in default if it fails to pay undisputed invoiced charges in accordance with Exhibit B, and such invoices remain unpaid for sixty (60) calendar days after the receipt of an invoice. If DOGAMI is in default, and regardless of whether Contractor elects to exercise its rights under Section 6.3 of the Agreement, Contractor's sole remedy shall be a claim against DOGAMI for the unpaid Services delivered and accepted by DOGAMI, less previous amounts paid and any claims which DOGAMI has against Contractor. If previous amounts paid to Contractor exceed the amount due to Contractor, Contractor shall pay any excess to DOGAMI upon written demand.

APPENDIX 1
to
Exhibit A
DESCRIPTION AND SPECIFICATIONS OF THE SERVICES

- n/a in the following tables stand for "Not Applicable"

Table 1: Price Table for Services.

Exhibit A Section:	Services	Wide-Area Cost per Square Mile					
		Size Brackets (Square Mile)					Minimum Square Miles Required
		40-100	101-150	151-200	201-250	251+	
2.2	Standard Lidar Survey: QL1: >= 8 points per square meter	$774	$616	$495	$438	$410	40
2.6 (a)	High Resolution Lidar Survey: QL0: >= 15 pulse per square meter	$1,038	$962	$786	$726	$647	40
2.6 (b)	Low Resolution Lidar Survey: QL2: >= 4 pulse per square meter	$664	$527	$451	$408	$377	40
2.6 (c)	Bathymetric Lidar	Custom Quote Based on Collection Area					
2.6 (d)	Hydro-Flattened Bare-Earth DEMs	$1,000 + ($4.50 * waterbody acres)					
2.6 (e)	Corridor Lidar	Custom Quote Based on Collection Area					
2.6 (f)	Hydro-Enforced Bare-Earth DEMs	Custom Quote Based on Collection Area					
2.6 (g)	3-inch pixel 4-band ortho imagery **and** infusion of imagery-derived RGBI values into lidar point cloud. **60% Overlap**	$583	$478	$426	$400	$389	40
2.6 (i)	**ORTHO ONLY:** 3-inch 4-band ortho imagery ONLY. **30% Overlap**	$433	$345	$298	$272	$261	40

2.6 (j)	**ORTHO ONLY:** 3-inch pixel 4-band ortho imagery ONLY. **60% Overlap**	$631	$508	$443	$408	$399	40
2.6 (k)	Thermal Infrared Imagery	Custom Quote Based on Collection Area					
2.6 (l)	Hyperspectral Imagery	Custom Quote Based on Collection Area					
2.6 (m)	Advanced Classification of Lidar Point Cloud.	Custom Quote Based on Collection Area					
2.6 (n)	Image Compression Rate	Custom Quote Based on Collection Area					
2.6 (o)	Building Footprints	Urban: $90 per square mile Rural: $40 per square mile $2,000 minimum purchase					

Table 2: Aggregate nominal pulse spacing and density.

Quality level	**Aggregate nominal pulse spacing (m)**	**Aggregate nominal pulse density (pls/m^2)**
QL0	≤ 0.35	≥ 8.0
QL1	≤ 0.35	≥ 8.0
QL2	≤ 0.71	≥ 2.0
QL3	≤ 1.41	≥ 0.5

Table 3: Relative vertical accuracy for light detection and ranging swath data.

Quality level	**Smooth surface repeatability, $RMSD_z$ (m)**	**Swath overlap difference, $RMSD_z$, (m)**
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

Table 4: Land cover classes for Absolute Vertical Accuracy Assessment.

Class number	**Land cover class or description**	**Previous reporting group**	**Current reporting group**
1	Clear or open, bare earth, low grass; for example, sand, rock, dirt, plowed fields, lawns, golf courses	FVA	NVA
2	Urban areas; for example, tall, dense man-made structures	SVA	
3	Tall grass, tall weeds, and crops; for example, hay, corn, and wheat fields	SVA	VVA
4	Brush lands and short trees; for example, chaparrals, mesquite	SVA	
5	Forested areas, fully covered by trees; for example, hardwoods, conifers, mixed forests	SVA	
6	Sawgrass	n/a	n/a
7	Mangrove and swamps	n/a	

Table 5. Recommended number of checkpoints based on project area

Project Area (Square Miles)	Horizontal Accuracy Testing of Orthoimagery and Planimetric	Vertical and Horizontal Accuracy Testing of Elevation Data		
	Total Number of Static 2D/3D Checkpoints	Number of Static 3D Checkpoints in NVA	Number of 3D Checkpoints in VVA	Total Number of Static 3D Check points
≤ 193	20	20	5	25
193 - 290	25	20	10	30
291 - 386	30	25	15	40
387 - 483	35	30	20	50
484 - 579	40	35	25	60
580 - 676	45	40	30	70
677 - 772	50	45	35	80
773 -869	55	50	40	90
≥ 870	60	55	45	100

Table 6: Absolute vertical accuracy for light detection and ranging data and digital elevation models

Quality level	$RMSE_z$ (non-vegetated) (m)	NVA at the 95-percent confidence level (m)	VVA at the 95th percentile (m)
QL0	≤0.050	≤0.098	≤0.15
QL1	≤0.100	≤0.196	≤0.30
QL2	≤0.100	≤0.196	≤0.30
QL3	≤0.200	≤0.392	≤0.60

Table 7: Classification code requirements for lidar point data

Code	Description
1	Processed, but unclassified
2	Bare earth
7	Low noise
9	Water
17	Bridge deck
18	High noise
20	Ignored ground (*typically breakline proximity*)
21	Snow (*if present and identifiable*)
22	Temporal exclusion (*typically nonfavored data in intertidal zones*)

Table 8: Minimum digital elevation model cell size.

Quality level	Minimum cell size (m)	Minimum cell size (ft)
QL0	0.5	1
QL1	0.5	1
QL2	1	2
QL3	2	5

References:

American Society for Photogrammetry and Remote Sens-ing (ASPRS), 2004, Vertical accuracy reporting for lidar data, version 1.0: American Society for Photo-grammetry and Remote Sensing, 20 p. [Also available at http://www.asprs.org/a/society/committees/lidar/Downloads/Vertical_Accuracy_Reporting_for_Lidar_Data.pdf.]

American Society for Photogrammetry and Remote Sens-ing (ASPRS), 2011, LAS specification (ver. 1.4–R13, July 2013): Bethesda, Md., American Society for Photogram-metry and Remote Sensing, 27 p. [Also available at http://www.asprs.org/wp-content/uploads/2010/12/LAS_1_4_r13.pdf.]

American Society for Photogrammetry and Remote Sensing (ASPRS), 2014, "Positional Accuracy Standards for Digital Geospatial Data"—Draft revision 5, version 1: Ameri-can Society for Photogrammetry and Remote Sensing, 39 p., accessed October 12, 2014, at http://www.asprs.org/wp-content/uploads/2015/01/ASPRS_Positional_Accuracy_Standards_Edition1_Version100_November2014.pdf.

Federal Geographic Data Committee, 1998, Geospatial positioning accuracy standards, Part 3—National stan-dard for spatial data accuracy: Federal Geographic Data Committee, Subcommittee for Base Carto-graphic Data, FGDC-STD-007.3-1998, 28 p. [Also available at https://www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3.]