Elevation Data Quality Assurance Report
Ketchikan, Alaska
November 30, 2014

Submitted to:

Federal Emergency Management Agency, Region 10
Department of Homeland Security
Federal Regional Center
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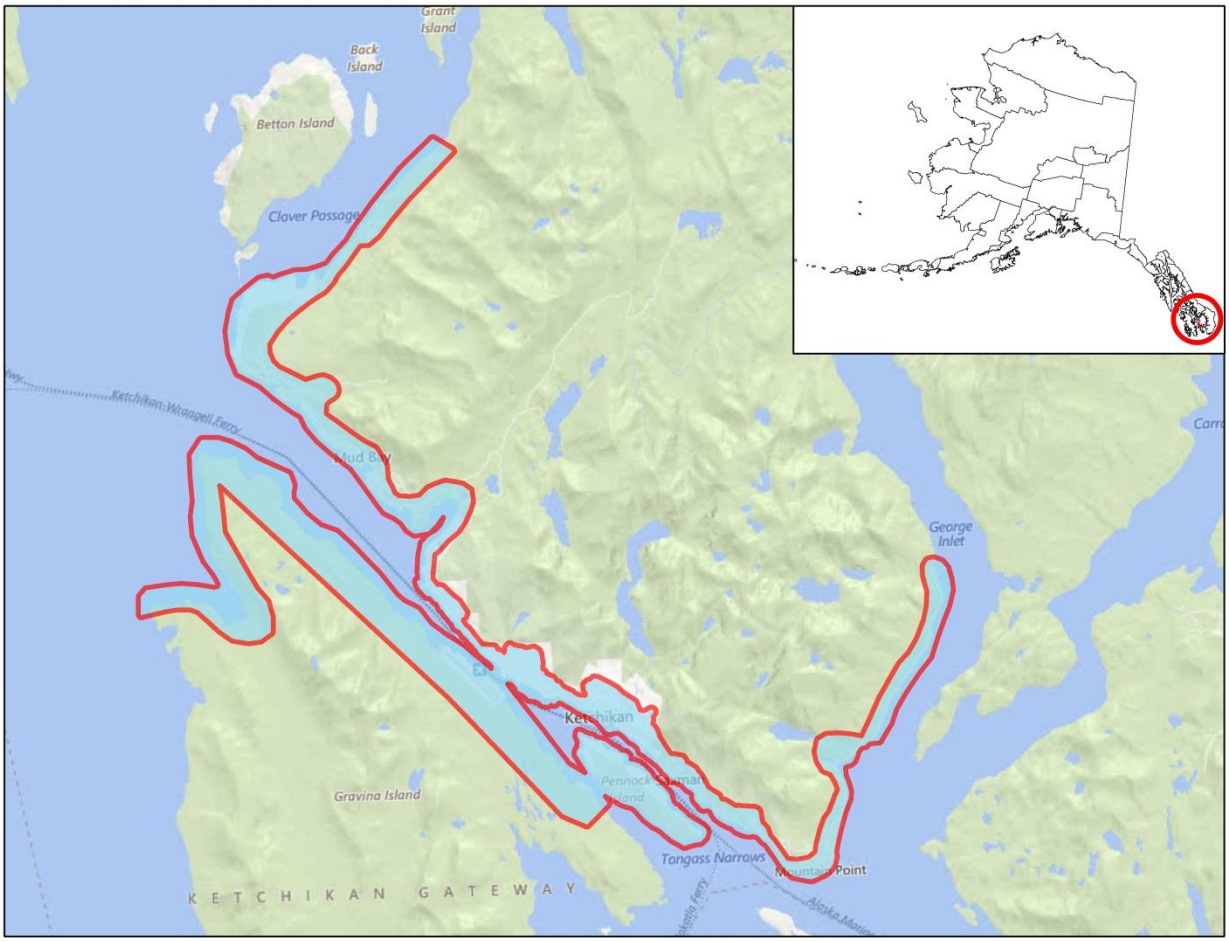
1. Executive Summary

Under FEMA task order HSFE10-13-J-0073 STARR has completed elevation data acquisition and LiDAR terrain products for Ketchikan, Alaska. The goal of this project is to create a classified bare-earth digital terrain dataset with a vertical accuracy Root Mean Square Error of <18.5cm capable of supporting 2 foot contours. Deliverables for this area include unclassified and bare earth LiDAR point cloud data in the American Society for Photogrammetry and Remote Sensing (ASPRS) LASer file format (ASPRS, LAS 1.2 Format Specification, 2-13), Digital Elevation Model (DEM) datasets, and contours.

Figure 1: Ketchikan, Alaska Project Area



Requirements from the Ketchikan contract scope of work mandate that all LiDAR collection activities meet the accuracy criteria provided in the Federal Emergency Management Agency (FEMA) Guidelines and Specifications (FEMA Guidelines and Standards for Flood Risk Analysis and Mapping), USGS LiDAR Base Specifications Version 1.0, and ASPRS standards for LAS 1.2

2. Overview

This report documents the independent quality control of data acquisition, processing methods, accuracy assessment, and deliverables for Ketchikan, Alaska in order to validate the quality of LiDAR data for use in FEMA Risk MAP projects.

Table 1: Ketchikan LiDAR Acquisition Project Details

FEMA Region 10 Ketchikan, Alaska LiDAR	
Collection/Processing Area	Approximately 36 square miles
LiDAR Acquisition Date(s)	7/12/2014 – 7/13/2014
Breaklines Required	No
Specification Level	Highest
LAS Version	1.2
LAS Point Data Format	1
Nominal Pulse Spacing	1 m
DEM Post Spacing	3ft DEM with 2 ft. contour accuracy
RMSE	< 18.5 cm
Vertical Accuracy, 95% Confidence Level FVA/CVA	24.5 cm/ 36.3 cm
Coordinate System	Alaska State Plane Zone 1
Horizontal Datum and Linear Units	NAD83 US Survey Feet
Vertical Datum and Linear Units	NAVD88 US Survey Feet

For specific information pertaining to the project area point cloud, DEM, and contour files see the Ketchikan, Alaska 2014 LiDAR and elevation mapping Quantum Spatial STARR Work Order 10 09 Production & Tech Svcs 001.PDF included in Appendix A of this document.

Table 2: QA Activity and Guideline and Specifications Matrix

QA Activity	FEMA G&S	USGS LiDAR Base Spec v1.0	ASPRS LAS v1.2	FEMA DCS 2014 FINAL
Vendor Submittal	X	X	X	X
Macro Review	X	X		
Micro Review	X	X	X	
Vertical Accuracy	X	X		X

3. LiDAR Data Review

STARR utilizes commercial software and proprietary scripts/applications to review LiDAR data. These tools, combined with guidelines and specifications, are incorporated into a standardized quality assurance workflow. The following table summarizes software and proprietary scripts/applications used in the review.

Table 3: Software/Tools used in Quality Assurance Review

Software/Tools	QA Process
ESRI ArcGIS ArcInfo	LiDAR Data Processing
ESRI 3D Analyst Extension	Visual Analysis of LiDAR Data
ESRI Spatial Analyst Extension	Grid Analysis for LiDAR Data
Fugro Viewer	Visual Analysis of LiDAR Data
Proprietary Scripts/Applications	Working with LAS files

3.1 Vendor Submittal

All project data has been delivered and accounted for. The completed Vendor Submittal Quality Assurance checklists are included in Appendix A of this document.

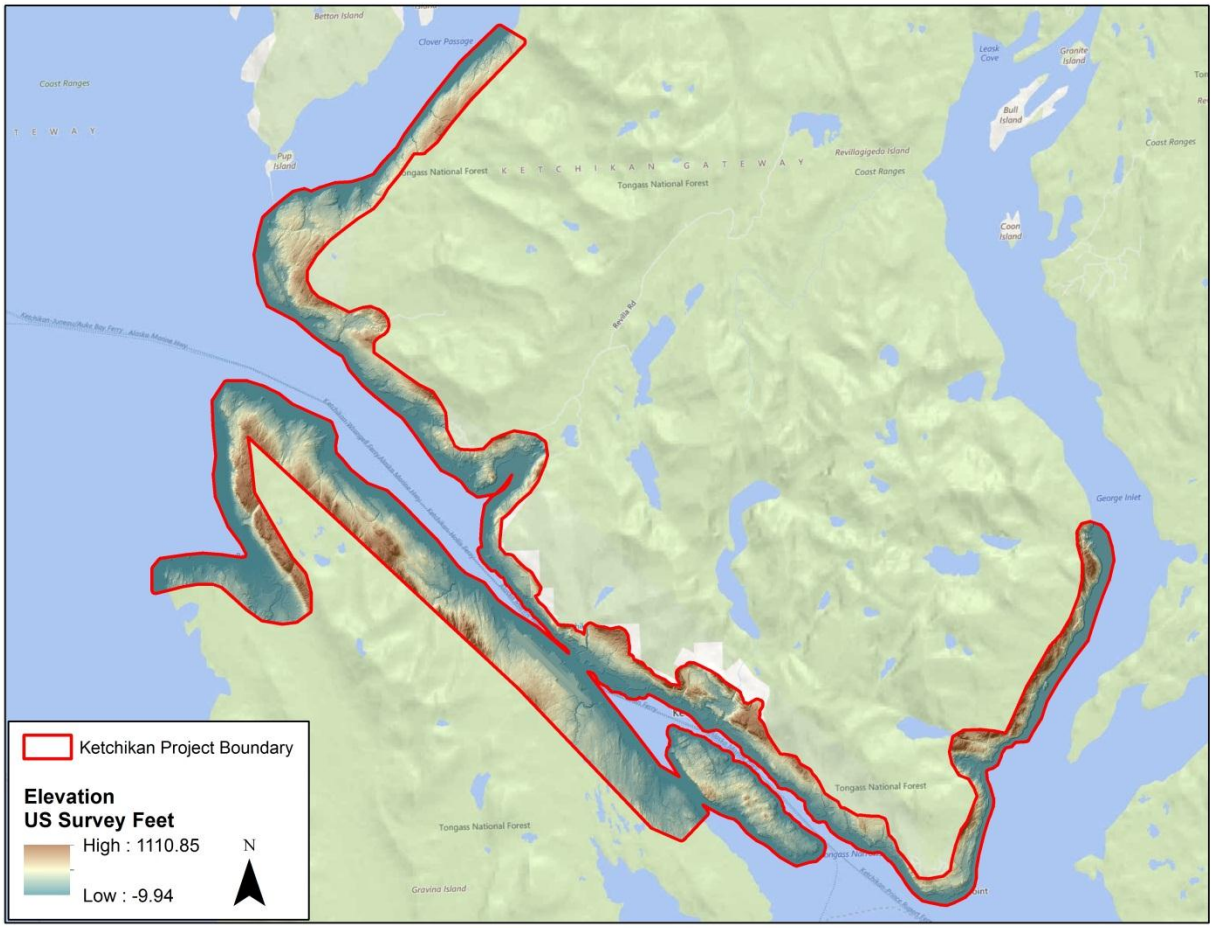
3.2 Macro Data Review

The macro review is conducted on the all return and fully classified point cloud datasets. The purpose of this review is to determine whether the dataset was produced in a manner consistent with requirements set forth in the FEMA guidelines and specifications. The individual review components are discussed in the following sections.

3.2.1 LiDAR Coverage and Completeness

The LiDAR data collected for Ketchikan, Alaska covers the area of interest and has an area of approximately 36 square miles. All LAS files and LiDAR derived products are included and have the correct projection and datum information for FEMA deliverables. All LiDAR derived products are seamless and consistent to the edge of the defined project area.

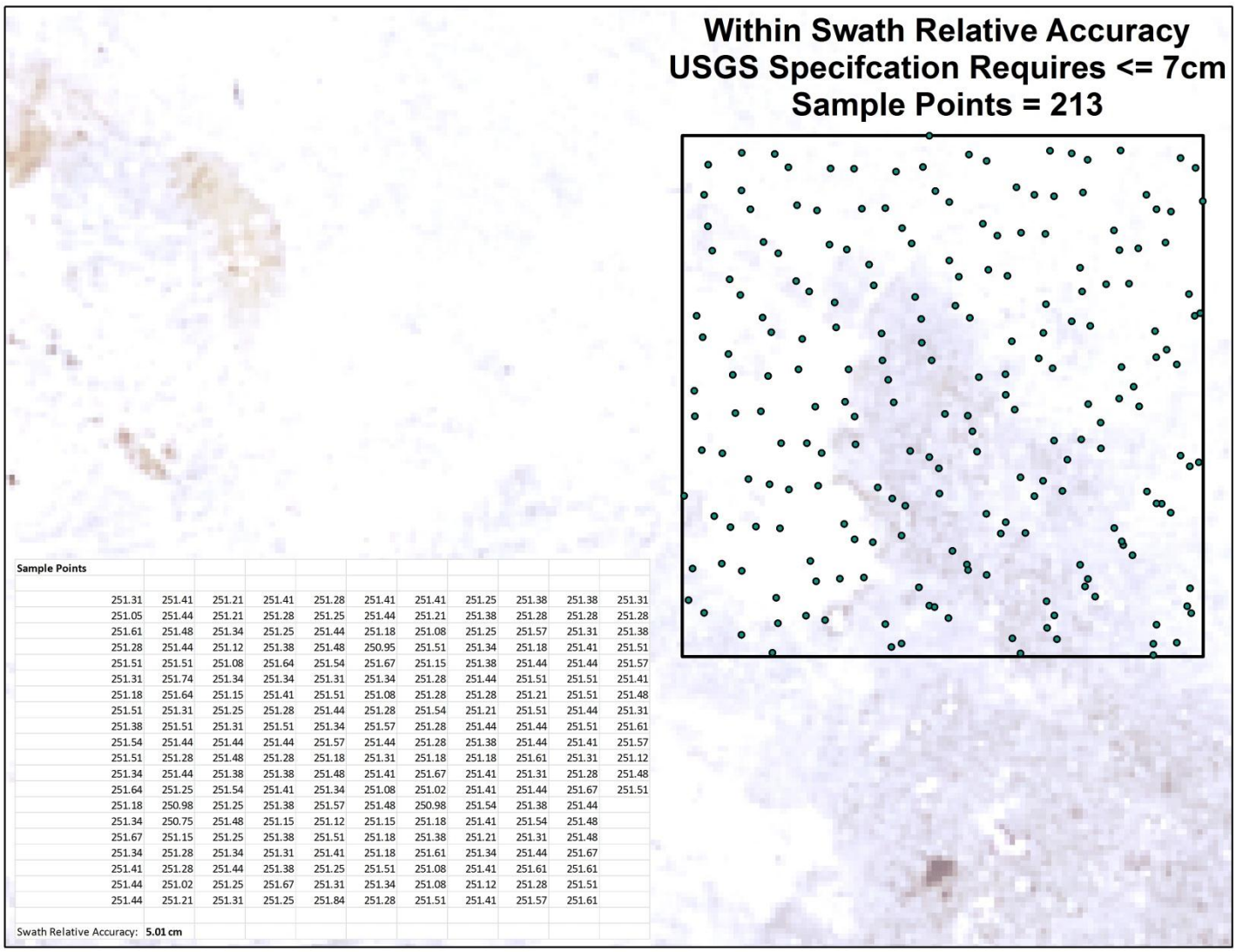
Figure 2: LiDAR Data Coverage



3.2.2 LAS Swath Overlap and Relative Accuracy

USGS LiDAR Base Specification requires a relative accuracy within a swath sample of <=7cm. The USGS Specification also requires that each swath have an overlap of 10% or greater and a relative accuracy within the overlap area of <= 10cm. The following figures illustrate the results of the swath testing.

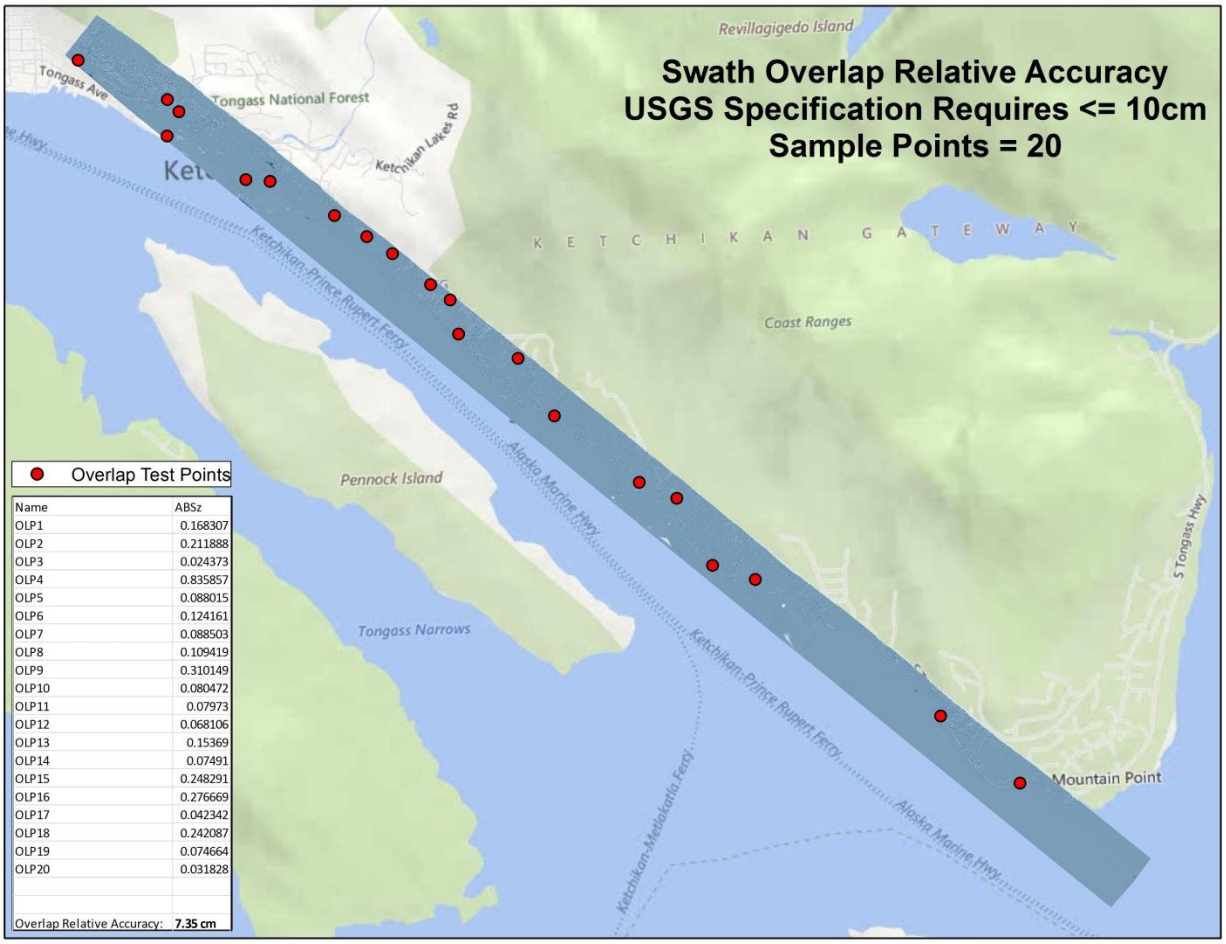
Figure 3: Sample LAS Swath Relative Accuracy



Sample Points										
251.31	251.41	251.21	251.41	251.28	251.41	251.41	251.25	251.38	251.38	251.31
251.05	251.44	251.21	251.28	251.25	251.44	251.21	251.38	251.28	251.28	251.28
251.61	251.48	251.34	251.25	251.44	251.18	251.08	251.25	251.57	251.31	251.38
251.28	251.44	251.12	251.38	251.48	250.95	251.51	251.34	251.18	251.41	251.51
251.51	251.51	251.08	251.64	251.54	251.67	251.15	251.38	251.44	251.44	251.57
251.31	251.74	251.34	251.34	251.31	251.34	251.28	251.44	251.51	251.51	251.41
251.18	251.64	251.15	251.41	251.51	251.08	251.28	251.28	251.21	251.51	251.48
251.51	251.31	251.25	251.28	251.44	251.28	251.54	251.21	251.51	251.44	251.31
251.38	251.51	251.31	251.51	251.34	251.57	251.28	251.44	251.44	251.51	251.61
251.54	251.44	251.44	251.44	251.57	251.44	251.28	251.38	251.44	251.41	251.57
251.51	251.28	251.48	251.28	251.18	251.31	251.18	251.18	251.61	251.31	251.12
251.34	251.44	251.38	251.38	251.48	251.41	251.67	251.41	251.31	251.28	251.48
251.64	251.25	251.54	251.41	251.34	251.08	251.02	251.41	251.44	251.67	251.51
251.18	250.98	251.25	251.38	251.57	251.48	250.98	251.54	251.38	251.44	
251.34	250.75	251.48	251.15	251.12	251.15	251.18	251.41	251.54	251.48	
251.67	251.15	251.25	251.38	251.51	251.18	251.38	251.21	251.31	251.48	
251.34	251.28	251.34	251.31	251.41	251.18	251.61	251.34	251.44	251.67	
251.41	251.28	251.44	251.38	251.25	251.51	251.08	251.41	251.61	251.61	
251.44	251.02	251.25	251.67	251.31	251.34	251.08	251.12	251.28	251.51	
251.44	251.21	251.31	251.25	251.84	251.28	251.51	251.41	251.57	251.61	

Swath Relative Accuracy: **5.01 cm**

Figure 4: Sample Swath Overlap Relative Accuracy



Name	ABSz
OLP1	0.168307
OLP2	0.211888
OLP3	0.024373
OLP4	0.835857
OLP5	0.088015
OLP6	0.124161
OLP7	0.088503
OLP8	0.109419
OLP9	0.310149
OLP10	0.080472
OLP11	0.07973
OLP12	0.068106
OLP13	0.15369
OLP14	0.07491
OLP15	0.248291
OLP16	0.276669
OLP17	0.042342
OLP18	0.242087
OLP19	0.074664
OLP20	0.031828
Overlap Relative Accuracy:	**7.35 cm**

Figure 5: Sample Swath Overlap > 10%

Table 2: Swath Overlap and Relative Accuracy Results

LAS Swath QA	Results	Pass/Fail
Swath Overlap	> 10%	Pass
Swath 23	5.01 cm	Pass
Overlap between swath 23 and 24	7.35 cm	Pass

3.2.3 LAS File Review

All LAS files submitted for review have header information that is compliant with ASPRS LAS specifications version 1.2. Each LAS file contains multiple discrete returns and has intensity values. The completed LAS Header Quality Assurance results are included Appendix A of this document.

3.2.4 Point density, Nominal Pulse Spacing, Spatial Distribution and Data Voids

The pulse density of a LiDAR data set is the number of pulses emitted by the LiDAR system commonly expressed as Points per Square Foot (ppsft) or Points per Square Meter (ppsm). Density is simply the total number of points divided by the total area. Nominal pulse spacing refers to the typical or average lateral distance between points in a LiDAR dataset. This is calculated as the square root of the LiDAR density (ppsm = $1/NPS^2$).

The nominal pulse spacing requirement for this project is approximately 1 m or 3.2808 ft. USGS and FEMA require NPS to be a minimum of 2 meters.

Table 3: Pont Density and Nominal Pulse Spacing Summary Statistics for All Returns Classified LiDAR

LiDAR Density and Nominal Pulse Spacing (m^2)		n = 106 LAS files
LiDAR Point Density (ppsm)	5	PASS
NPS	0.4m	PASS

Figure 6: Point Density Frequency Histogram

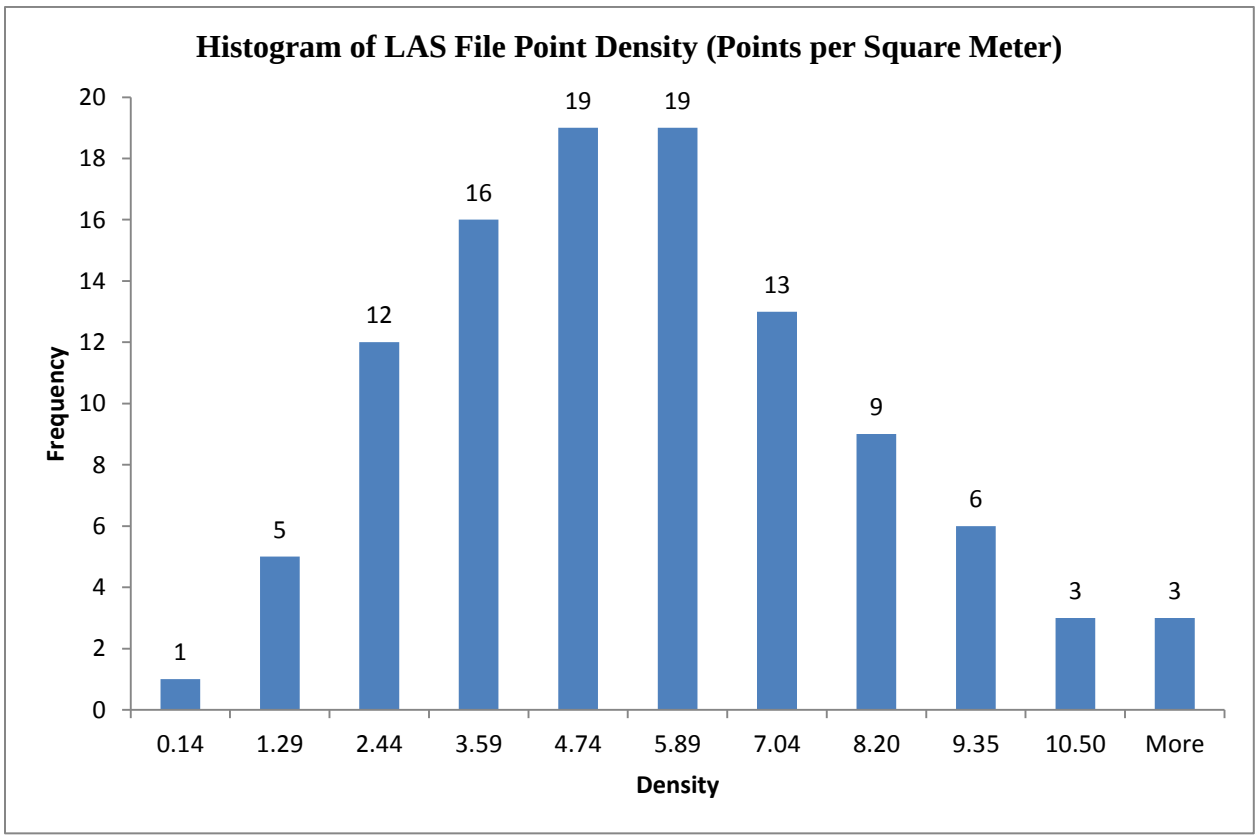
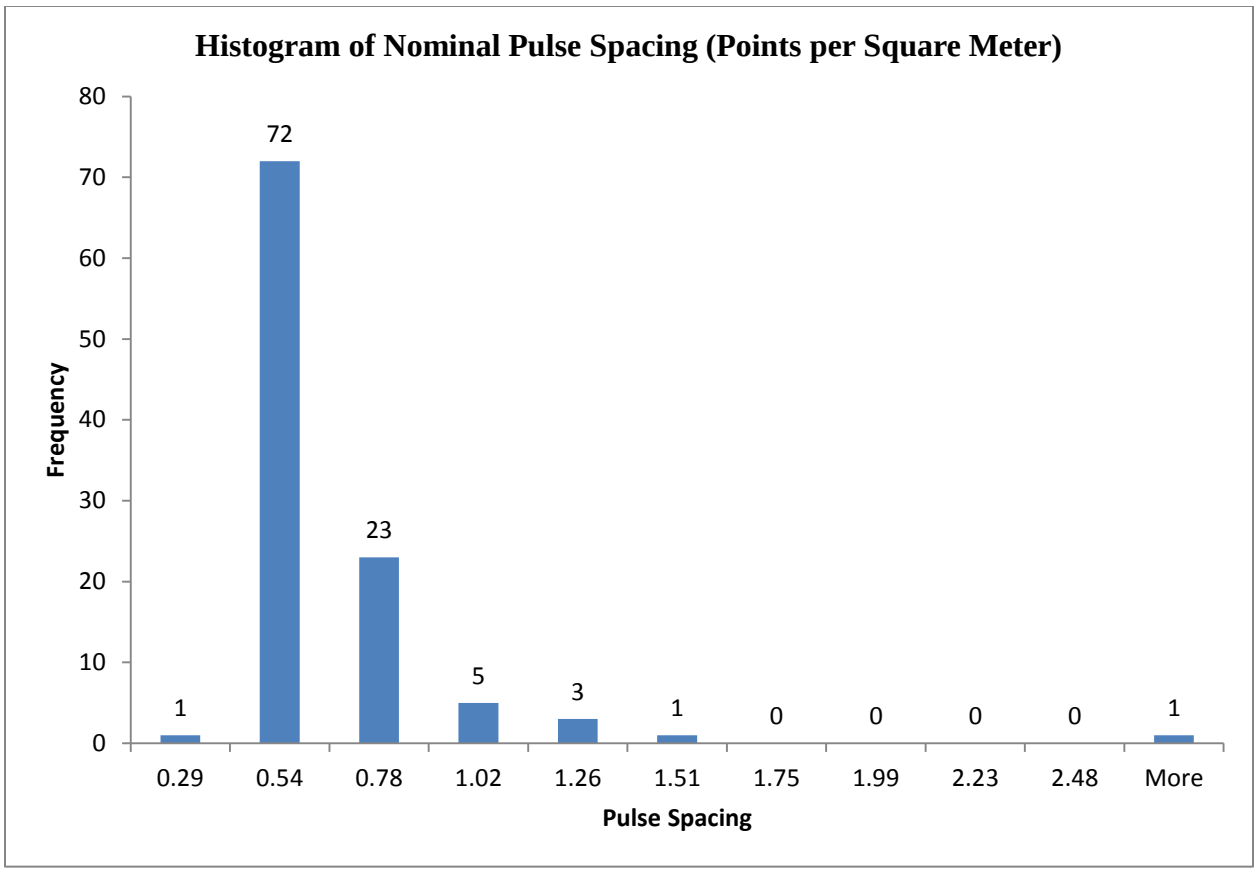


Figure 7: Nominal Pulse Spacing Frequency Histogram



From Section 1.6 of the USGS LiDAR Guidelines and Base Specification Version 1.0:

> *The spatial distribution of geometrically usable points is expected to be uniform and free from clustering. In order to ensure uniform densities throughout the dataset:*
>
> - *A regular grid, with cell size equal to the design NPS*2 will be laid over the data.*
> - *At least 90% of the cells in the grid shall contain at least 1 LiDAR point.*
> - *Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath (tile).*

To test the Ketchikan project, a 2-meter box grid was created for the unclassified raw LiDAR point cloud data. The percentage of cells with counts greater than or equal to one complies with the USGS specification of 90%.

Table 4: Spatial Distribution QC Results

Test Parameters	Point Count	Percent of Total
Grid cells with at least 1 LiDAR point	9,171,046	95.31
Grid cells without a LiDAR point	450,539	4.68
Total cells tested	9,621,585	100

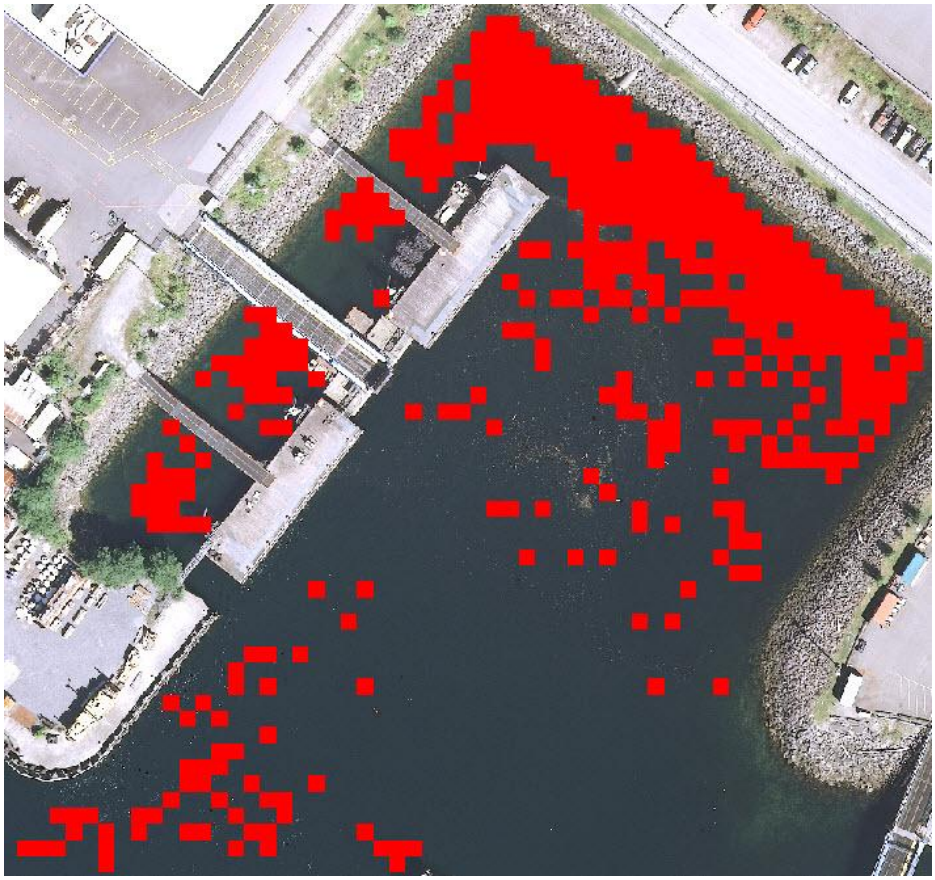
3.2.4 Data Voids

From section 1.5 of the USGS LiDAR Guidelines and Base Specification version 1.0:

> *Data Voids [areas => $(4*NPS)^2$, measured using 1st-returns only] within a single swath (tile) are not acceptable, except:*
>
> - *where caused by water bodies*
> - *where caused by areas of low near infra-red (NIR) reflectivity such as asphalt or composition roofing*
> - *where appropriately filled-in by another swath*

All areas were found to be in compliance with the USGS specification. The review confirmed that the data voids occur in legitimate areas. The following figure provides samples that portray samples of data voids found within the Ketchikan dataset.

Figure 8: Four Examples of Legitimate Data Voids



3.3 Micro Data Review

Micro reviews were completed on 5% of the fully classified point cloud tiles. Tiles selected for review were chosen throughout the project area with a focus on areas of urban development and hydrographic significance. Each tile was reviewed to ensure:

- Scan lines were removed from bare earth;
- Excessive Noise is not evident in bare earth;
- Elevation Steps do not exist;
- Gaps/Voids are only found in acceptable areas as noted in Section 3.2.4;
- Edge matching between tiles is appropriate and consistent;
- Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.);
- Proper definition of roads and drainage patterns is evident;
- Areas are not "over-smoothed" during filtering;
- Corn Row Effects, Mounds and Divots, and other anomalies are not evident.

All tiles reviewed meet project requirements for classified LiDAR data and can be used for floodplain mapping activities. The completed Micro Data Review Quality Assurance checklist is included in Appendix A of this document.

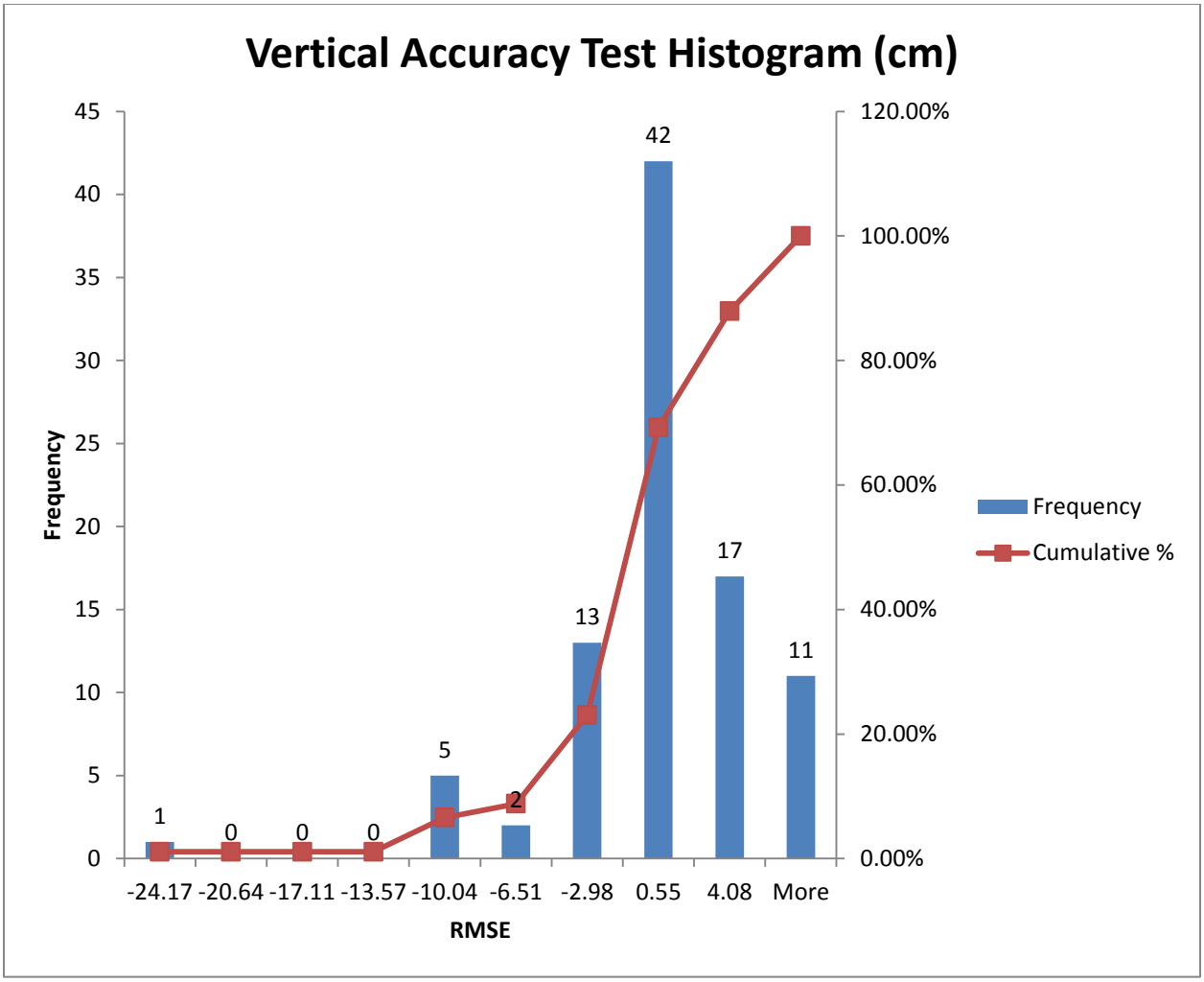
4. Vertical Accuracy Verification

An independent review and verification of submitted FVA and CVA survey data with vendor provided LAS files was completed to insure reported vertical accuracy is correct. Survey data points containing field collected GPS elevation values were buffered by 10 meters. LiDAR points contained within the buffered areas are selected and used to create a TIN. The TIN facet z value closest to the x and y control point location is compared to the height of the survey point. The height difference is evaluated statistically and compared to the submitted FVA and CVA testing results to insure the vertical accuracy meets project expectations. All FVA and CVA survey data submitted for this project has been confirmed to meet project requirements.

Table 5: Vertical Accuracy Verification Results

Target 95th Percentile	Tested 95th Percentile	Pass/ Fail	Target RMSE	Tested RMSE	Pass/Fail
36.3 cm	5.13 cm	Pass	18.5 cm	4.96 cm	Pass

Figure 9: CVA Test Histogram



5. Conclusions

Based upon the submittal verification, acquisition reports, macro/micro reviews and vertical accuracy confirmation, Ketchikan, Alaska dataset meets all applicable project specifications defined in FEMA task order HSFE10-13-J-0073 dated September 26, 2013. This data meets all project requirements for FEMA Risk MAP elevation acquisition and can be used for flood risk analysis.

Approvals

QA Team Lead: **James L. Huffines Date: 11/30/2014**

6. References

Links to guidelines and specifications used in production of the LiDAR datasets:

1. Federal Emergency Management Agency, Standards for Flood Risk Analysis and Mapping, November 18, 2014, Standard ID 40, 43-49, http://www.fema.gov/media-library/assets/documents/35313
2. Federal Emergency Management Agency, Procedure Memorandum No. 61 - Standards for LiDAR and Other High Quality Digital Topography, http://www.fema.gov/vi/media-library/assets/documents/34953
3. U.S. Geological Survey, LiDAR Guidelines and Base Specification, Version 1.2 2014 http://pubs.usgs.gov/tm/11b4/
4. American Society for Photogrammetry and Remote Sensing, LAS v1.2, http://www.asprs.org/a/society/committees/standards/asprs_las_format_v12.pdf
5. Federal Emergency Management Agency, Technical Reference Data Capture (Nov 2014), http://www.fema.gov/media-library/assets/documents/34519

Appendix A: Supporting Documentation

Raw Point Cloud Vendor Submittal Checklist		Project: Ketchikan, AK
Vendor: Quantum Spatial		**Reviewed By: Diane Rogers**
Section: Descriptive Project Information		**Date: 07OCT2014**
Item	**Included (Y/N)**	**Comments**
Metadata – Project	Y	
Metadata – Lift	Y	
Metadata – Swath Deliverables	Y	
Metadata – Field Survey	Y	
Compliance Form – Survey	Y	Combined into one form – but PE seal missing – not compliant – Replacement received .
Compliance Form – LiDAR	Y	Combined into one form – but PE seal missing – not compliant – Replacement received
Flight Reports – Pre-flight	N	Information is contained with the Post-Flight report
Flight Reports – Post-flight	Y	
Base Station Point Shapefile	Y	Part of the ground control shape file
Flight Lines As Flown Trajectories Polyline Shapefile	Y	Provided 11/18/14
Flight Lines Calibration Polyline Shapefile	Y	Part of the trajectories shape file
Flight Lines Planned Flight Lines Polyline Shapefile	N	Not provided
Section: Survey Data		**Date: 07OCT2014**
Item	**Included (Y/N)**	**Comments**
Ground Control – Accuracy Report	Y	Included in post flight report
Ground Control – Shapefile and Final Coordinates	Y	
Ground Control – Final Report	Y	Included in post flight report
Vertical Accuracy – FVA Accuracy Report	Y	Included in post flight report
Vertical Accuracy – Shapefile and Final Coordinates	Y	
Vertical Accuracy – FVA Accuracy Final Report	Y	Included in post flight report
Vertical Accuracy – FVA Accuracy Testing Results	Y	Excel spreadsheet with formulas not provided – Spreadsheet subsequently received.
Section: Raw Point Cloud LiDAR		**Date:07OCT2014**
Item	**Included (Y/N)**	**Comments**
Project Area Coverage (100m Buffer) Polygon Shapefile	Y	

LiDAR Swath – LAS v1.2 or v1.3 < 2GB	Y	
LiDAR Swath – Project Swath Index Polygon Shapefile	Y	Provided 11/18/14

Classified Point Cloud Vendor Submittal Checklist		**Project: Ketchikan, AK**
Vendor: Quantum Spatial		**Reviewed By: Diane Rogers**
Section: Descriptive Project Information		**Date: 07OCT2014**
Item	**Included (Y/N)**	**Comments**
Metadata – Project	Y	
Metadata – Tiled Deliverables	Y	
Metadata – Field Survey	Y	
Compliance Form – Survey	Y	Combined into 1 form – but PE seal missing – subsequently provided w/seal
Compliance Form – LiDAR Post Processing	Y	Combined into 1 form – but PE seal missing – subsequently provided w/seal
Section: Survey Data		**Date: 07OCT2014**
Item	**Included (Y/N)**	**Comments**
Vertical Accuracy – FVA/CVA Accuracy Report	Y	Included in post flight report
Vertical Accuracy – Shapefile and Final Coordinates	Y	
Vertical Accuracy – FVA/CVA Accuracy Final Report	Y	Included in post flight report
Vertical Accuracy – FVA/CVA Accuracy Testing Results	Y	Excel spreadsheet with formulas was not provided, subsequently provided
Section: Classified Point Cloud LiDAR		**Date:07OCT2014**
Item	**Included (Y/N)**	**Comments**
Project Area Coverage (100m Buffer) Polygon Shapefile	Y	
LiDAR Tiles – LAS v1.2 or v1.3	Y	
LiDAR Tiles – Project Tile Index Polygon Shapefile	Y	

Survey Data Checklist		**Project: Ketchikan AK**
Vendor: Quantum Spatial		**Reviewed By: Diane Rogers**
Section: Main		**Date: 07OCT2014**
Item	**Included (Y/N)**	**Comments**
Survey is referenced to NGS control monuments in the NSRS using appropriate horizontal and vertical control	Y	
Base station locations are the "best" horizontal (second order or better) and vertical (third order or better) available and have a stability of "C" or better	Y	
New control conforms to the Standards and Specifications for Geodetic Control Networks (1984), FGCC	Y	
Primary control monuments established with GPS meet or exceed NOS NGS-58 "Guidelines for Establishing GPS-Derived Ellipsoidal Heights (Standards: 2 cm and 5 cm)" using the appropriate and latest geoid model and should be monumented to maintain stability and reoccupation if necessary	Y	
Ground control stations meet local network accuracy at the 95% accuracy level of 2 cm horizontally and vertically	Y	
Supporting documentation submitted such as processing reports, minimally and constrained 3-D least squares adjustment, pictures, of the stations, etc.	Y	
Description of process used to test the points	Y	
A graphic depicting the spatial distribution of the ground survey points	Y	
FVA checkpoints must exist in the project area	Y	
FVA checkpoints as open area	Y	
SVA for up to three significant land cover categories	Y	
SVA checkpoints must exist in the area where bare-earth processing occurred	Y	
An analysis of checkpoints that have errors exceeding the 95th percentile in SVA and CVA calculations	N	No discussion has been included for these checkpoints
Descriptive statistics and RMSE in FVA and/or CVA calculations.	N	Descripting statistics have been included in the post-flight report, however the excel spreadsheet has not been included in the submittal. Submittal does not meet the requirements.

Post-flight Aerial Acquisition and Calibration Report Checklist		Project: Ketchikan AK
Vendor: Quantum Spatial		**Reviewed By: Diane Rogers**
Section: Flight Logs		**Date: 08OCT14**
Item	**Included**	**Comments**
Flight logs – Job #/name	Y	
Flight logs – Lift #	N	
Flight logs – Block or AOI	N	
Flight logs – Date	Y	
Flight logs – Aircraft type	N	
Flight logs – Aircraft tail #	Y	
Flight logs – Lines – #	Y	
Flight logs – Lines – direction	Y	
Flight logs – Lines – start/stop	Y	
Flight logs – Lines – altitude	Y	
Flight logs – Lines – scan angle	N	
Flight logs – Lines – speed	Y	
Flight logs – Conditions	N	
Flight logs – Comments	N	
Flight logs – Pilot name	Y	
Flight logs – Operator name	Y	
Flight logs – Automatic Gain Control switch setting	Y	
Flight logs – Laser pulse rate	Y	
Flight logs – Mirror rate	N	
Flight logs – Field of view	Y	
Flight logs – Airport of operations	Y	
Flight logs – GPS base stations names or numbers	N	

Section: GPS Base station		
Item	**Included**	**Comments**

GPS base station – names	Y	
GPS base station – lat/longs	Y	
GPS base station – heights	N	
GPS base station – map	N	
GPS base station – Base height (Ellipsoidal meters)	Y	
GPS base station – Max PDOP	N	
GPS base station – Map of locations	Y	
Section: GPS/IMU Quality		
GPS quality – Max Horizontal GPS Variance (cm)	N	
GPS quality – Max Vertical GPS Variance (cm)	N	
GPS quality – separation plot	Y	
GPS quality – altitude plot	Y	
GPS quality – PDOP plot	Y	
Plot of GPS distance from base station/s	Y	
Notes on GPS quality (High, Good, etc.)	N	
Section: Data Verification and Quality Control		
Description of data verification and QC process	Y	
Results of verification and QC process steps	Y	
Section: Spatial Data		
Base Station Point Shapefile	Y	
Ground Control Point Shapefile	Y	
Project Area Coverage (100m Buffer) Polygon Shapefile	N	
Flight Lines As Flown Trajectories Polyline Shapefile	N	
Flight Lines Calibration Polyline Shapefile	N	
Flight Lines Planned Flight Lines Polyline Shapefile	N	
Project Swath Index Polygon Shapefile	N	
Project Tile Index Polygon Shapefile	Y	

LAS Header Checklist		Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: James L. Huffines**
Files Reviewed: All classified LAS		
Section: Public Block		**Date: 11/14/2014**
Item	**Included**	**Comments**
File Signature (“LASF”)	Y	
File Source ID	Y	65535
Global Encoding	Y	0 Not Set GPS Week Time
Version Major\Minor	Y	Version 1.2
System Identifier	Y	Quantum Spatial
Generating Software	Y	LasMonkey 1.7.2
Header Size	Y	
Offset to point data	Y	
Number of Variable Length Records	Y	1
Point Data Format ID (0-99 for spec)	Y	Format 1
Point Data Record Length	Y	
Number of point records	Y	
Number of points by return	Y	3-5 returns
X, Y, and Z scale factor	Y	
X, Y, and Z offset	Y	
X, Y, and Z Max	Y	Appears to be have Z values as feet
X, Y, and Z Min	Y	Appears to be have Z values as feet
Any field in the Public Header Block that is not required and is not used must be zero filled.	Y	

Required Public Block Item Definitions:

File Signature - The file signature must contain the four characters “LASF”, and it is required by the LAS specification.

File Source ID (Flight Line Number if this file was derived from an original flight line) - This field should be set to a value between 1 and 65,535, inclusive. A value of zero (0) is interpreted to mean that an ID has not been assigned. In this case, processing software is free to assign any valid number. Note that this scheme allows a LIDAR project to contain up to 65,535 unique sources. A source can be considered an original flight line or it can be the result of merge and/or extract operations. All of the sources are the results of processing and are not based on the flight line number.

Global Encoding - This is a bit field used to indicate certain global properties about the file. The meaning of GPS Time in the Point Records 0 (not set) -> GPS time in the point record fields is GPS Week Time (the same as previous versions of LAS) 1 (set) -> GPS Time is standard GPS Time (satellite GPS Time) minus 1 x 109 . The offset moves the time back to near zero to improve floating point resolution.

Version Major\Minor - The version number consists of a major and minor field. The major and minor fields combine to form the number that indicates the format number of the current specification itself.

System Identifier - files often result from extraction, merging or modifying existing data files. Values should include: String identifying hardware ("ALS50"), "MERGE", "MODIFICATION", "EXTRACTION", "TRANSFORMATION", "OTHER" or a string up to 32 characters identifying the operation.

Generating Software – provides a mechanism for specifying which generating software package and version was used during LAS file creation (e.g. "TerraScan V-10.8", "REALM V-4.2" and etc.).

Header Size - The size, in bytes, of the Public Header Block itself

Offset to point data - The actual number of bytes from the beginning of the file to the first field of the first point record data field. This data offset must be updated if any software adds data from the Public Header Block or adds/removes data to/from the Variable Length Records.

Number of Variable Length Records - This field contains the current number of Variable Length Records. This number must be updated if the number of Variable Length Records changes at any time.

Point Data Format ID - The point data format ID corresponds to the point data record format type. LAS 1.2 define types 0, 1, 2 and 3.

Point Data Record Length - The size, in bytes, of the Point Data Record

Number of point records – The total number of point records within the file

Number of points by return - This field contains an array of the total point records per return. The first unsigned long value will be the total number of records from the first return, and the second contains the total number for return two, and so forth up to five returns.

X, Y, and Z scale factor - The scale factor fields contain a double floating point value that is used to scale the corresponding X, Y, and Z long values within the point records. The corresponding X, Y, and Z scale factor must be multiplied by the X, Y, or Z point record value to get the actual X, Y, or Z coordinate. For example, if the X, Y, and Z coordinates are intended to have two decimal point values, then each scale factor will contain the number 0.01.

X, Y, and Z offset - The offset fields should be used to set the overall offset for the point records. In general these numbers will be zero, but for certain cases the resolution of the point data may not be large enough for a given projection system. However, it should always be assumed that these numbers are used.

So to scale a given X from the point record, take the point record X multiplied by the X scale factor, and then add the X offset. (Xcoordinate = (Xrecord * Xscale) + Xoffset, Ycoordinate = (Yrecord * Yscale) + Yoffset, Zcoordinate = (Zrecord * Zscale) + Zoffset)

Max and Min X, Y, and Z - The max and min data fields are the actual unscaled extents of the LAS point file data, specified in the coordinate system of the LAS data.

LAS Header Checklist		
Section: Variable Length Records		**Date: 11/14/2014**
Item	**Included (Y/N)**	**Comments**
GeoKeyDirectoryTag	Y	VLR present in LAS header
User ID 'LASF_Projection'	Y	VLR present in LAS header
Record ID: 34735	Y	VLR present in LAS header
Length after Header	Y	VLR present in LAS header
'GeoTiff Projection Keys'	Y	VLR present but Horizontal Datum is not included

Required Variable Length Record Definitions:

Georeferencing Information - Georeferencing for the LAS format will use the same robust mechanism that was developed for the GeoTIFF standard. The variable length header records section will contain the same data that would be contained in the GeoTIFF key tags of a TIFF file. Since LAS is not a

raster format and each point contains its own absolute location information, only 3 of the 6 GeoTIFF tags are necessary. The GeoKeyDirectoryTag (34735),

GeoDoubleParamsTag (34736), and GeoASCIIParamsTag (34737) records are used. Only the GeoKeyDirectoryTag record is required. The GeoDoubleParamsTag and GeoASCIIParamsTag records may or may not be present, depending on the content of the GeoKeyDirectoryTag record.

GeoKeyDirectoryTag Record (mandatory) - User ID: LASF_Projection, Record ID: 34735. This record contains the key values that define the coordinate system.

GeoDoubleParamsTag Record (Optional) - User ID: LASF_Projection, Record ID: 34736. This record is simply an array of doubles that contain values referenced by tag sets in the GeoKeyDirectoryTag record.

GeoAsciiParamsTag Record (Optional) - User ID: LASF_Projection, Record ID: 34737. This record is simply an array of ASCII data. It contains many strings separated by null terminator characters which are referenced by position from data in the GeoKeyDirectoryTag record.

LAS Header Checklist		
Section: Point Data Record		**Date: 11/30/2014**
Item	**Included (Y/N)**	**Comments**
Point record format 1,3,4, or 5	Y	Format 1
X, Y, Z	Y	
Intensity	Y	
Edge of Flight Line	Y	
Scan Direction Flag	Y	
Return Number	Y	
Number of Returns (given pulse)	Y	
Classification	Y	1 and 2
Scan Angle Rank (-90 to +90)	Y	
Point Source ID	Y	
GPS Time	Y	

Required Point Data Record Definitions:

X, Y, and Z – The X, Y, and Z values are stored as long integers. The X, Y, and Z values are used in conjunction with the scale values and the offset values to determine the coordinate for each point as described in the Public Header Block section.

Intensity – The integer representation of the pulse return magnitude

Edge of Flight Line – The Edge of Flight Line data bit has a value of 1 only when the point is at the end of a scan. It is the last point on a given scan line before it changes direction.

Scan Direction Flag – denotes the direction at which the scanner mirror was traveling at the time of the output pulse. A bit value of 1 is a positive scan direction, and a bit value of 0 is a negative scan direction (where positive scan direction is a scan moving from the left side of the in-track direction to the right side and negative the opposite).

Return Number – The Return Number is the pulse return number for a given output pulse. A given output laser pulse can have many returns, and they must be marked in sequence of return. The first return will have a Return Number of one, the second a Return Number of two, and so on up to five returns.

Number of Returns (for this emitted pulse) – The Number of Returns is the total number of returns for a given pulse. For example, a laser data point may be return two (Return Number) within a total number of five returns.

Scan Angle Rank – The Scan Angle Rank is a signed one-byte number with a valid range from -90 to +90. The Scan Angle Rank is the angle (rounded to the nearest integer in the absolute value sense) at which the laser point was output from the laser system including the roll of the aircraft. The scan angle is within 1 degree of accuracy from +90 to –90 degrees. The scan angle is an angle based on 0 degrees being nadir, and –90 degrees to the left side of the aircraft in the direction of flight.

Point Source ID – This value indicates the file from which this point originated. Valid values for this field are 1 to 65,535 inclusive with zero being used for a special case discussed below. The numerical value corresponds to the File Source ID from which this point originated. Zero is reserved as a convenience to system implementers. A Point Source ID of zero implies that this point originated in this file. This implies that processing software should set the Point Source ID equal to the File Source ID of the file containing this point at some time during processing.

GPS Time – The GPS Time is the double floating point time tag value at which the point was acquired. It is GPS Week Time if the Global Encoding low bit is clear and POSIX Time if the Global Encoding low bit is set (see Global Encoding in the Public Header Block description).

Classification – Standard set of ASPRS classifications

Classification Value	Definition
0	Created, Never Classified
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	Ignored Ground (breakline proximity)
11	Withheld if Withheld bit is not implemented in processing software
12	Overlap (Should not be included)
13-31	Reserved for ASPRS Definition

LAS File Review

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11/14/2014----->LAS Header Review

Total Files Reviewed: 106

****

LAS Version: 1.2

Horizontal Datum: NAD83

Projection: Alaska 01 - Ft US

XY (Horizontal) Units: Linear Foot US Survey

Vertical Datum: VertCS_North_American_Vertical_Datum_1988

Z Units: Vertical Foot US Survey

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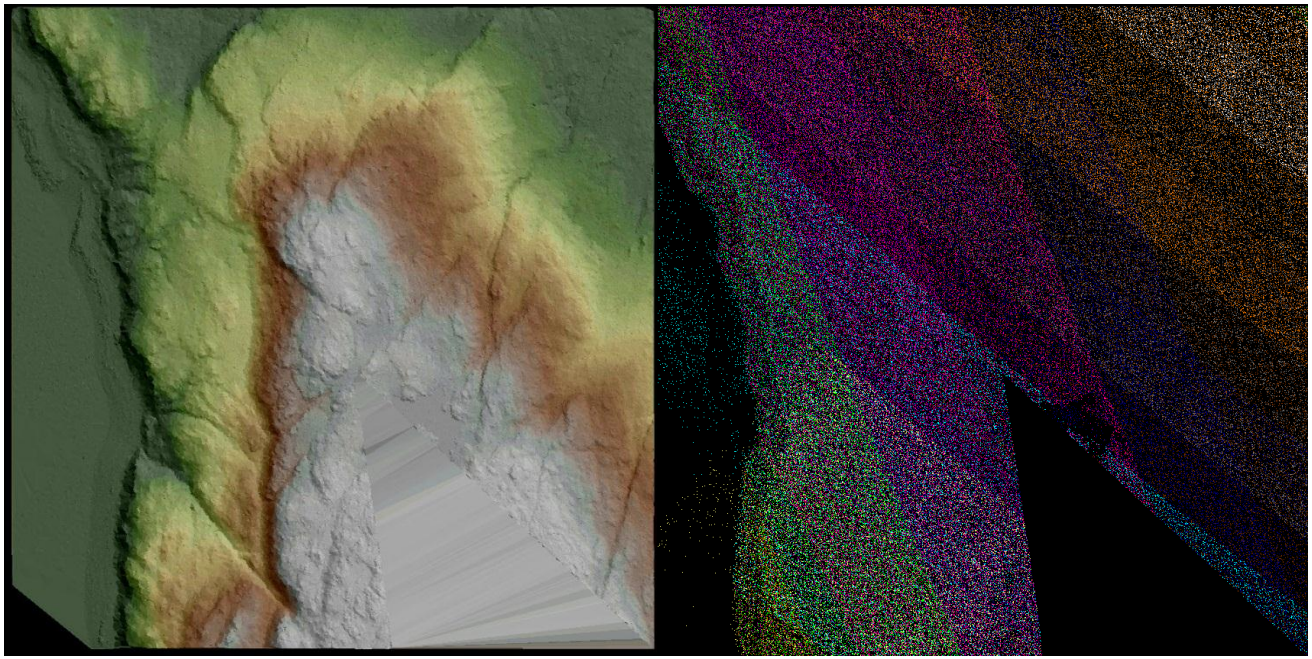
STARR

FEMA Region X Ketchikan, Alaska LiDAR Dataset

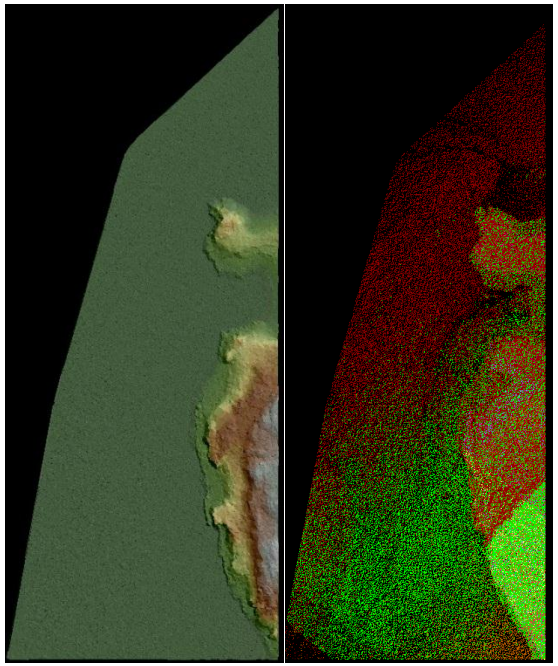
Classified LiDAR Micro Review

Quality Assurance Forms
11/30/2014

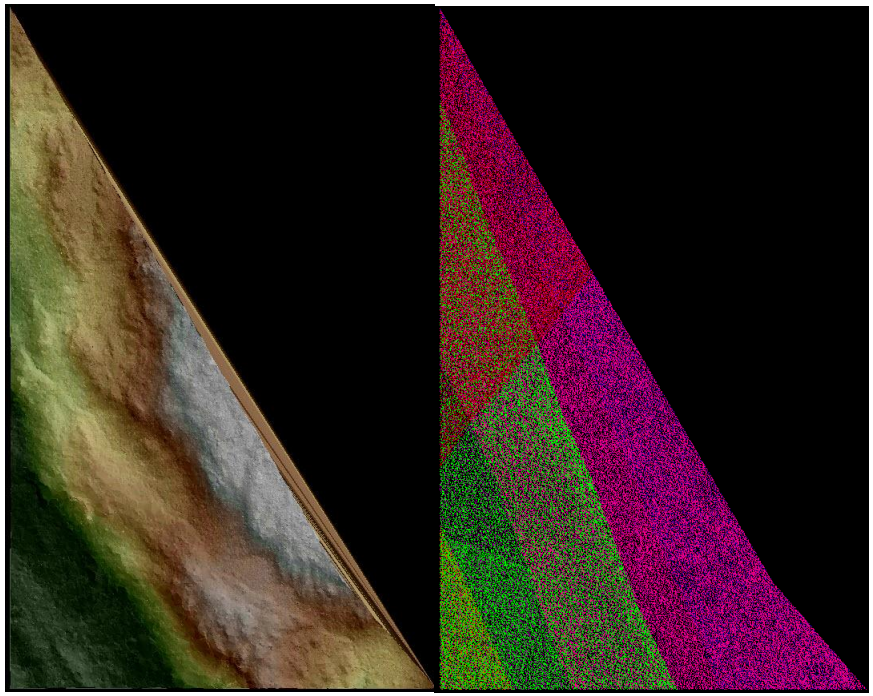
Classified Point Cloud Data Visual Checklist		**Project: Ketchikan, Alaska**
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30621310.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scan lines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Heavily Forested Area



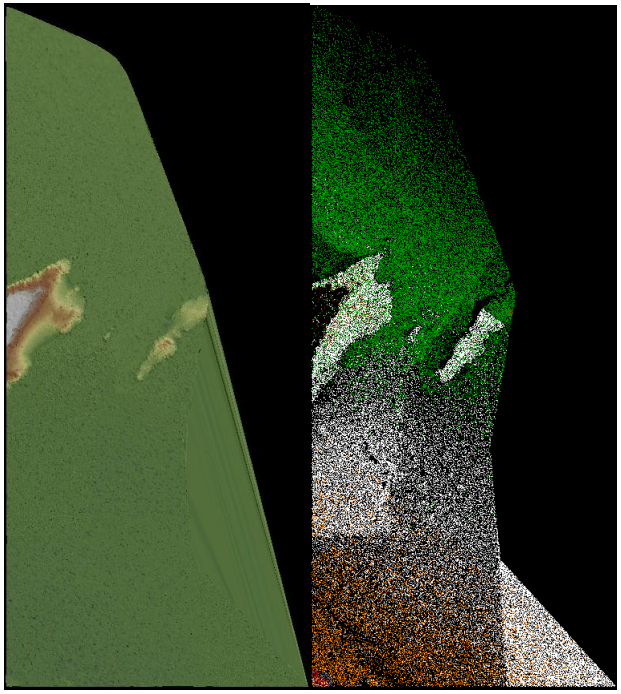
Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30621329.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scan lines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Heavily Forested



Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30671300.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	

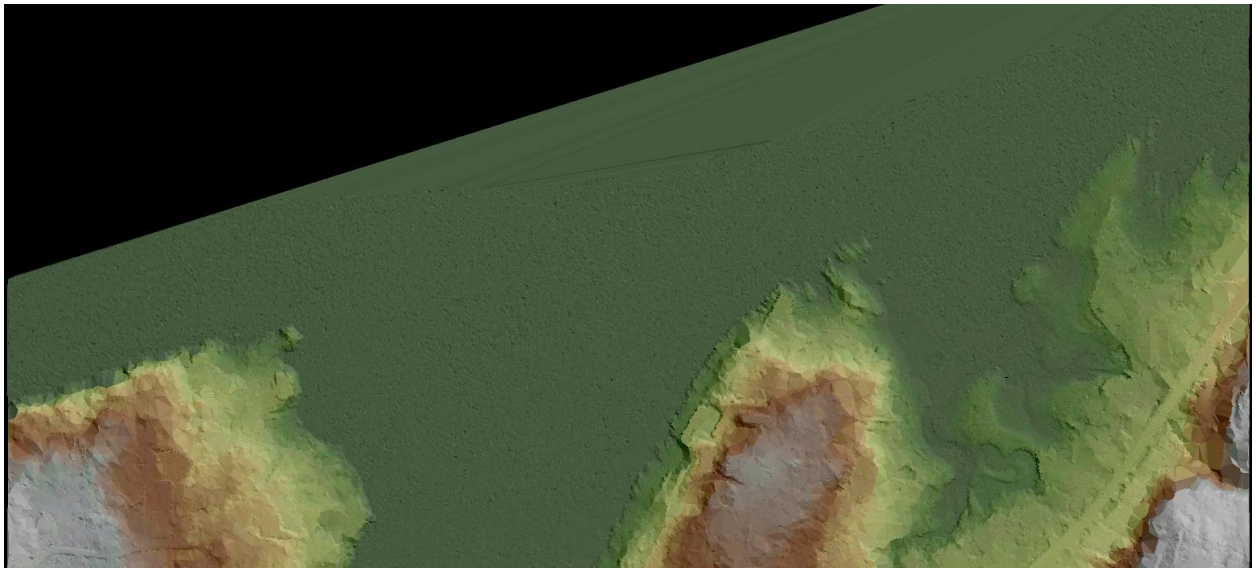


Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30721310.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Not much "earth" in this tile lots of open water

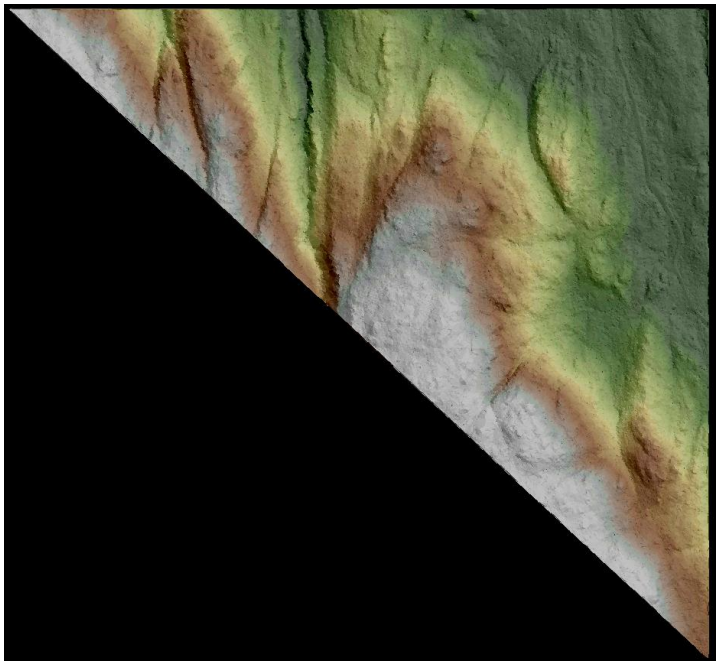


Classified Point Cloud Data Visual Checklist		**Project: Ketchikan, Alaska**
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30721324.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Very few points…this tile is small and on the edge of project

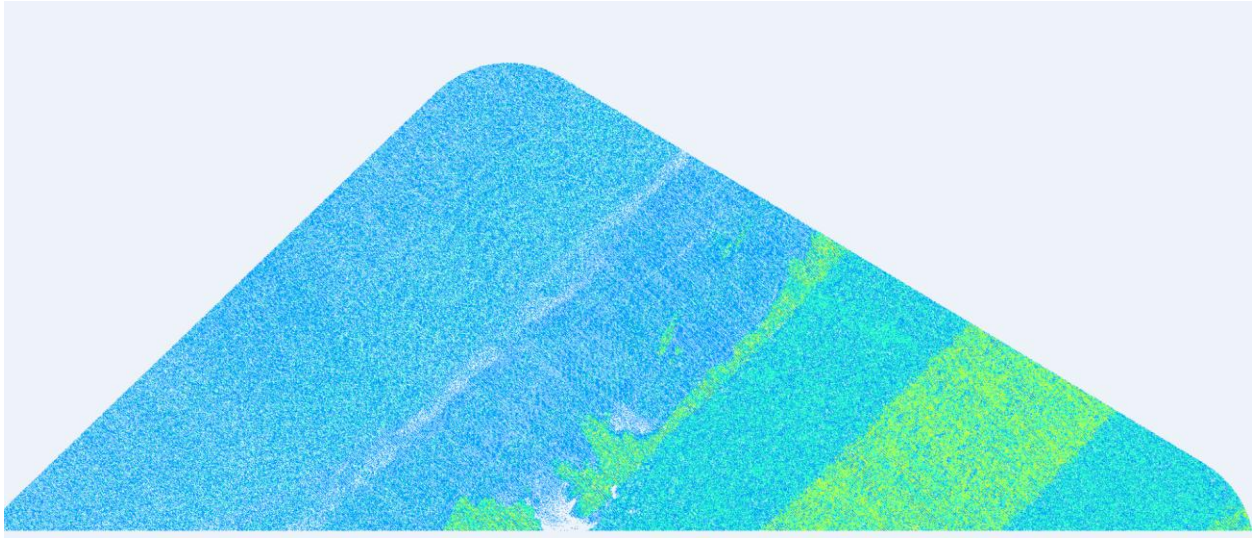
Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30721334.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	



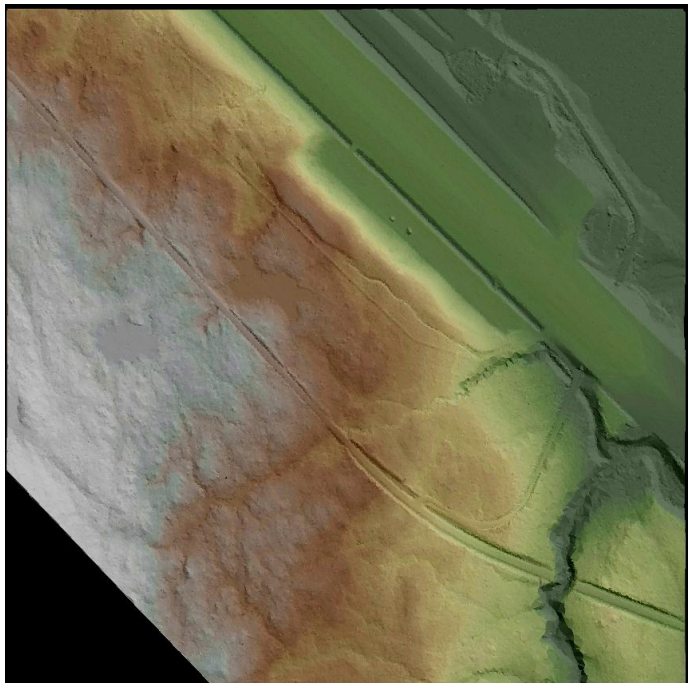
Classified Point Cloud Data Visual Checklist		**Project: Ketchikan, Alaska**
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30811291.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Drainage looks good



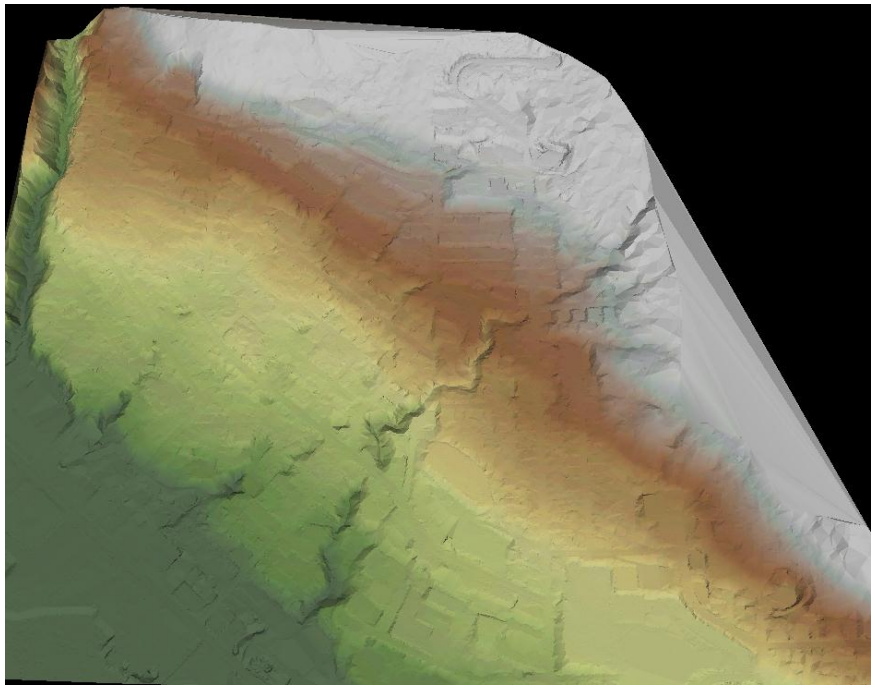
Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30861348.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	



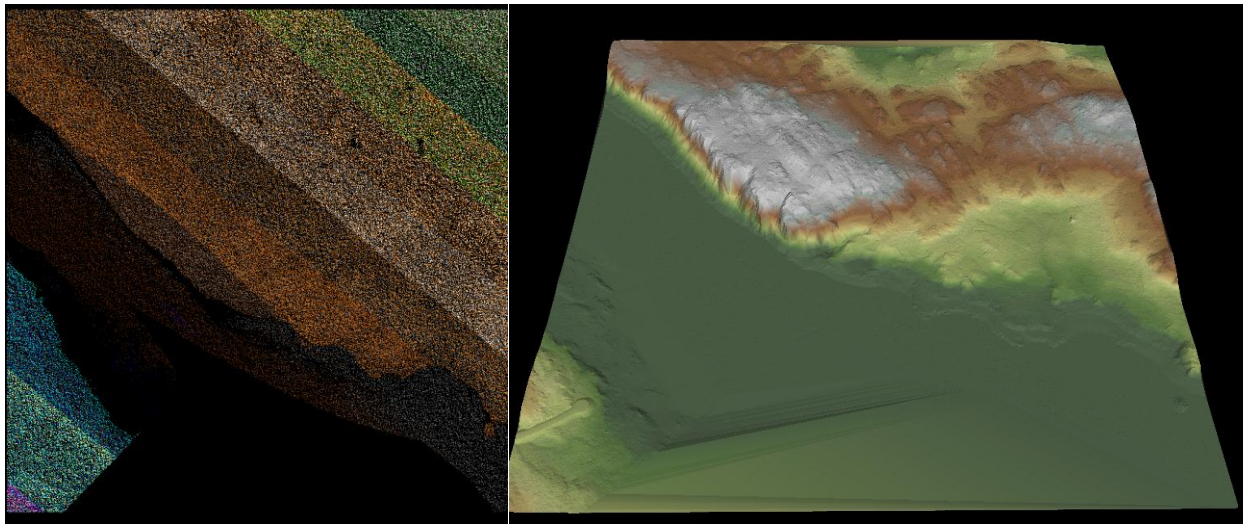
Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30911286.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	



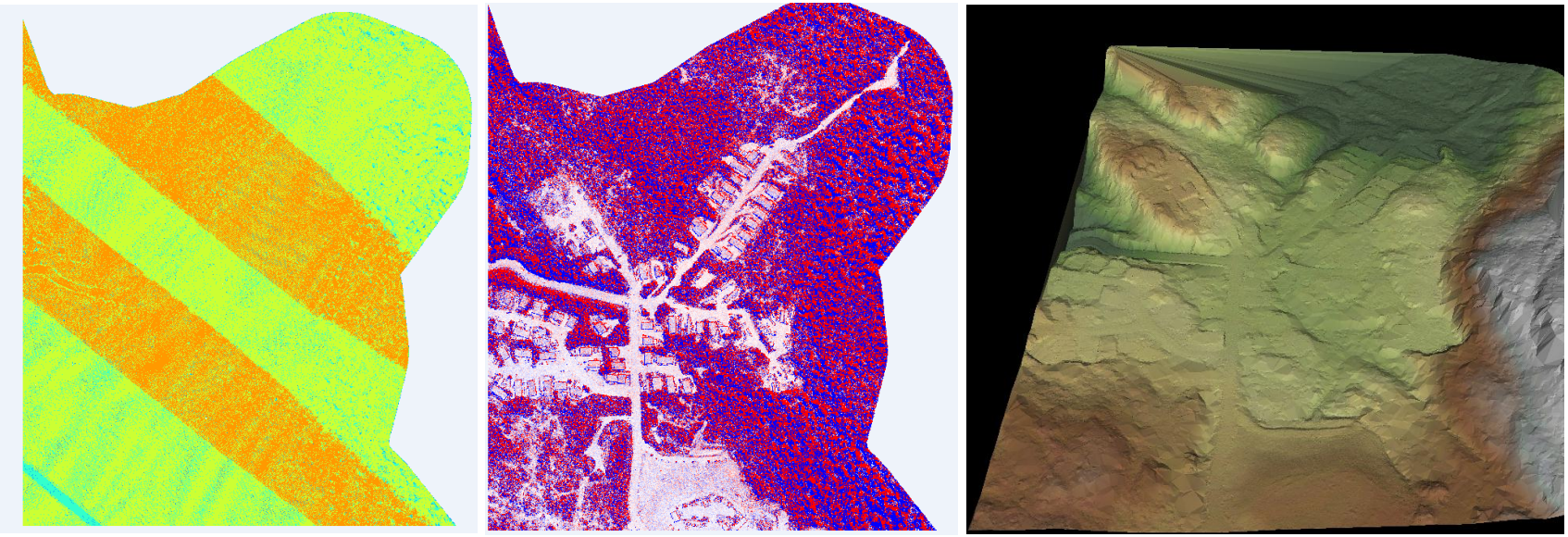
Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 30961291.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	City of Ketchikan



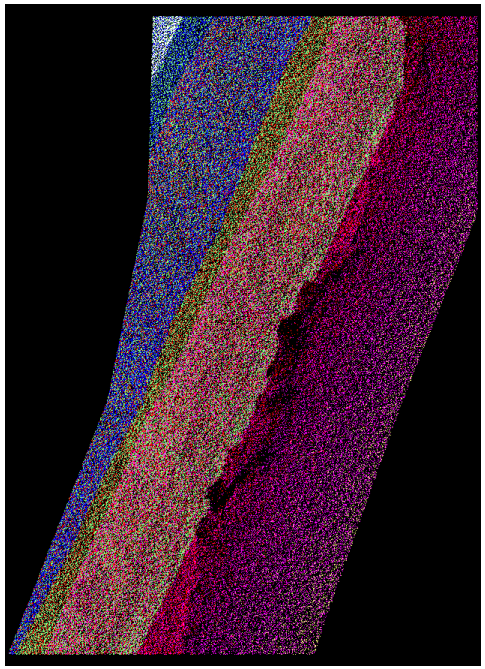
Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 31051276.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	

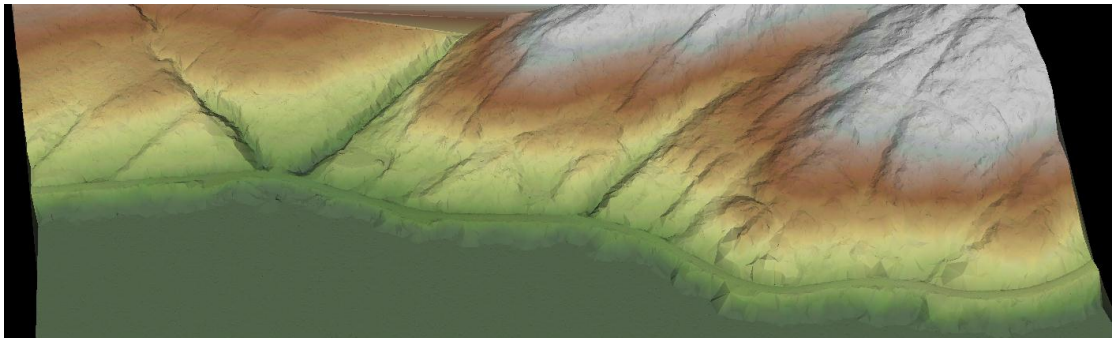


Classified Point Cloud Data Visual Checklist		Project: Ketchikan, Alaska
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 31101286.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	



Classified Point Cloud Data Visual Checklist		**Project: Ketchikan, Alaska**
Vendor: Quantum Spatial, Inc.		**Reviewed By: JLH**
LAS File: 31391296.las		**Date: 11/30/2014**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	Culverts along the highway
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	





FEMA Final Deliverable Checklist		Project: Ketchikan, Alaska	Date:11/30/2014
Guidance: FEMA Data Capture Technical Reference 2014		Reviewed By: James L. Huffines	
Section: FEMA DCS Compliance			
Item	**P/F/NA**	**Comments**	
Folder Structure			
Correspondence			
General			
Metadata (xml)	P	Passed MIP Metadata Upload Testing	
Correct naming convention (12345C_Terrain_metadata)	P		
Correct title and case number	P		
Purpose clearly describes floodplain mapping intention	P		
Bounding Coordinates match LAS tile index	P		
Place Keyword matches metadata naming convention	P		
Logical Consistency describes the LAS classifications	P		
All items listed in lineage are included in deliverable	P		
Process step matches the LAS classifications	P		
Projection information is correct	P		
Distribution information is correct	P		
Contact information is correct	P		
Project Narrative			
Purpose clearly describes floodplain mapping intention			
Text describes the LAS classifications			
Text includes spatial reference			
Text includes vertical accuracy test results			
Text includes scope of work			
Text includes MIP location			
LiDAR Compliance Form			
Survey Compliance Form			
Supplemental Data			
Survey Data and Vertical Accuracy Test Results			
LiDAR Collection Area			
QA Report and supporting documentation			
Pre and Post Flight Reports and supporting data			
LiDAR Project Tile Index			
All tiles listed in tile index are accounted for and have correct names			
Index does not have gaps or overlapping tiles			
Spatial reference is correct			

FEMA Final Deliverable Checklist		Project: Ketchikan, Alaska	Date:11/30/2014
Guidance: FEMA Data Capture Technical Reference 2014		Reviewed By: James L. Huffines	
Section: FEMA DCS Compliance LiDAR Datasets			
Item	**P/F/NA**	**Comments**	
Folder Structure	P		
Source			
Raw Point Cloud Data			
All tiles are present and accounted for			
Include tile index with all tiles included with correct names			
Index does not have gaps or overlapping tiles	NA	Raw Point Cloud in Swath Format	
Spatial reference is correct			
Final			
Breaklines	NA		
File is complete and covers project area	NA		
Spatial reference is correct	NA		
Classified Point Cloud Data	P		
All tiles are present and accounted for	P		
Include tile index with all tiles included with correct names	P		
Index does not have gaps or overlapping tiles	P		
Spatial reference is correct	P		