CWCB Del 3

Summary USGS National Geospatial Program Lidar Base Specification Version 1.3 Report

Quality level tested: QL2

Report generated on 3/16/2020

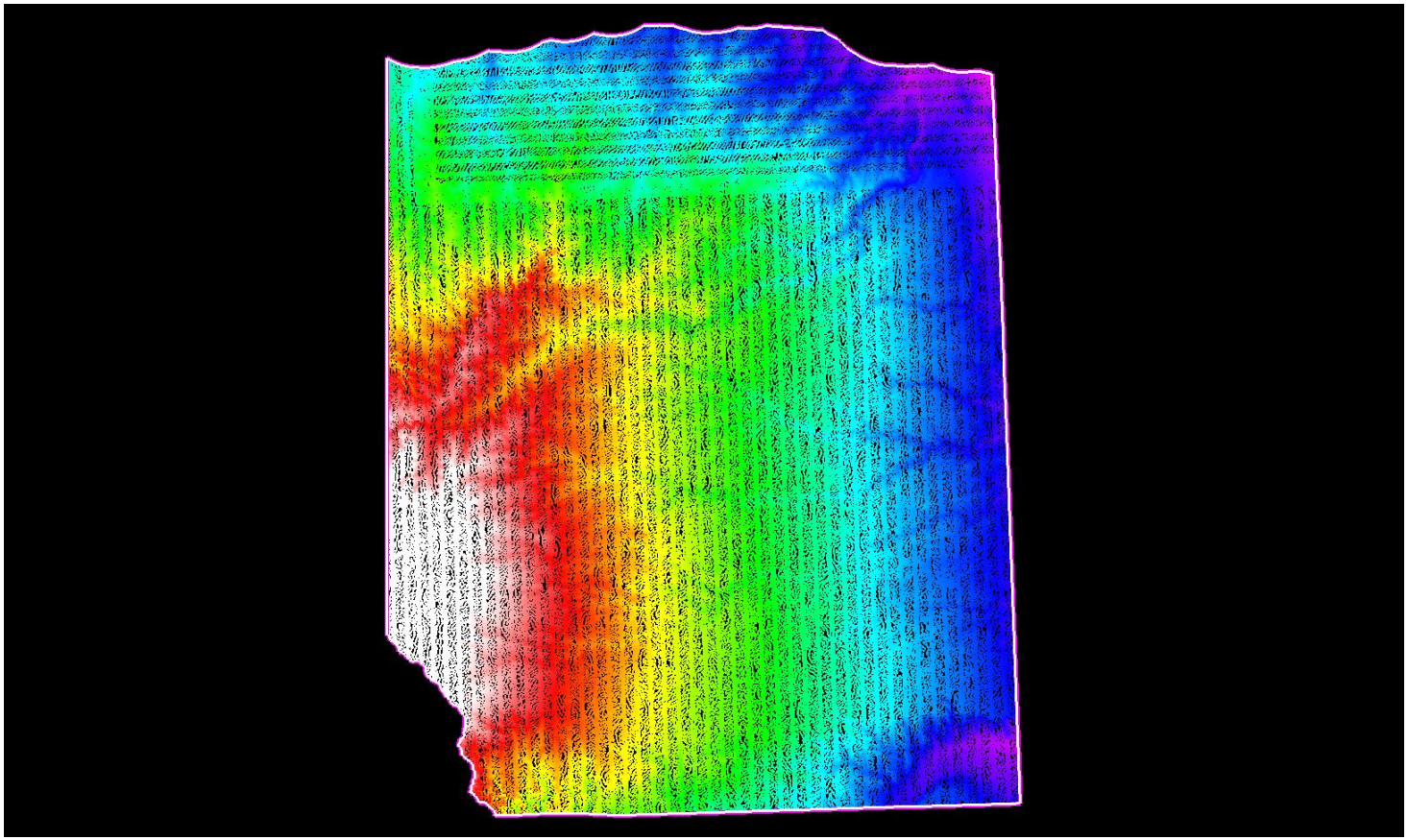
This document reports on compliance with the USGS National Geospatial Program Lidar Base Specification Version 1.3. The complete specification, which also contains a list of abbreviations, acronyms, and a glossary of related terms, can be found here.

Test Number	No Issue Points Identified	Test Results Need Review	Unable to Grade See Report Content
C-1			X
C-2			X
C-3			X
C-4.1	X		
C-4.2			X
C-5			X
C-6.1		X	
C-6.2	X		
C-7			X
DPH-1.1	X		
DPH-1.2	X		
DPH-1.3			X
DPH-1.4			X
DPH-2			X
DPH-3	X		
DPH-4	X		
DPH-5	X		
DPH-6	X		
DPH-7.1	X		
DPH-7.2		X	
DPH-8			X
DPH-9.1	X		
DPH-9.2			Skipped
DPH-10			X
DPH-11	X		
DPH-12			X
DPH-13			X
DPH-14			X
DPH-15			X
DPH-16			X

C-1 Report on Collection Area

The USGS Lidar Base Specification Version 1.3 states: "The defined project area (DPA) shall be buffered by a minimum of 100 meters (m) to create a buffered project area (BPA). Data collection is required for the full extent of the BPA. For all products to be consistent to the limit of the DPA, all products shall be generated to the full extent of the BPA. Because data and products are generated under contract for the complete BPA, they shall also be delivered to the customer."

The purpose of this section is to show lidar coverage to the extent of a 100 meter buffer of the defined project area boundary.



White polygon is defined project area (DPA) boundary
Purple polygon is buffered project area (BPA) boundary

C-2 Report on Multiple Discrete Returns

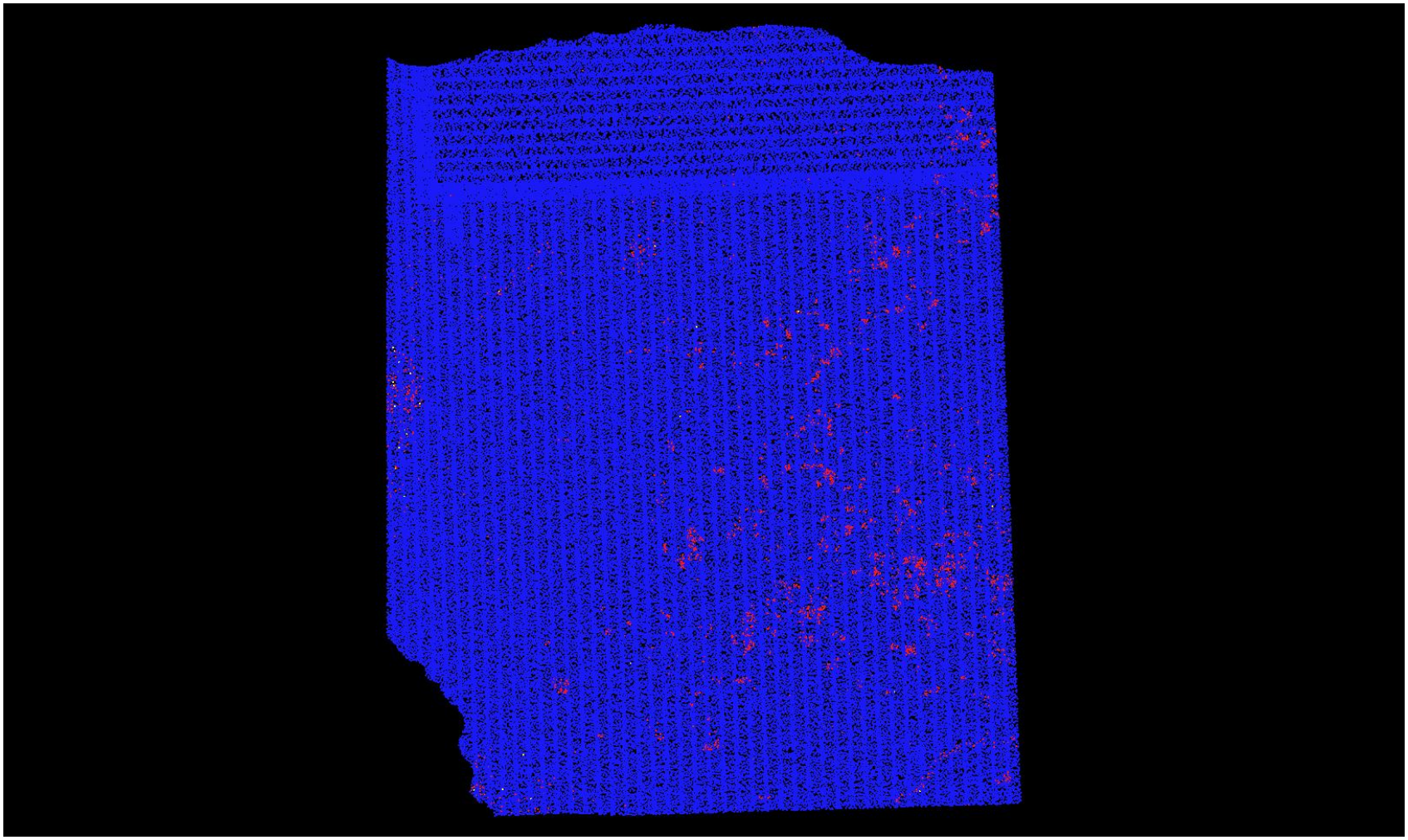
The USGS Lidar Base Specification Version 1.3 states: "Deriving and delivering multiple discrete returns is required in all conventional lidar data collection efforts. Data collection shall be capable of at least three returns per pulse. Full waveform collection is acceptable and is promoted; however, full waveform data are regarded as supplemental information."

The purpose of this section is to report on the presence and quantities of lidar returns in the LAS data. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

File	First return	Second return	Third return	Other returns	Total points
Total	41,192,469,965	645,542,667	6,519,971	72,741	41,844,605,344

C-2 Report on Multiple Discrete Returns - All Returns

The purpose of this section is to show a graphic of lidar data points colored by all returns. Blank flight lines can indicate a collection or processing problem dealing with lidar return attribute information.



C-3 Report on Intensity Values

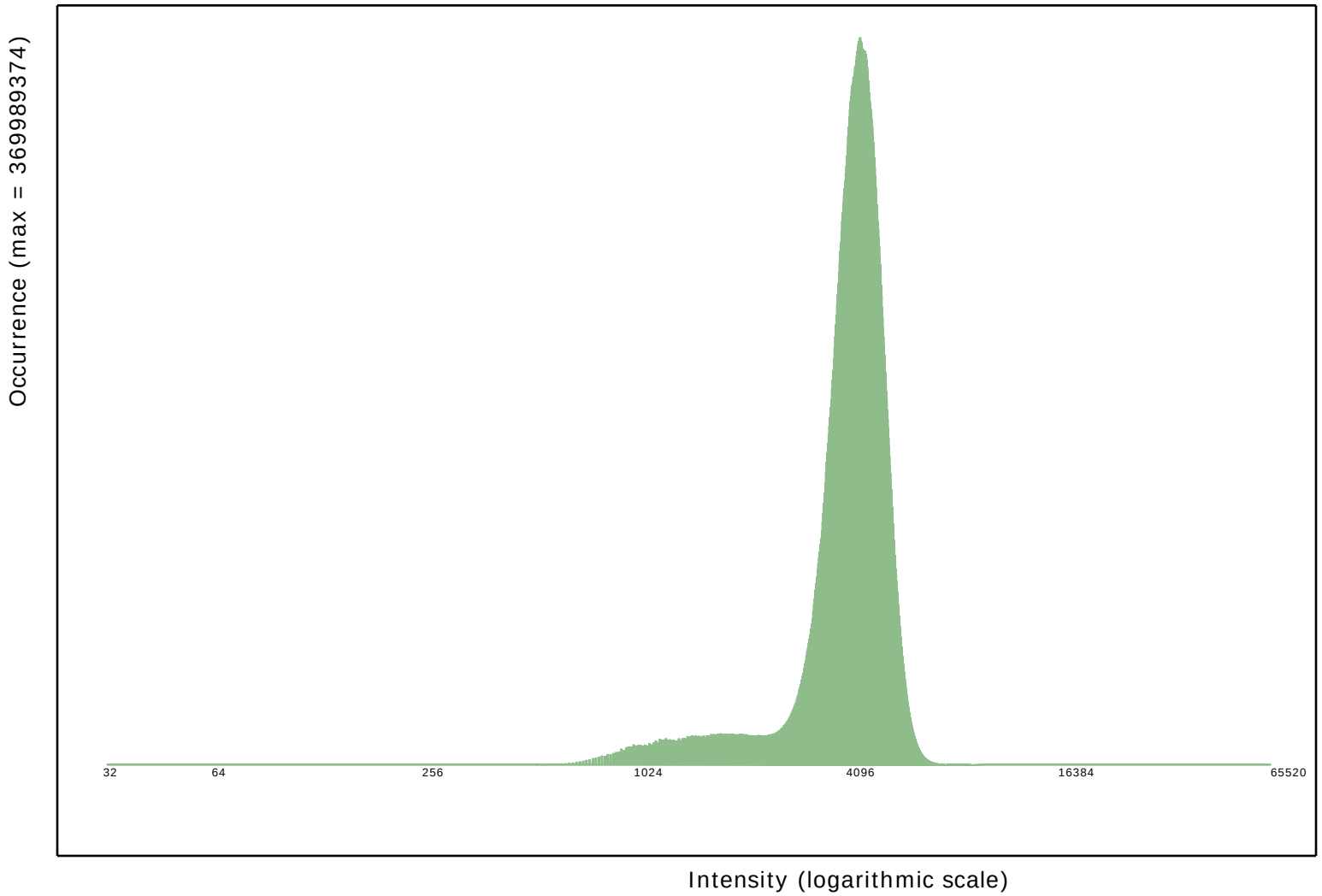
The USGS Lidar Base Specification Version 1.3 states: "Intensity values are required for each multiple discrete return. The values recorded in the LAS files shall be normalized to 16 bit, as required by the LAS Specification version 1.4-R13 (ASPRS, 2011). It warrants re-emphasis that intensity normalization is strictly linear. Common image stretches (minimum-maximum, standard deviations, percent clip, histogram, and so forth) are expressly forbidden."

The purpose of this section is to report on the presence and quantities of lidar intensity in the LAS data.

File	Minimum	Maximum	Mean	Median	Mode
Overall Statistics	32	65,520	4,448	4,496	4,496

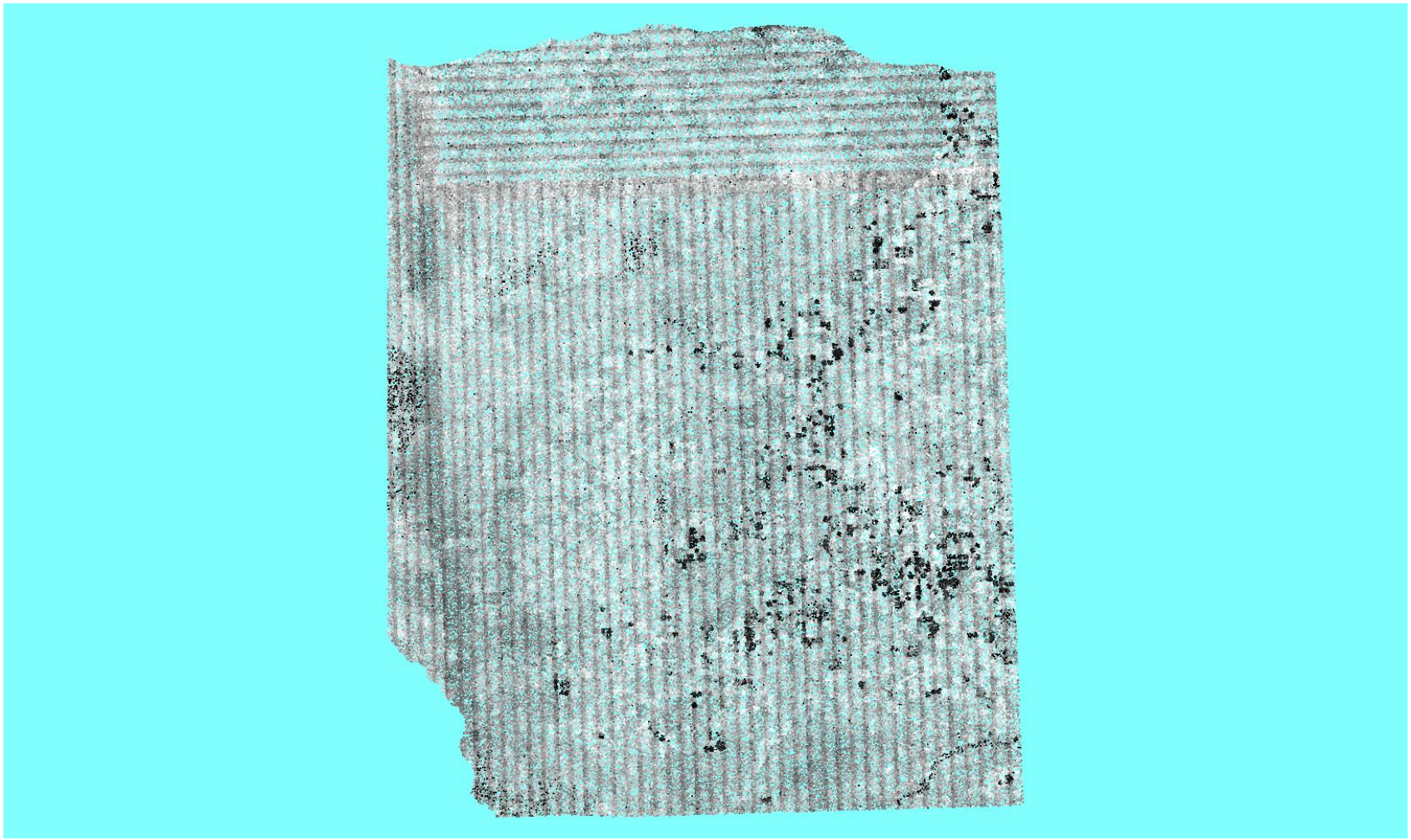
C-3 Report on Intensity Values - continued

The purpose of this section is to show a frequency distribution chart of intensities throughout all of the lidar files.



C-3 Report on Intensity Values - continued

The purpose of this section is to show a graphic of lidar data points colored by intensity. Blank flight lines can indicate a collection or processing problem dealing with lidar intensity attribute information.



C-4.1 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification Version 1.3 states: "Assessment and reporting of the NPS are made against single swath, single instrument, first-return-only data, including only the geometrically usable part of the swath and excluding acceptable data voids. Higher net densities of lidar point measurements are being achieved more often by flying multiple passes of the lidar instrument over the project area or flying with large amounts (greater than [>] 50 percent) of overlap between swaths, creating a need for a new term to describe total pulse density without being confused with NPS and NPD. This specification will use the terms aggregate nominal pulse spacing (ANPS) and aggregate nominal pulse density (ANPD) to describe the net overall pulse spacing and density, respectively. The required ANPS and ANPD by QL are listed in Table 1. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m^2, pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

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

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported.

Quality level tested: QL2

Units: US Survey Feet

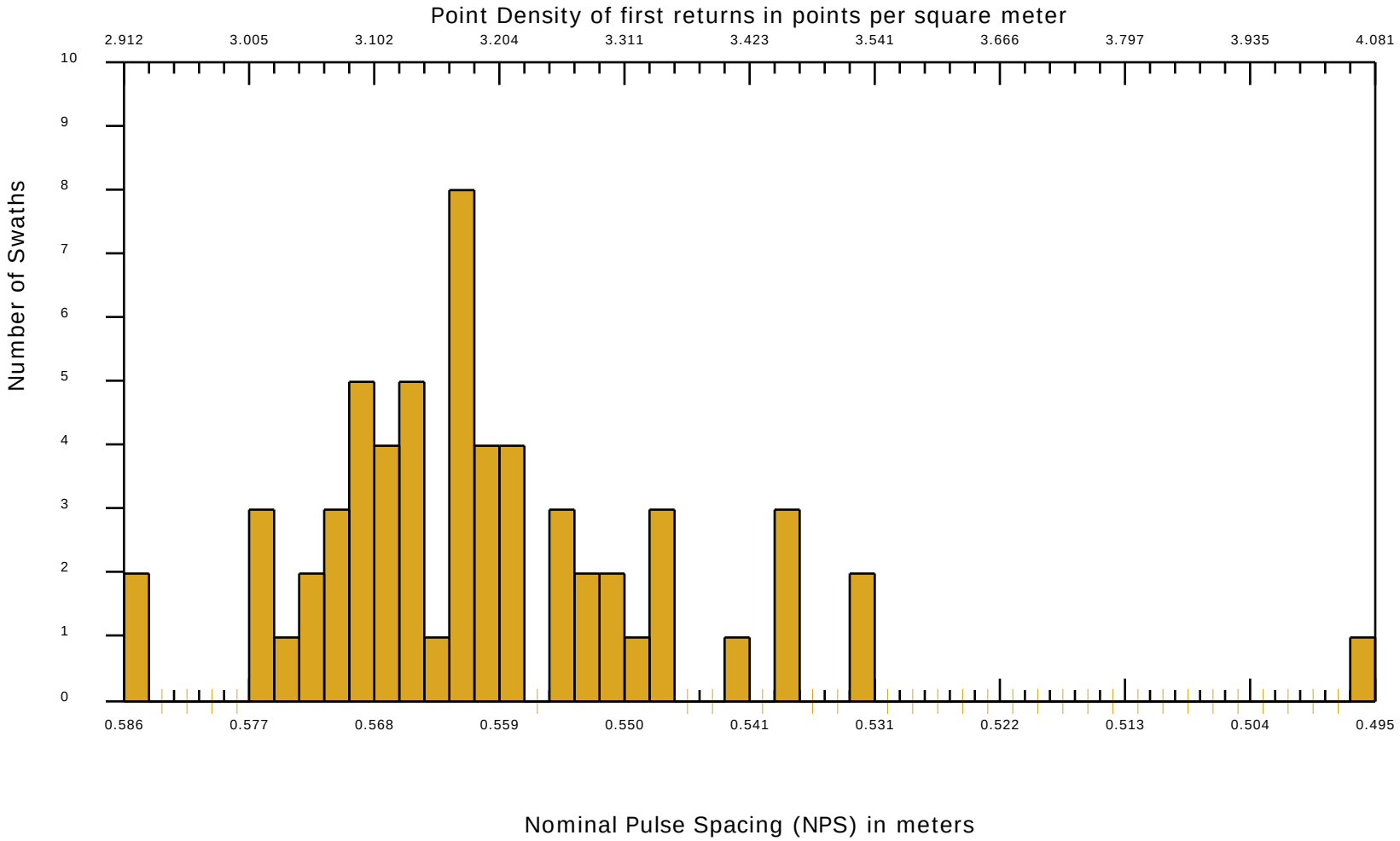
File	Number of First Returns	Area	Point Density	NPS
Average			3.197/0.297 pp Square Meter/ pp Square US Survey Foot	0.559/1.835 Meter/ US Survey Feet

C-4.1 Report on Nominal Pulse Spacing (NPS) - continued

Boundary ID	Number of First Returns	Area	Point Density	NPS
Aggregate	41,071,278,194	106,197,488,093	4.166/0.387 pp Square Meter/ pp Square US Survey Foot	0.490/1.608 Meter/ US Survey Feet

C-4.1 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.



The purpose of this supplemental Summary Table is to report the results of alternative density testing techniques that are sometimes used in the lidar community (see the Detailed Report PDF for more details). Focus should be made on comparing the results of these testing methodologies versus the current USGS LBS v 1.3 testing method (C-4.1). Note the similar results using the Nyquist sampling criteria and often dissimilar results of using the straight grid method. An emphasis is strongly recommended to examine the difference of how varying grid cell sizes affect the results when using the grid method.

C-4.2 Summary Table of Supplemental, Non-USGS LiDAR Base Specification version 1.3, Density Testing Methodology Results

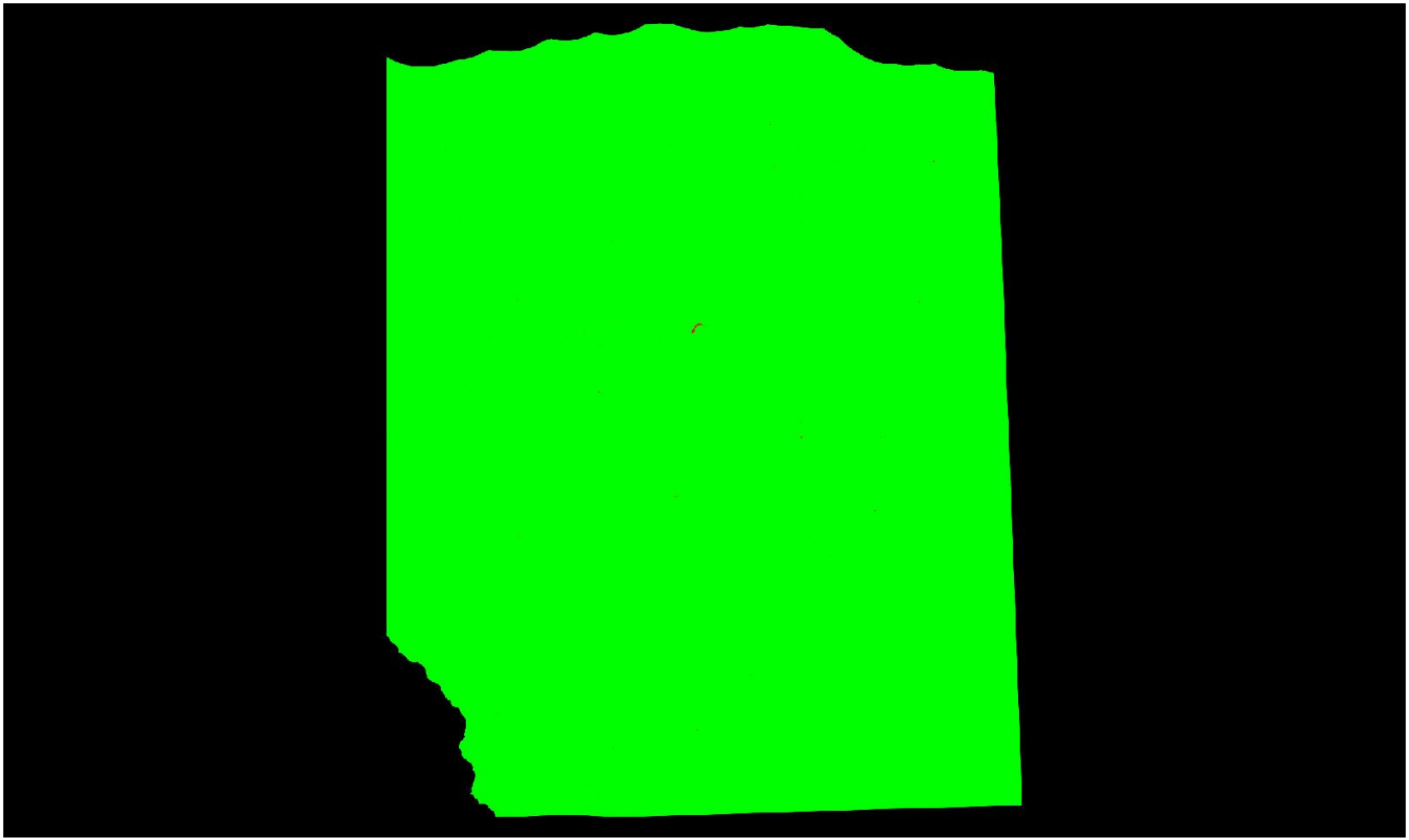
Test Name	Use Overlap Bit Flag Points	Raster Cell Size (in meters)	Minimum Point Count Requirement for Pass (green cells)	Percent of Passing Cells	Percent of Failing Cells
Grid Cell Size Based on Nyquist Sampling Criteria (2 x Required NPS) Including Overlap Bit Flagged Points	Yes	2 x 0.71 = 1.42	1	0.00	100.00
Grid Cell Size Based on Nyquist Sampling Criteria (2 x Required NPS) Excluding Overlap Bit Flagged Points	No	2 x 0.71 = 1.42	1	0.00	100.00
Grid Based Test: Grid Cell = 1m x 1m, Required PPSM Tested Including Overlap Bit Flagged Points	Yes	1	1 x 2 = 2	0.00	100.00
Grid Based Test: Grid Cell = 10m x 10m, Required PPSM Tested on Scaled Up Point Count Including Overlap Bit Flagged Points	Yes	10	100 x 2 = 200	0.00	100.00
Grid Based Test: Grid Cell = 100m x 100m, Required PPSM Tested on Scaled Up Point Count Including Overlap Bit Flagged Points	Yes	100	10,000 x 2 = 20,000	0.00	100.00
Grid Based Test: Grid Cell = 1,000m x 1,000m, Required PPSM Tested on Scaled Up Point Count Including Overlap Bit Flagged Points	Yes	1000	1,000,000 x 2 = 2,000,000	0.00	100.00
Grid Based Test: Grid Cell = 1m x 1m, Required PPSM Tested Excluding Overlap Bit Flagged Points	No	1	1 x 2 = 2	0.00	100.00
Grid Based Test: Grid Cell = 10m x 10m, Required PPSM Tested on Scaled Up Point Count Excluding Overlap Bit Flagged Points	No	10	100 x 2 = 200	0.00	100.00
Grid Based Test: Grid Cell = 100m x 100m, Required PPSM Tested on Scaled Up Point Count Excluding Overlap Bit Flagged Points	No	100	10,000 x 2 = 20,000	0.00	100.00
Grid Based Test: Grid Cell = 1,000m x 1,000m, Required PPSM Tested on Scaled Up Point Count Excluding Overlap Bit Flagged Points	No	1000	1,000,000 x 2 = 2,000,000	0.00	100.00

C-5 Report on Data Voids

The USGS Lidar Base Specification Version 1.3 states: "Data voids in lidar are gaps in the point cloud coverage caused by surface absorbance, scattering, or refraction of the lidar pulse (that is, where laser pulse energy is not returned to the sensor), instrument or processing anomalies or failure, obstruction of the lidar pulse, or improper collection because of flight plans. A data void is considered to be any area greater than or equal to (4 x ANPS) squared), which is measured using first returns only. Data voids within a single swath are not acceptable, except in the following circumstances:
(1) where caused by waterbodies;
(2) where caused by areas of low near infrared reflectivity, such as asphalt or composition roofing;
(3) where caused by lidar shadowing from buildings or other features; or
(4) where appropriately filled in by another swath."

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications.

C-5 Report on Data Voids



Cell size: 9.318 US Survey Feet

- Green: Cells containing at least 1 first return lidar point (number of cells = 1,223,042,110)
- Red: Cells containing no first return lidar points (number of cells = 174,697)
- Background Color: Null data

C-6.2 Report on Spatial Distribution and Regularity of Individual Swaths

File	Percentage of Cells that Contain >= 1

Pass: 60 files (percentage >= 90%)
Fail: 0 files (percentage < 90%)

C-7 Report on Collection Conditions

The USGS Lidar Base Specification Version 1.3 states: "Conditions for collection of lidar data will follow these guidelines: (1) Atmospheric conditions shall be cloud and fog free between the aircraft and ground during all collection operations. (2) Ground conditions shall be snow free. Very light, undrifted snow may be acceptable with prior approval. (3) Ground conditions shall be free of extensive flooding or any other type of inundation."

Note: Other collection condition requirements are also listed but cannot be automatically derived with this reporting tool.

The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map for the extent of the lidar at the time of collection.

Ground Conditions:

Flight Date: 08/15/2019
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=37.5100528013428+N%2C+102.53762710468+W&ql=station&var=ssm_depth&dy=2019&dm=8&dd=15&dh=22&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-103.082238997066&min_y=37.0022853065331&max_x=-101.993015212293&max_y=38.0178202961525&coord_x=-102.53762710468&coord_y=37.5100528013428&zbox_n=&zbox_s=&zbox_e=&zbox_w=&metric=0&bgvar=dem&shdvar=shading&width=800&height=450&nw=800&nh=450&h_o=0&font=0&js=1&uc=0

Flight Date: 08/17/2019
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=37.5100528013428+N%2C+102.53762710468+W&ql=station&var=ssm_depth&dy=2019&dm=8&dd=17&dh=20&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-103.082238997066&min_y=37.0022853065331&max_x=-101.993015212293&max_y=38.0178202961525&coord_x=-102.53762710468&coord_y=37.5100528013428&zbox_n=&zbox_s=&zbox_e=&zbox_w=&metric=0&bgvar=dem&shdvar=shading&width=800&height=450&nw=800&nh=450&h_o=0&font=0&js=1&uc=0

Flight Date: 08/18/2019
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=37.5100528013428+N%2C+102.53762710468+W&ql=station&var=ssm_depth&dy=2019&dm=8&dd=18&dh=22&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-103.082238997066&min_y=37.0022853065331&max_x=-101.993015212293&max_y=38.0178202961525&coord_x=-102.53762710468&coord_y=37.5100528013428&zbox_n=&zbox_s=&zbox_e=&zbox_w=&metric=0&bgvar=dem&shdvar=shading&width=800&height=450&nw=800&nh=450&h_o=0&font=0&js=1&uc=0

Flight Date: 08/19/2019
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=37.5100528013428+N%2C+102.53762710468+W&ql=station&var=ssm_depth&dy=2019&dm=8&dd=19&dh=19&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-103.082238997066&min_y=37.0022853065331&max_x=-101.993015212293&max_y=38.0178202961525&coord_x=-102.53762710468&coord_y=37.5100528013428&zbox_n=&zbox_s=&zbox_e=&zbox_w=&metric=0&bgvar=dem&shdvar=shading&width=800&height=450&nw=800&nh=450&h_o=0&font=0&js=1&uc=0

C-7 Report on Collection Conditions - Continued

Ground Conditions:

Flight Date: 08/20/2019
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=37.5100528013428+N%2C+102.53762710468+W&ql=station&var=ssm_depth&dy=2019&dm=8&dd=20&dh=19&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-103.082238997066&min_y=37.0022853065331&max_x=-101.993015212293&max_y=38.0178202961525&coord_x=-102.53762710468&coord_y=37.5100528013428&zbox_n=&zbox_s=&zbox_e=&zbox_w=&metric=0&bgvar=dem&shdvar=shading&width=800&height=450&nw=800&nh=450&h_o=0&font=0&js=1&uc=0

Flight Date: 08/22/2019
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=37.5100528013428+N%2C+102.53762710468+W&ql=station&var=ssm_depth&dy=2019&dm=8&dd=22&dh=22&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-103.082238997066&min_y=37.0022853065331&max_x=-101.993015212293&max_y=38.0178202961525&coord_x=-102.53762710468&coord_y=37.5100528013428&zbox_n=&zbox_s=&zbox_e=&zbox_w=&metric=0&bgvar=dem&shdvar=shading&width=800&height=450&nw=800&nh=450&h_o=0&font=0&js=1&uc=0

Flight Date: 08/26/2019
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=37.5100528013428+N%2C+102.53762710468+W&ql=station&var=ssm_depth&dy=2019&dm=8&dd=26&dh=19&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-103.082238997066&min_y=37.0022853065331&max_x=-101.993015212293&max_y=38.0178202961525&coord_x=-102.53762710468&coord_y=37.5100528013428&zbox_n=&zbox_s=&zbox_e=&zbox_w=&metric=0&bgvar=dem&shdvar=shading&width=800&height=450&nw=800&nh=450&h_o=0&font=0&js=1&uc=0

DPH-1.1 Report on ASPRS LAS File Format (Tiled Data) - Compliance

The USGS Lidar Base Specification Version 1.3 states: "All processing will be carried out with the understanding that all point deliverables are required to be in LAS format, version 1.4, using PDRF 6, 7, 8, 9 or 10. Data producers are encouraged to review the LAS specification version 1.4-R13 in detail (ASPRS, 2011)."

The purpose of this section is to show a table of LAS 1.4 compliance test results for each tiled file.

File	LAS Version/PDRF	System ID	Legacy Point Count	Legacy Return Counts	File Source ID	Global Encoding	VLRs / EVLRs	WKT	Intensity	Point Count with Bad Return Info

Pass: 12021 files
Fail: 0 files

DPH-1.2 Report on ASPRS LAS File Format (Tiled Data) - File Integrity

The purpose of this section is to show a table of LAS 1.4 file integrity test results for each tiled file.

File	Number of Points Outside Extent	Offset To Point Data	Offset To EVLR	Number Of Points	Number of Points by Return	Number of Duplicate Points

Pass: 12021 files
Fail: 0 files

DPH-1.3 Report on ASPRS LAS File Format (Tiled Data) - Informational

The purpose of this section is to show a table of LAS 1.4 file informational test results for each tiled file.

File	GPS Time min	GPS Time max	Extended Scan Angle	Scan Angle Rank	Scanner Channel	Scan Direction	Edge of Flight Line	User Data	Counts for Synthetic	Key-points	Withheld	Overlap
	249936145.53	250884578.18	[-4797, 4540]	[-28.782, 27.24]	[0, 0]	[0, 1]	[0, 1]	[0, 0]	0	0	28859127	14224542736

DPH-1.4 Report on Elevation by Class for Tiled Data

The purpose of this section is to show a table of the Minimum and Maximum elevation (Z) values by Class for each tiled file.

File	Class	Z Min	Z Max
	1	3271.827	5418.135
	2	3436.424	5230.849
	7	2527.127	5203.494
	9	3462.483	4796.595
	17	3521.646	5111.02
	18	3733.995	5518.007
	20	3462.608	4797.13

DPH-2 Report on Full Waveform

The USGS Lidar Base Specification Version 1.3 states: "If full waveform data are recorded during collection, the waveform packets shall be delivered. LAS deliverables, including waveform data, shall use external auxiliary files with the extension .wdp to store waveform packet data. See the LAS specification version 1.4-R13 (ASPRS, 2011) for additional information."

The purpose of this section is to show the presence of waveform data for the lidar data.

All LAS files have no waveform data present.

DPH-3 Report on Time of Global Positioning System Data

The USGS Lidar Base Specification Version 1.3 states: "The time of GPS data shall be recorded as Adjusted GPS Time at a precision sufficient to allow unique timestamps for each pulse. Adjusted GPS Time is defined to be standard (or satellite) GPS time minus 10^9. The encoding tag in the LAS header shall be properly set. See LAS specification version 1.4–R13 (ASPRS, 2011) for additional information."

The purpose of this section is to show the GPS time type within the LAS files for the lidar data.

All LAS files are formatted as Adjusted GPS Time.

DPH-4 Report on Datums

The USGS Lidar Base Specification Version 1.3 states: "To maximize the usability of 3DEP lidar and elevation products, all data collected shall be tied to the datums listed below: For the CONUS, unless otherwise specified by the user and agreed to in advance by the USGS–NGP:
The horizontal datum for latitude and longitude and ellipsoid heights will be the North American Datum of 1983 (NAD 83) using the most recently NGS-published adjustment (currently NAD 83, epoch 2010.00, realization of 2011). The vertical datum for orthometric heights will be the North American Vertical Datum of 1988 (NAVD 88). 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 [2017] Geoid12b model)."
Note: See the specification document for requirements concerning non-contiguous areas of the United States.

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. The project specifications should be reviewed to ensure that the Datums listed in this report are as expected.

All LAS tiled files are defined as:

Horizontal Datum = NAD83 (National Spatial Reference System 2011)
Horizontal EPSG Code = 1116
Vertical Datum = North American Vertical Datum 1988
Vertical EPSG Code = 5103

DPH-5 Report on Coordinate Reference System

The USGS Lidar Base Specification Version 1.3 states: "Lidar data and all related or derived data and products shall be processed and delivered in a single CRS agreed upon in advance of data collection by the USGS–NGP and all project partners and cooperators. The complete CRS definition and its WKT representation, both horizontal and vertical, shall be documented as part of the agreement. Each project shall be processed and delivered in a single CRS, except in cases where a project area covers multiple CRSs such that processing in a single CRS would introduce unacceptable distortions in part of the project area. In such cases, the project area is to be split into subareas appropriate for each CRS. Each subarea shall be processed and delivered as a separate subproject with its own CRS."

The purpose of this section is to show the coordinate reference systems of the LAS files for the lidar data. The project specifications should be reviewed to ensure that the Coordinate Reference Systems listed in this report are as expected.

All LAS files are defined as:

Horizontal CRS = NAD83(2011) / Colorado South (ftUS)
EPSG Code = 6432
Vertical CRS = NAVD88 height (ftUS)
EPSG Code = 6360
Geoid Model = US Geoid Model of 2012 B

DPH-6 Report on Units of Reference

The USGS Lidar Base Specification Version 1.3 states: "All references to the units of measure 'Feet' and 'Foot' shall specify 'International', 'Intl', 'U.S. Survey', or 'US'."

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar data. The project specifications should be reviewed to ensure that the Units listed in this report are as expected.

All LAS files are defined as:

Horizontal Unit = US Survey Foot
Vertical Unit = US Survey Foot

DPH-7.1 Report on File Source ID

The USGS Lidar Base Specification Version 1.3 states: "At the time of its creation and prior to any further processing, each swath shall be assigned a unique file source ID, and 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 persisted 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)."

The purpose of this section is to report on the File Source ID for the lidar data.

0 tiled files are in violation with non-zero File Source ID.

DPH-7.2 Report on Swath Geographic Locations

The purpose of this section is to report on geographic locations for the generated swaths. Each generated swath is named based on unique Point Source IDs from the tiled data and should not exist in more than one contiguous geographic location unless separated by water within the swath. Manual inspection of failing swaths is recommended.

5 generated swaths PASS Location Testing.
55 generated swaths FAIL Location Testing.

DPH-8 Report on Smooth Surface Precision (intraswath)

The USGS Lidar Base Specification Version 1.3 states: "The precision of lidar is the quantified assessment of variations in measurements of a surface that, under ideal theoretical conditions, would be without variation. Assessment will be made on hard surfaced areas (for example, parking lots or large rooftops) containing only single return lidar points. 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. Sample areas will be approximately 100 pixels. 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 the 'Smooth surface' column of Table 2 for the QL of information that is being collected."

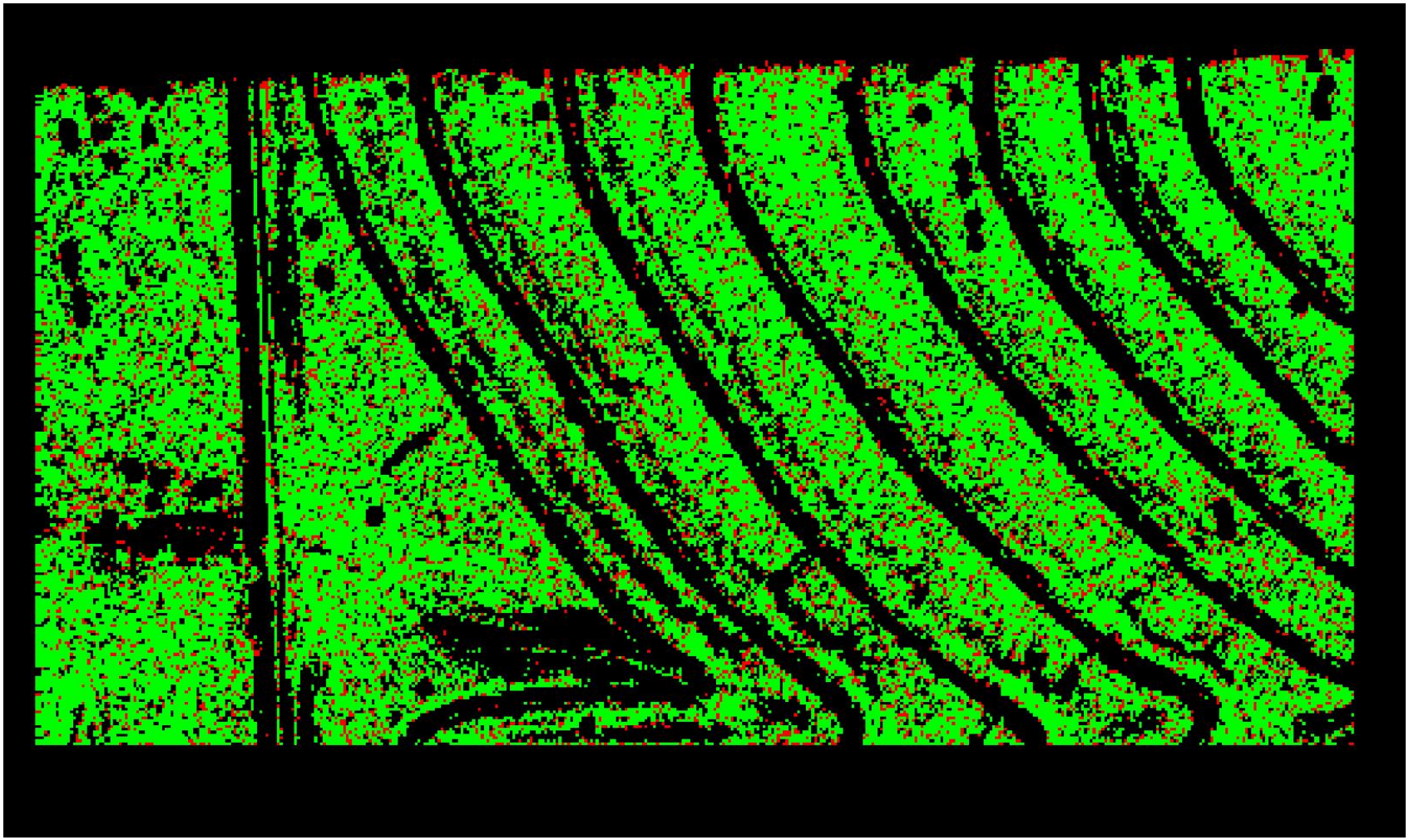
Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

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

The purpose of this section is to evaluate smooth surface repeatability / intraswath precision by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of clusters of single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops).

DPH-8 Report on Smooth Surface Precision (intraswath) - continued



0	0.060	0.597 (Meter)
0	0.196	1.960 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that are not applicable for depicting sensor noise within individual swaths (e.g., trees, moving cars, etc.).

DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification Version 1.3 states: "Overlap consistency is a measure of the geometric agreement of two overlapping swaths, and a fundamental measure of the quality of the calibration or boresight adjustment of the data in each lift. It is of particular importance because the match between the swaths of a single lift is a strong indicator of the geometric quality of the overall dataset, establishing the quality and accuracy limits of all downstream data and products. The principles used with swaths can also be applied to the overlap between lifts and projects as well. Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns. Assessment is limited to areas of <10-degree slope. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
(1) Adjacent, overlapping parallel swaths within a project,
(2) Cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
(3) Adjacent, overlapping lifts.
Each overlap 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. The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in the 'Swath overlap' column of Table 2 for the QL of information that is being collected."

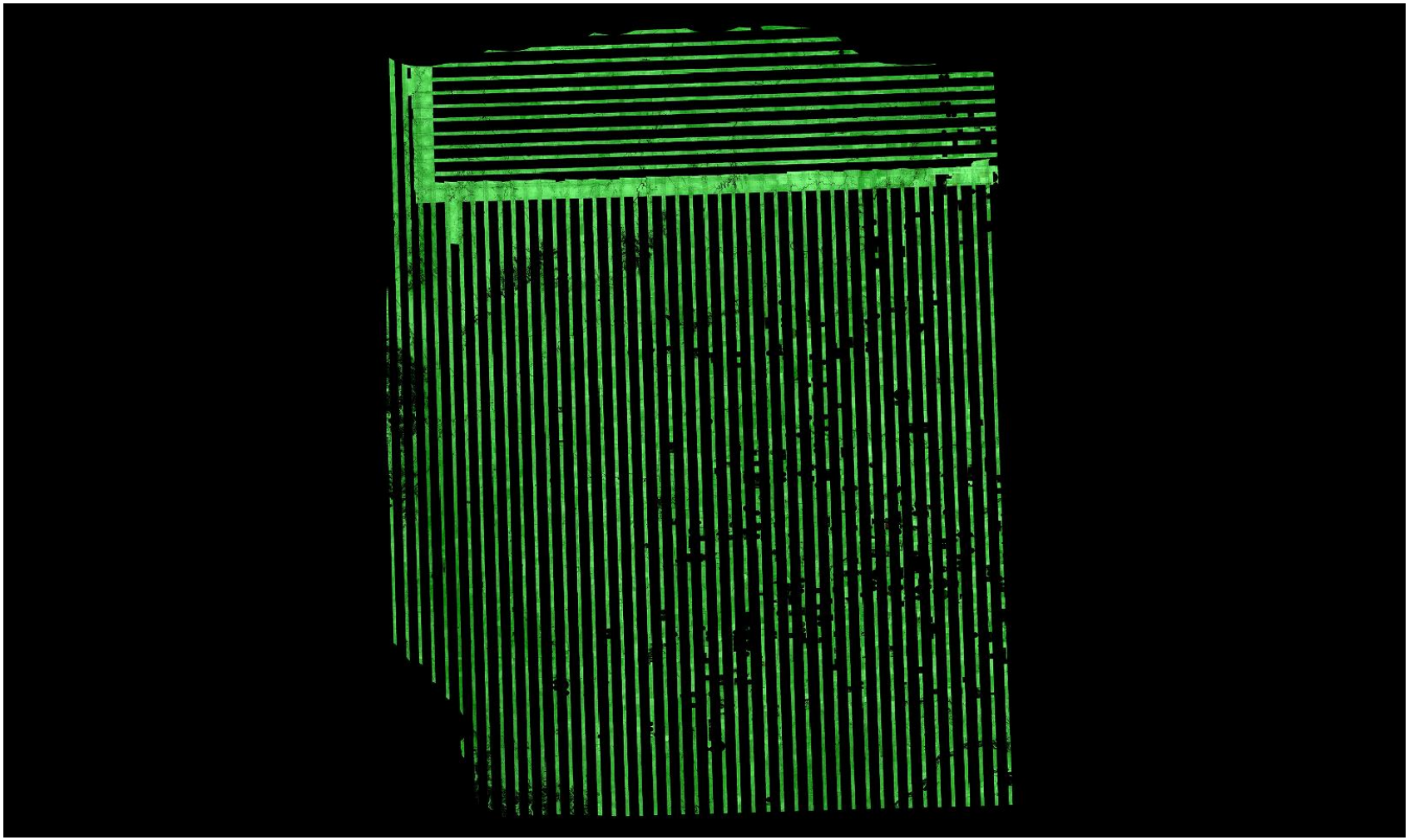
Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

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

The purpose of this section is to show a thematically rendered map of a flightline separation raster for all of the data processed. Processing has been done to isolate measurements either to specific classes of points or to clusters of single returns (depending on the method selected), limited within areas of <10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. The swath overlap difference RMSDz values are reported on the following page(s).

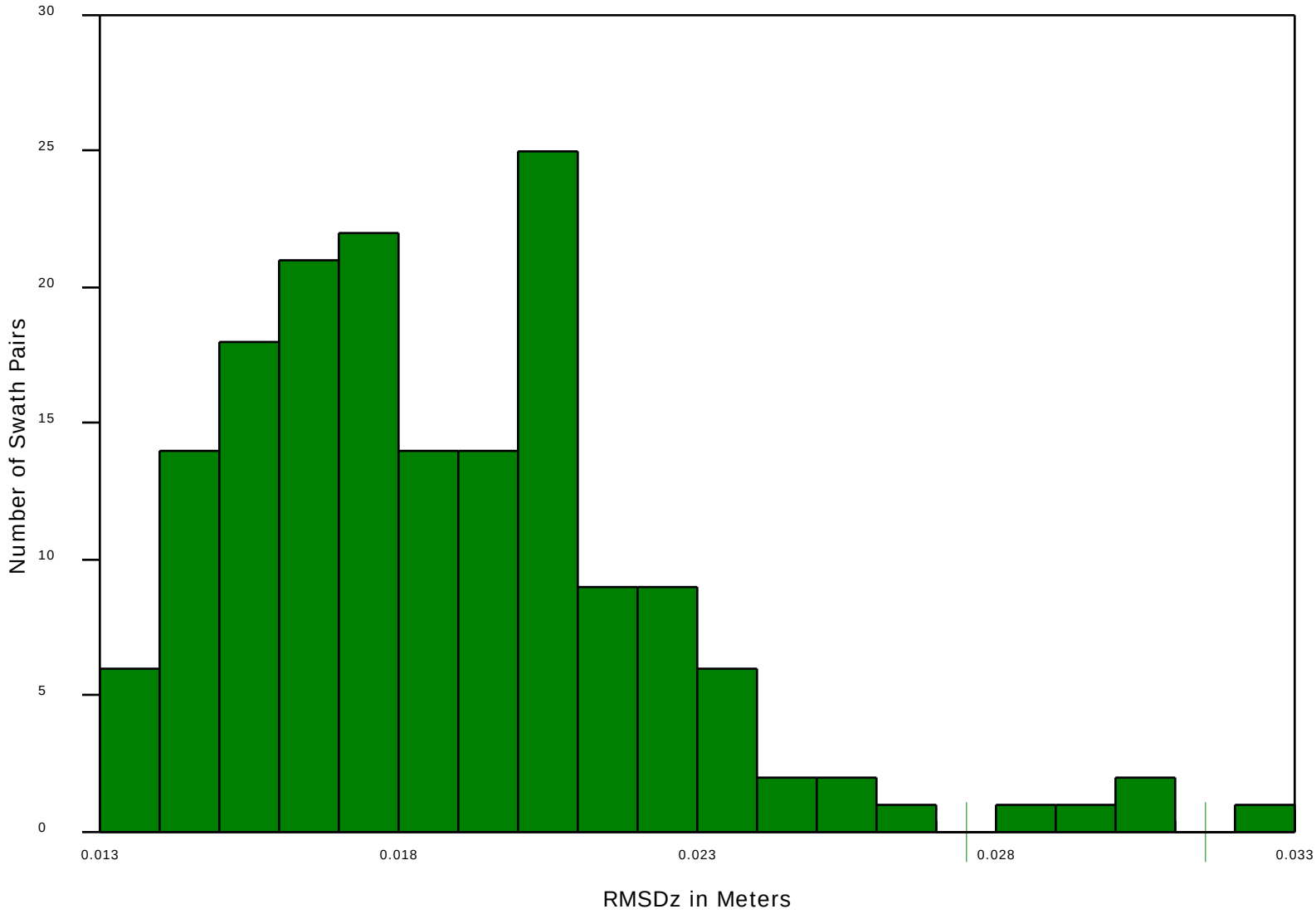
DPH-9.1 Report on Overlap Consistency (interswath) - continued



A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between flight lines (e.g., trees, moving cars, etc.).

DPH-9.1 Report on Overlap Consistency (interswath) - continued

The purpose of this section is to show a frequency distribution chart of RMSDz values.



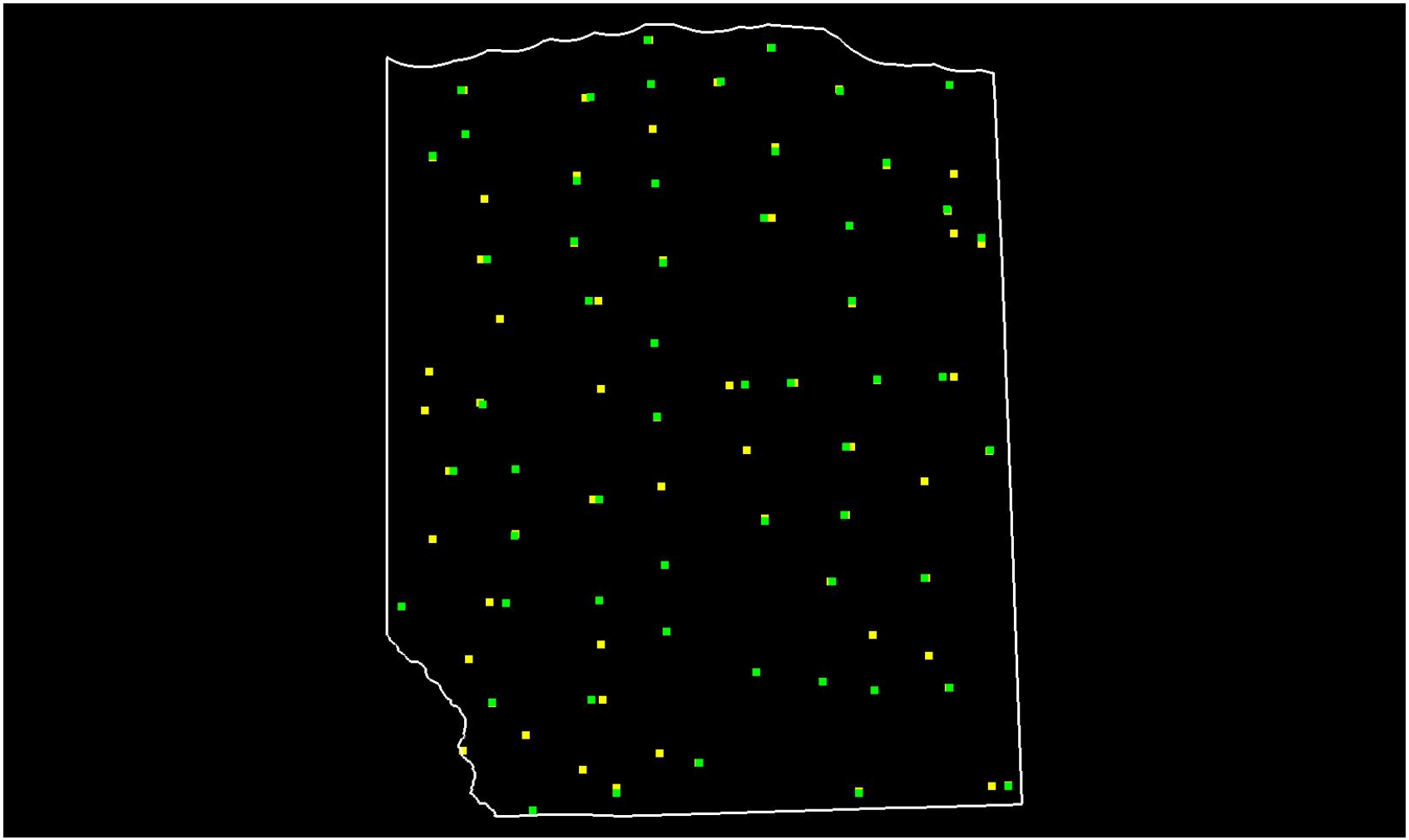
DPH-10 Report on Check Points

The USGS Lidar Base Specification Version 1.3 states: "In the "Positional Accuracy Standards for Digital Geospatial Data" (ASPRS, 2014) the required number of check points for vertical accuracy assessment is tied to the areal extent of the project. This requirement has also been adopted in the LBS. Data producers are encouraged to carefully review the new and revised requirements in the ASPRS standards. Check points 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). Ground that has been plowed or otherwise disturbed is not acceptable. The same check points may be used for NVA assessment of the point data and DEM. Check points for VVA assessments shall be surveyed in vegetated areas (typically characterized by multiple return lidar). Although the nature of vegetated areas makes absolute definition of a suitable test area difficult, these areas will meet the requirements below. As stated in the "National Standards for Spatial Data Accuracy (Federal Geographic Data Committee, 1998) and reiterated in the ASPRS (2014), it is unrealistic to prescribe detailed requirements for check point locations because many unpredictable factors will affect field operations and decisions, and the data producer often requires the freedom to use their best professional judgment. The quantity and location of check points shall meet the following requirements, unless alternative criteria are approved by the USGS–NPG in advance:

- The ASPRS-recommended total number of check points for a given project size shall be met.
- The ASPRS-recommended distribution of the total number of check points between NVA and VVA assessments shall be met.
- Check points within each assessment type (NVA and VVA) will be well-distributed across the entire project area; see "Glossary" section at the end of this specification for a definition of "well-distributed."
- Within each assessment type, check points will be distributed among all constituent land cover types in approximate proportion to the areas of those land cover types (ASPRS, 2014)."

The purpose of this section is to show check points (NVA and VVA).

DPH-10 Report on Check Points - continued



Yellow points are NVA, green points are VVA.
White polygon is defined project area (DPA) boundary

DPH-10 Report on Check Points - continued

Total check points: 132

Check points in defined project area (DPA): 132

Total NVA check points in defined project area (DPA): 76

Total VVA check points in defined project area (DPA): 56

Total defined project area (DPA): 9866.109 square KM

Density of check points in defined project area (DPA): 0.013 points per square KM

TABLE C.1 RECOMMENDED NUMBER OF CHECKPOINTS BASED ON AREA

Project Area (Square Kilometers)	Horizontal Accuracy Testing of Orthoimagery and Planimetrics	Vertical and Horizontal Accuracy Testing of Elevation Data sets		
	Total Number of Static 2D/3D Checkpoints (clearly-defined points)	Number of Static 3D Checkpoints in NVA[9]	Number of Static 3D Checkpoints in VVA	Total Number of Static 3D Checkpoints
≤500	20	20	5	25
501-750	25	20	10	30
751-1000	30	25	15	40
1001-1250	35	30	20	50
1251-1500	40	35	25	60
1501-1750	45	40	30	70
1751-2000	50	45	35	80
2001-2250	55	50	40	90
2251-2500	60	55	45	100

[9]Although vertical check points are normally not well defined, where feasible, the horizontal accuracy of lidar data sets should be tested by surveying approximately half of all NVA check points at the ends of paint stripes or other point features that are visible and can be measured on lidar intensity returns.

Source: ASPRS Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0. - November 2014)

DPH-11 Report on Absolute Vertical Accuracy

The USGS Lidar Base Specification Version 1.3 states: "Absolute vertical accuracy of the lidar data and the derived DEM will be assessed and reported in accordance with the ASPRS (2014). Two broad land cover types shall be assessed: vegetated and nonvegetated. Three absolute accuracy values shall be assessed and reported: (1) NVA for the point data, (2) NVA for the DEM, and (3) VVA for the DEM. The minimum NVA and VVA requirements for all data, using the ASPRS methodology, are listed in Table 4. Both the NVA and VVA required values shall be met."

Table 4. Absolute vertical accuracy for light detection and ranging data and digital elevation models.

[QL, quality level, $RMSE_z$, root mean square error in the z direction; NVA, nonvegetated vertical accuracy; VVA, vegetated vertical accuracy; m, meter; ≤, less than or equal to]

Quality level	$RMSE_z$ (nonvegetated) (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

The purpose of this section is to report on the absolute vertical accuracy of the lidar data and DEMs generated from it by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) against surveyed ground check points.

DPH-11 Report on Absolute Vertical Accuracy - continued

Units: Meter (/US Survey Feet)

Vertical Accuracy Class tested: 10-cm

Check Points in defined project area (DPA):	132
Check Points with Lidar Coverage	132
Check Points with Lidar Coverage (NVA)	76
Check Points with Lidar Coverage (VVA)	56
Average Z Error (NVA)	-0.020/-0.065
Maximum Z Error (NVA)	0.084/0.276
Median Z Error (NVA)	-0.012/-0.039
Minimum Z Error (NVA)	-0.147/-0.481
Standard deviation of Vertical Error (NVA)	0.045/0.148
Skewness of Vertical Error (NVA)	-0.405
Kurtosis of Vertical Error (NVA)	-0.069
Non-vegetated Vertical Accuracy (NVA) RMSE(z) [1]	0.049/0.161 PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- [1]	0.096/0.315 PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-	0.096/0.315
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM) [2]	0.050/0.165 PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level (DEM) +/- [2]	0.098/0.098 PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile (DEM) +/- [2]	0.191/0.626 PASS

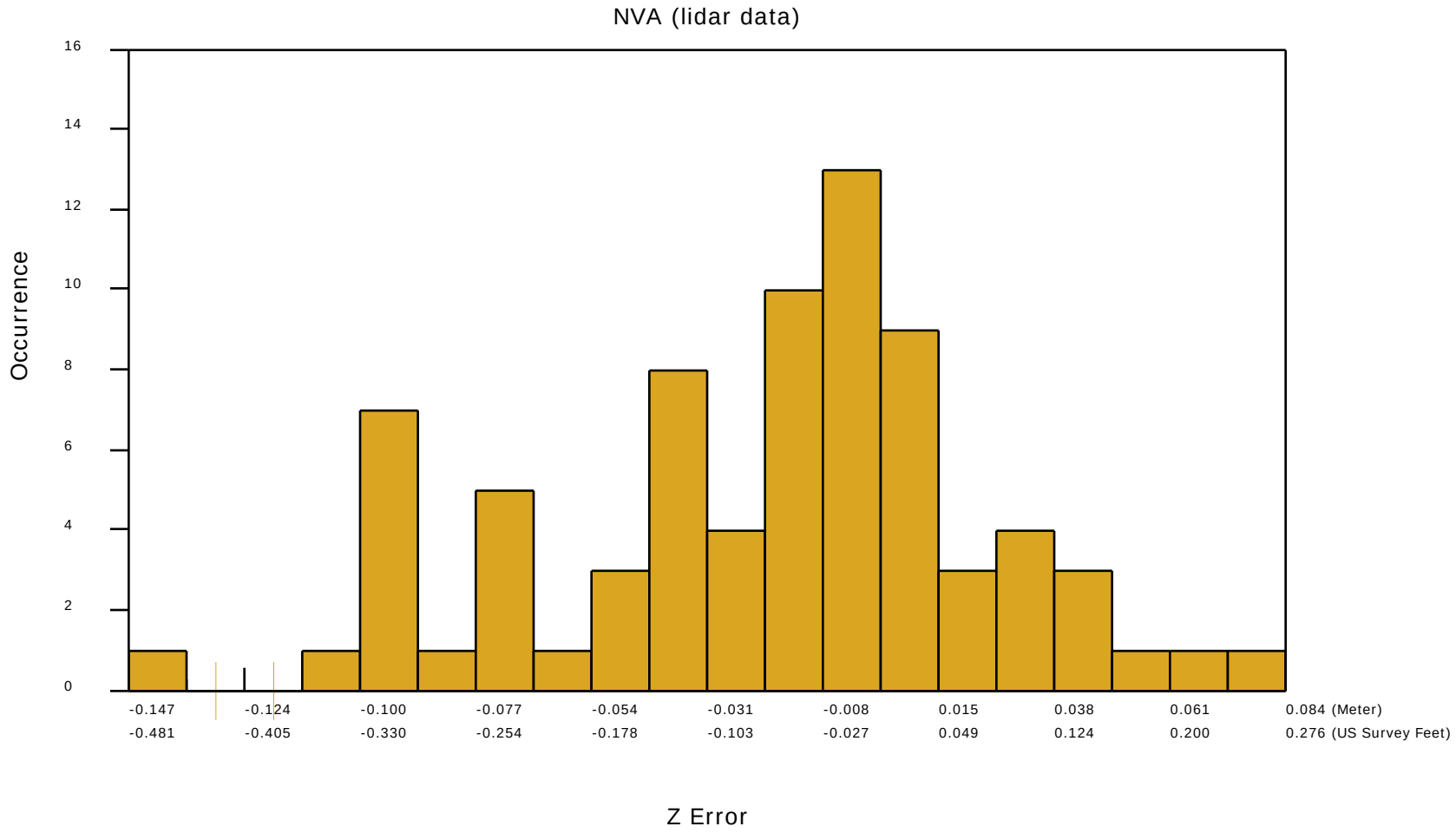
This data set was tested to meet ASPRS Positional Accuracy Standard for Digital Geospatial Data (2014) for a 10-cm RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be RMSEz = 4.9cm, equating to +/- 9.6cm at the 95% confidence level. Actual VVA accuracy was found to be +/- 19.1cm at the 95th percentile.

[1] This value is calculated from TIN-based testing of the lidar point cloud data.

[2] This value is calculated from RAM-based grid testing of the lidar data. The grid cells are sized according to the Quality Level selected, and are defined in the USGS NGP Lidar Base Specification Version 1.3 (page 24, Table 6).

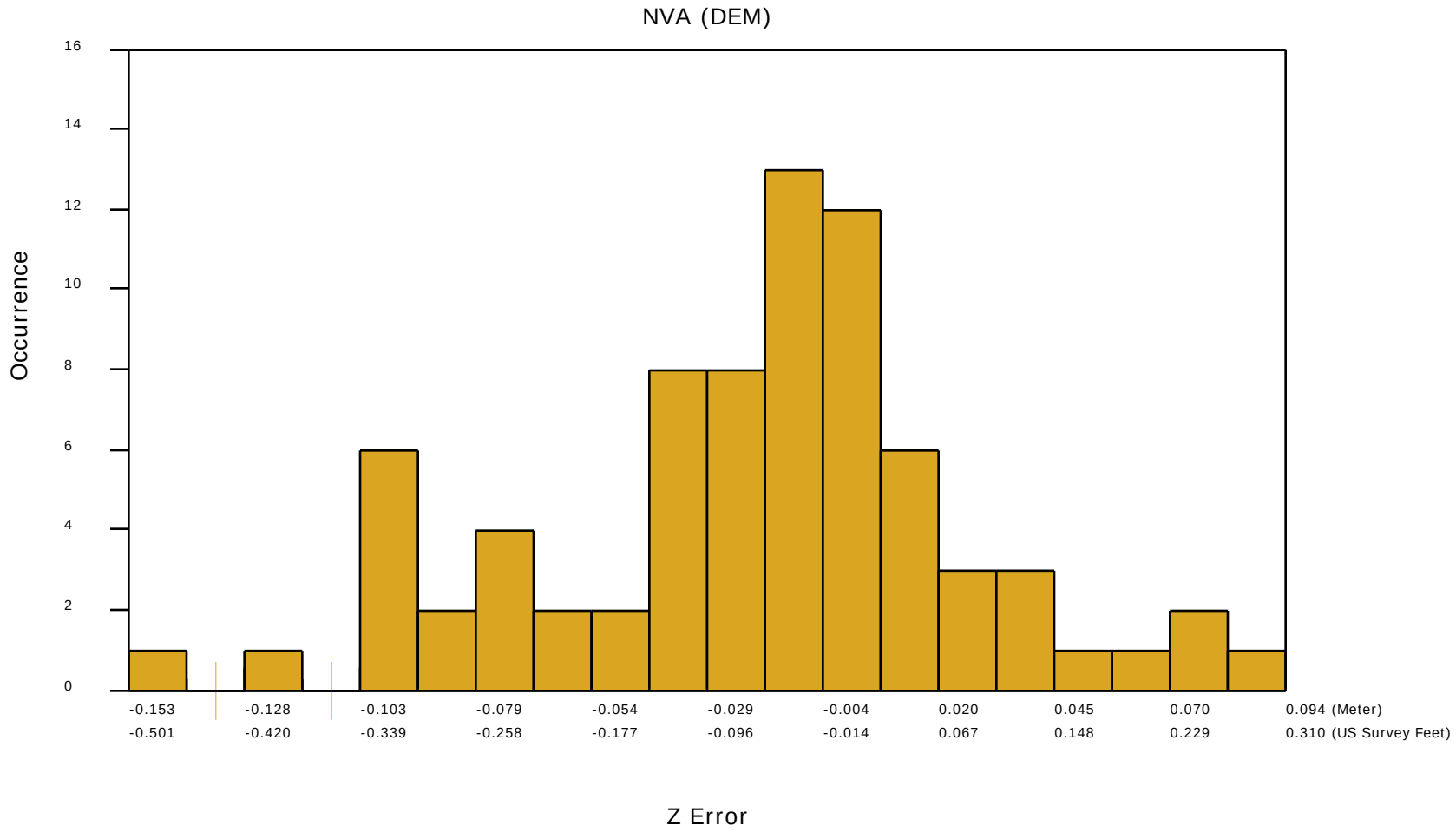
DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a frequency distribution chart of the non-vegetated vertical accuracy (NVA) of the lidar point cloud data measured against surveyed ground check points.



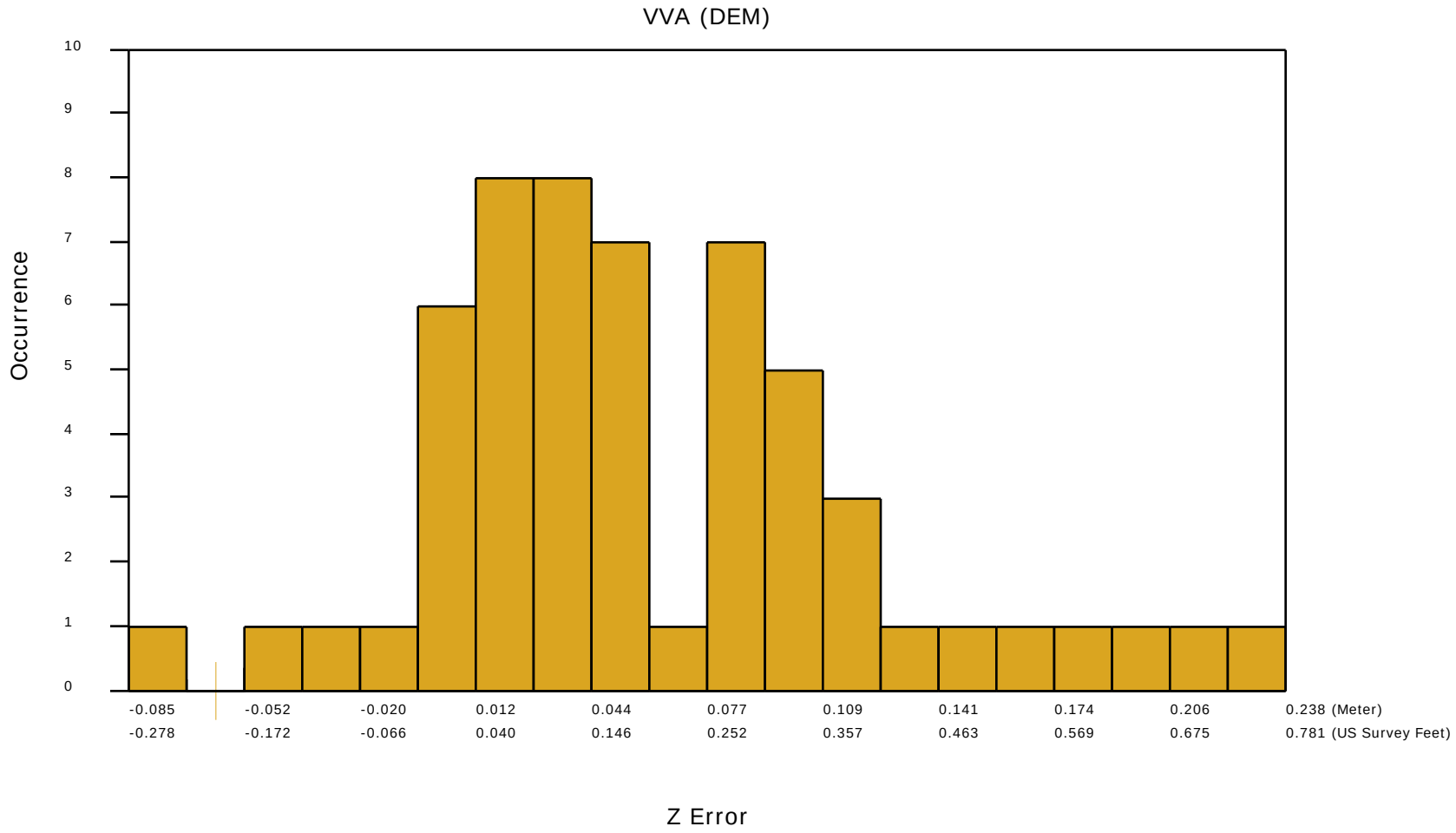
DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a frequency distribution chart of the non-vegetated vertical accuracy (NVA) of the DEM data measured against surveyed ground check points.



DPH-11 Report on Absolute Vertical Accuracy - continued

The purpose of this section is to show a frequency distribution chart of the vegetated vertical accuracy (VVA) of the DEM data measured against surveyed ground check points.



DPH-12 Report on Use of the LAS Withheld Flag

The USGS Lidar Base Specification Version 1.3 states: "Outliers, blunders, geometrically unreliable points near the extreme edge of the swath, and any other points the data producer deems unusable are to be identified using the withheld bit flag, as defined in LAS specification version 1.4-R13 (ASPRS, 2011). The withheld bit flag is primarily used to denote points identified during preprocessing or through automated postprocessing routines as geometric blunders. Noise points subsequently identified during manual classification and quality assurance/quality control (QA/QC) are typically assigned the appropriate standard LAS classification values for noise–class 7 is used for low noise and class 18 is used for high noise. Noise classes are primarily used to denote points that are valid but not earth-bound (for example, birds) or spurious (for example, artificially induced deviations in elevation at or near land/water interfaces)."

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar data files.

Total Withheld points (all classes, all files)	28859127

DPH-13 Report on Use of the LAS Overlap Flag

The USGS Lidar Base Specification Version 1.3 states: "The LAS specification version 1.4-R13 (ASPRS, 2011) includes a new overlap flag. Although strictly speaking, the term "overlap" would mean all lidar points lying within any overlapping areas of two or more swaths, the overlap bit flag is intended to identify overage points, which are only a subset of overlap points. For more information on the difference between overlap and overage, refer to Figures 4–5 (at the back of the report) and the "Glossary" section. Identification of overage points allows their simple exclusion from subsequent processes where the increased density and elevation variability they introduce is unwanted (that is, DEM generation). For some years, overage points were commonly identified using class 12, precluding other valuable classification (for example, bare-earth, water). The overlap bit flag provides a discrete method to identify overage points while preserving the ability to classify the points in the normal way. Overage points shall be identified using the LAS overlap bit flag in all point data deliverables."

The purpose of this section is to list the presence and quantities of points flagged as Overlap for all lidar data files.

Total Overlap points (all classes, all files)	14224542736

DPH-14 Report on Point Classification

The USGS Lidar Base Specification Version 1.3 states: "The minimum classification scheme required for lidar data is listed in Table 5. Additional classes may be required on specific projects. The following requirements apply to point classification: (1) All points not identified as withheld shall be properly classified. (2) No points in the classified LAS deliverable may remain assigned to class 0. Model key points, if calculated, shall be identified using the key point bit flag as defined in LAS specification version 1.4–R13 (ASPRS, 2011). Model key points may, in addition, be identified using class 8 at the discretion of the data producer. No classification code or value may be used to identify overage (overlap) points. All overage (overlap) points shall be identified using the overlap bit flag, as defined in LAS specification version 1.4–R13 (ASPRS, 2011)."

Table 5. Minimum light detection and ranging data classification scheme.

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*)

The purpose of this section is to report total numbers of points for each class within the LAS files.

DPH-14 Report on Point Classification - Class Totals

The purpose of this section is to list the number of points in each classification so that the user can determine if any points exist in unintended classes.

Class	Total	MKP	WH	Class	Total	MKP	WH	Class	Total	MKP	WH	Class	Total	MKP	WH
0	00	00	00	64	00	00	00	128	00	00	00	192	00	00	00
1	3,397,551,667	00	28,859,127	65	00	00	00	129	00	00	00	193	00	00	00
2	38,472,438,671	00	00	66	00	00	00	130	00	00	00	194	00	00	00
3	00	00	00	67	00	00	00	131	00	00	00	195	00	00	00
4	00	00	00	68	00	00	00	132	00	00	00	196	00	00	00
5	00	00	00	69	00	00	00	133	00	00	00	197	00	00	00
6	00	00	00	70	00	00	00	134	00	00	00	198	00	00	00
7	2,362,951	00	00	71	00	00	00	135	00	00	00	199	00	00	00
8	00	00	00	72	00	00	00	136	00	00	00	200	00	00	00
9	710,549	00	00	73	00	00	00	137	00	00	00	201	00	00	00
10	00	00	00	74	00	00	00	138	00	00	00	202	00	00	00
11	00	00	00	75	00	00	00	139	00	00	00	203	00	00	00
12	00	00	00	76	00	00	00	140	00	00	00	204	00	00	00
13	00	00	00	77	00	00	00	141	00	00	00	205	00	00	00
14	00	00	00	78	00	00	00	142	00	00	00	206	00	00	00
15	00	00	00	79	00	00	00	143	00	00	00	207	00	00	00
16	00	00	00	80	00	00	00	144	00	00	00	208	00	00	00
17	147,075	00	00	81	00	00	00	145	00	00	00	209	00	00	00
18	218,173	00	00	82	00	00	00	146	00	00	00	210	00	00	00
19	00	00	00	83	00	00	00	147	00	00	00	211	00	00	00
20	35,385	00	00	84	00	00	00	148	00	00	00	212	00	00	00
21	00	00	00	85	00	00	00	149	00	00	00	213	00	00	00
22	00	00	00	86	00	00	00	150	00	00	00	214	00	00	00
23	00	00	00	87	00	00	00	151	00	00	00	215	00	00	00
24	00	00	00	88	00	00	00	152	00	00	00	216	00	00	00
25	00	00	00	89	00	00	00	153	00	00	00	217	00	00	00
26	00	00	00	90	00	00	00	154	00	00	00	218	00	00	00
27	00	00	00	91	00	00	00	155	00	00	00	219	00	00	00
28	00	00	00	92	00	00	00	156	00	00	00	220	00	00	00
29	00	00	00	93	00	00	00	157	00	00	00	221	00	00	00
30	00	00	00	94	00	00	00	158	00	00	00	222	00	00	00
31	00	00	00	95	00	00	00	159	00	00	00	223	00	00	00
32	00	00	00	96	00	00	00	160	00	00	00	224	00	00	00
33	00	00	00	97	00	00	00	161	00	00	00	225	00	00	00
34	00	00	00	98	00	00	00	162	00	00	00	226	00	00	00
35	00	00	00	99	00	00	00	163	00	00	00	227	00	00	00
36	00	00	00	100	00	00	00	164	00	00	00	228	00	00	00
37	00	00	00	101	00	00	00	165	00	00	00	229	00	00	00
38	00	00	00	102	00	00	00	166	00	00	00	230	00	00	00
39	00	00	00	103	00	00	00	167	00	00	00	231	00	00	00
40	00	00	00	104	00	00	00	168	00	00	00	232	00	00	00
41	00	00	00	105	00	00	00	169	00	00	00	233	00	00	00
42	00	00	00	106	00	00	00	170	00	00	00	234	00	00	00
43	00	00	00	107	00	00	00	171	00	00	00	235	00	00	00
44	00	00	00	108	00	00	00	172	00	00	00	236	00	00	00
45	00	00	00	109	00	00	00	173	00	00	00	237	00	00	00
46	00	00	00	110	00	00	00	174	00	00	00	238	00	00	00
47	00	00	00	111	00	00	00	175	00	00	00	239	00	00	00
48	00	00	00	112	00	00	00	176	00	00	00	240	00	00	00
49	00	00	00	113	00	00	00	177	00	00	00	241	00	00	00
50	00	00	00	114	00	00	00	178	00	00	00	242	00	00	00
51	00	00	00	115	00	00	00	179	00	00	00	243	00	00	00
52	00	00	00	116	00	00	00	180	00	00	00	244	00	00	00
53	00	00	00	117	00	00	00	181	00	00	00	245	00	00	00
54	00	00	00	118	00	00	00	182	00	00	00	246	00	00	00
55	00	00	00	119	00	00	00	183	00	00	00	247	00	00	00
56	00	00	00	120	00	00	00	184	00	00	00	248	00	00	00
57	00	00	00	121	00	00	00	185	00	00	00	249	00	00	00
58	00	00	00	122	00	00	00	186	00	00	00	250	00	00	00
59	00	00	00	123	00	00	00	187	00	00	00	251	00	00	00
60	00	00	00	124	00	00	00	188	00	00	00	252	00	00	00
61	00	00	00	125	00	00	00	189	00	00	00	253	00	00	00
62	00	00	00	126	00	00	00	190	00	00	00	254	00	00	00
63	00	00	00	127	00	00	00	191	00	00	00	255	00	00	00

Bold – point counts in 'Minimum classified point cloud classification scheme' (see table on previous page)

– point counts in Classes beyond the minimum

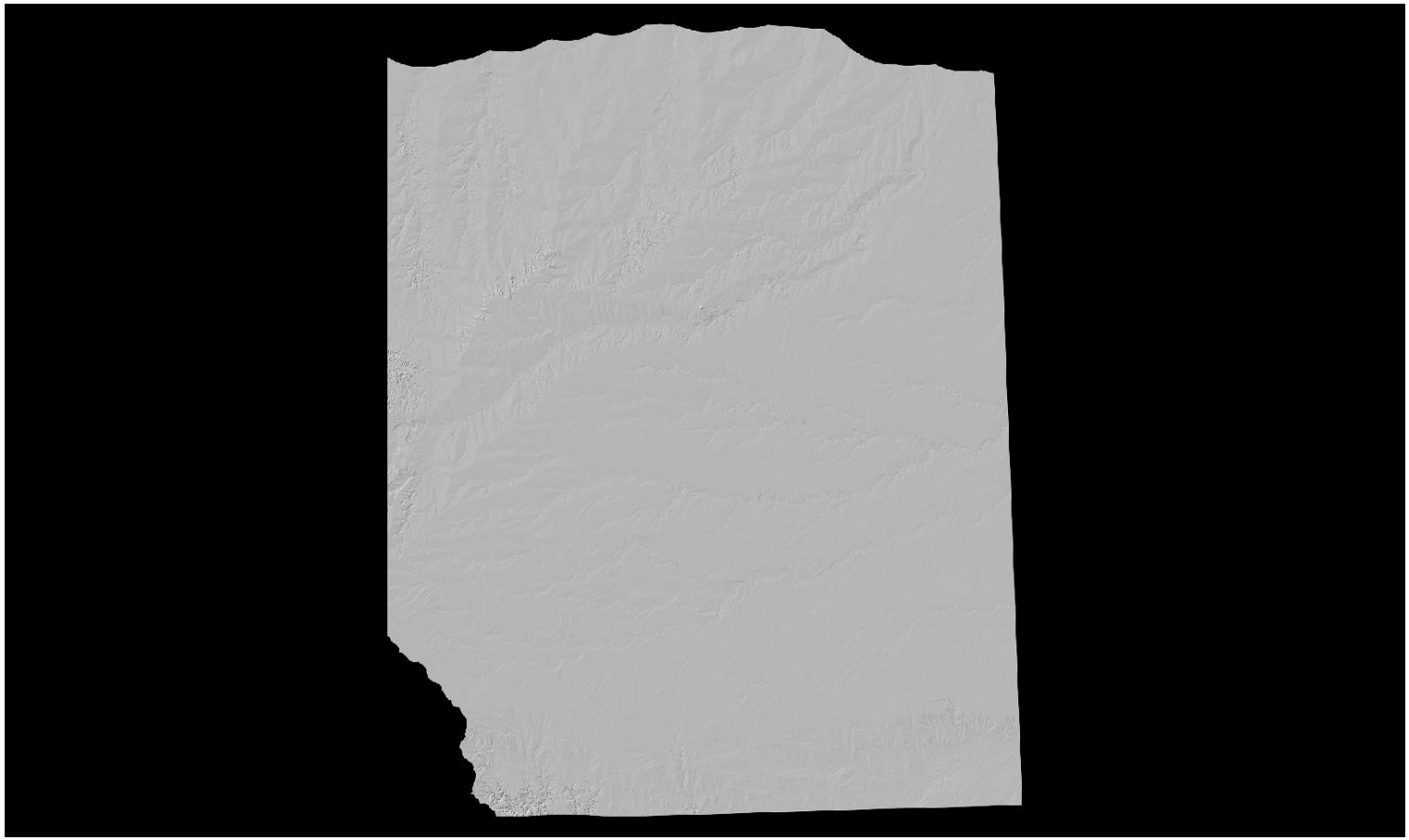
– disallowed point counts per USGS spec

– not all Class 0 points flagged as Withheld

DPH-15 Report on Classification Consistency

The USGS Lidar Base Specification Version 1.3 states: "Point classification is to be consistent across the entire project. Noticeable variations in the character, texture, or quality of the classification between tiles, swaths, lifts, or other non-natural divisions will be cause for rejection of the entire deliverable."

The purpose of this section is to show the bare earth surface hillshade product for classification consistency inspection.



DPH-16 Report on Tiles

The USGS Lidar Base Specification Version 1.3 states: "A single nonoverlapping project tiling scheme will be established and agreed upon by the data producer and the USGS–NGP before collection. This scheme will be used for all tiled deliverables: The tiling scheme shall use the same coordinate reference system and units as the data. The tile size shall be an integer multiple of the cell size for raster deliverables. The tiles shall be indexed in x and y to an integer multiple of the x and y dimensions of the tile. The tiled deliverables shall edge-match seamlessly and without gaps. The tiled deliverables shall conform to the project tiling scheme without added overlap."

The purpose of this section is to report on the unallowed presence of overlap in the project tile scheme.

Units: US Survey Feet

The following lists tiles that are overlapped.

Tile	Approx. Width	Approx. Height	Overlap

NONE