CWCB_Block5_2_Areas

Summary USGS National Geospatial Program Lidar Base Specification Version 1.2 Report

Quality level tested: QL2

Report generated on 2/27/2019

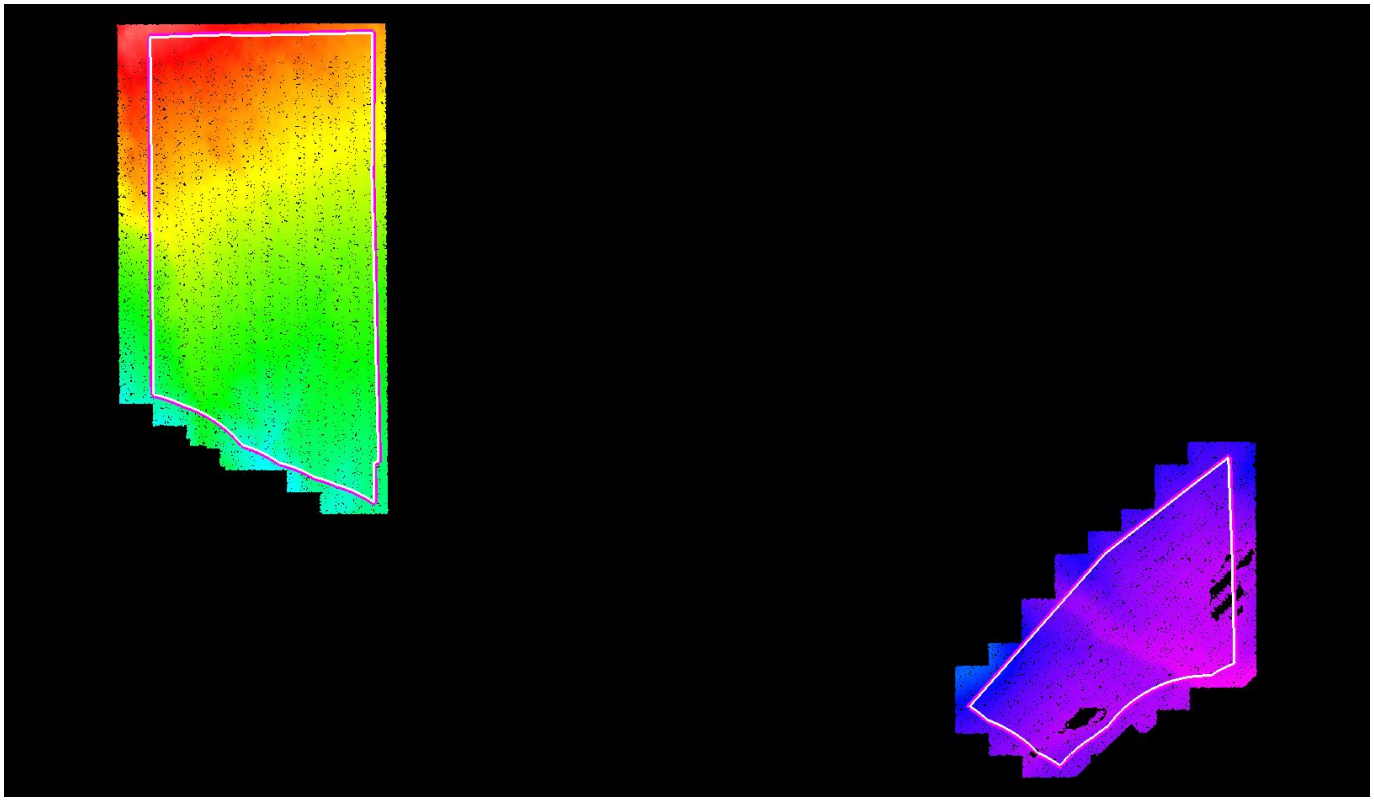
This document reports on compliance with the USGS National Geospatial Program Lidar Base Specification Version 1.2. The complete specification, which also contains a list of abbreviations, acronyms, and a glossary of related terms, can be found here.

C-1 Report on Collection Area (Swath Data)

The USGS Lidar Base Specification Version 1.2 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. In order for all products to be consistent to the edge of the DPA, all products shall be generated to the full extent of the BPA. Because data and products are generated for the complete BPA, they shall also be delivered to the customer."

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

Data Source - D:\00_CWCB\Block_5\Swath
Result Path - D:\00_CWCB\Block_5\Block_5_QC\C_1\CollectionArea_Swath.jpg

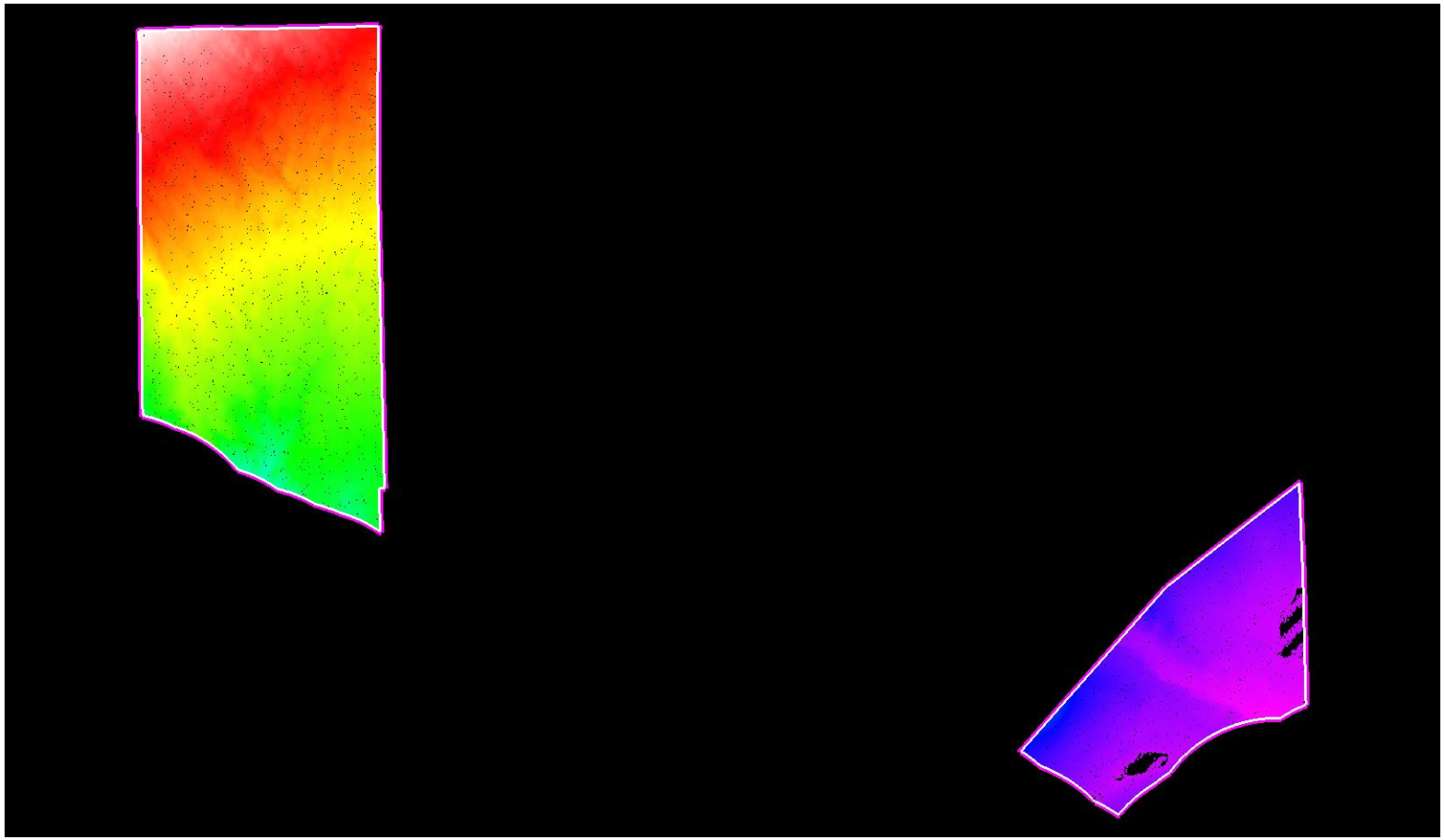


White polygon is defined project area (DPA) boundary
Purple polygon is buffered project area (BPA) boundary

C-1 Report on Collection Area (Tiled Data)

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

Data Source - D:\00_CWCB\Block_5\Client_LAS
Result Path - D:\00_CWCB\Block_5\Block_5_QC\C_1\CollectionArea_Tiles.jpg



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

C-2 Report on Multiple Discrete Returns (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "Deriving and delivering multiple discrete returns is required in all data collection efforts. Data collection shall be capable of at least three returns per pulse. Full waveform collection is acceptable and will be 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 swath data. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

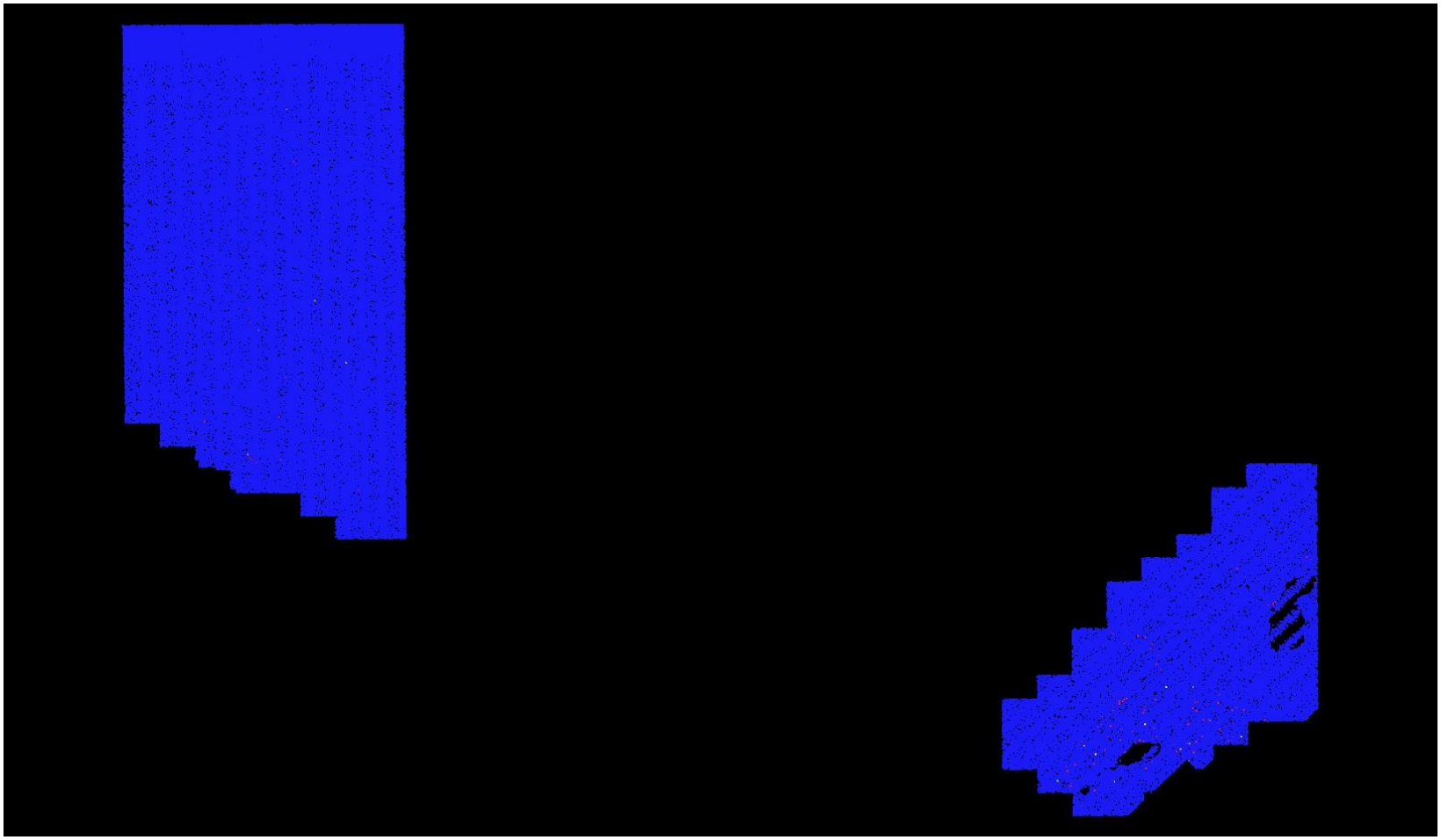
Boresighted Files - D:\00_CWCB\Block_5\Swath

File	First return	Second return	Third return	Other returns	Total points
Total	2,579,833,897	2,996,195	367,321	15,262	2,583,212,675

C-2 Report on Multiple Discrete Returns (Swath Data) - All Returns

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

Data Source - D:\00_CWCB\Block_5\Swath
Result Path - D:\00_CWCB\Block_5\Block_5_QC\C_2\ColorByReturns_Boresighted.jpg



C-2 Report on Multiple Discrete Returns (Tiled Data)

The USGS Lidar Base Specification Version 1.2 states: "Deriving and delivering multiple discrete returns is required in all data collection efforts. Data collection shall be capable of at least three returns per pulse. Full waveform collection is acceptable and will be 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 tiled data. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

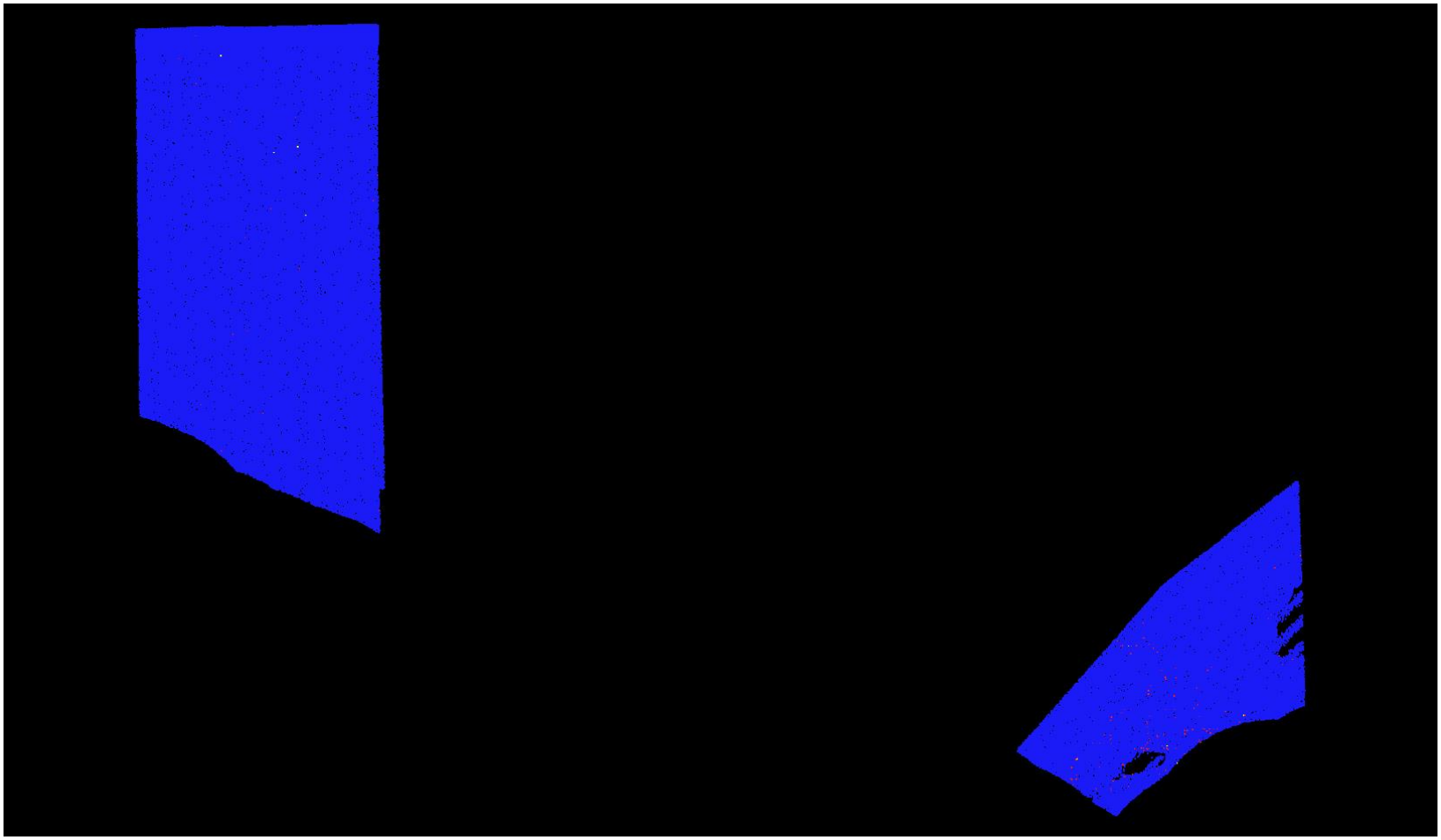
Classified Files - D:\00_CWCB\Block_5\Client_LAS

File	First return	Second return	Third return	Other returns	Total points
Total	1,940,605,872	2,280,563	280,636	11,584	1,943,178,655

C-2 Report on Multiple Discrete Returns (Tiled Data) - All Returns

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

Data Source - D:\00_CWCB\Block_5\Client_LAS
Result Path - D:\00_CWCB\Block_5\Block_5_QC\C_2\ColorByReturns_Classified.jpg



C-3 Report on Intensity Values (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "Intensity values are required for each multiple discrete return. The values recorded in the LAS files shall be normalized to 16 bit, as described in the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011)."

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

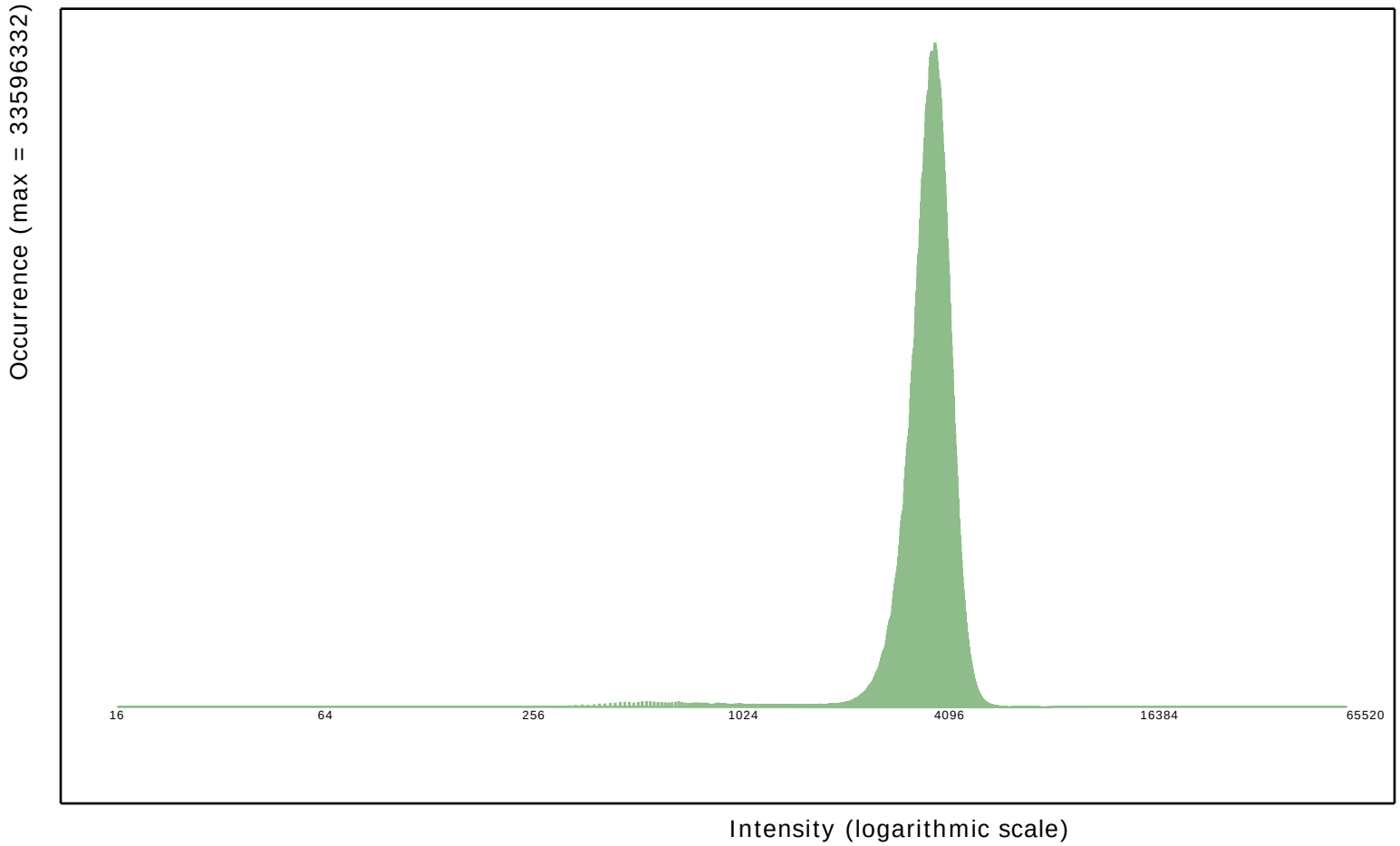
Boresighted Files - D:\00_CWCB\Block_5\Swath

File	Minimum	Maximum	Mean	Median	Mode
Overall Statistics	16	65,520	4,060	4,080	4,128

C-3 Report on Intensity Values (Swath Data) - continued

The purpose of this section is to show a frequency distribution chart of intensities throughout all of the lidar swath files. It is important to understand that 8-bit intensity lidar systems have a valid intensity range from 0-255, and 12-bit intensity lidar systems have a valid intensity range from 0-4095.

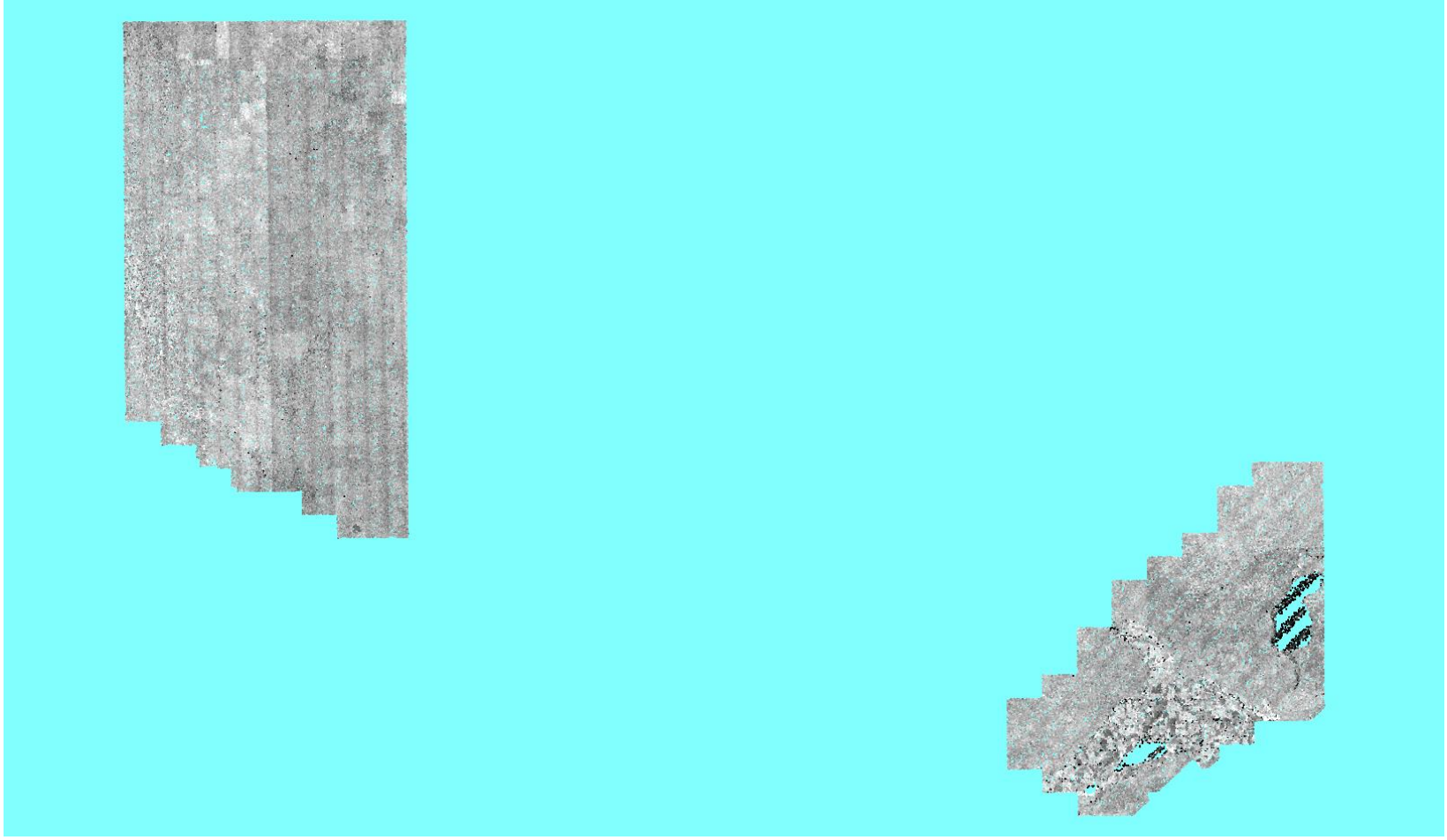
Data Source - D:\00_CWCB\Block_5\Swath



C-3 Report on Intensity Values (Swath Data) - continued

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

Data Source - D:\00_CWCB\Block_5\Swath
Result Path - D:\00_CWCB\Block_5\Block_5_QC\C_3\ColorByIntensity_Boresighted.jpg



C-3 Report on Intensity Values (Tiled Data)

The USGS Lidar Base Specification Version 1.2 states: "Intensity values are required for each multiple discrete return. The values recorded in the LAS files shall be normalized to 16 bit, as described in the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011)."

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

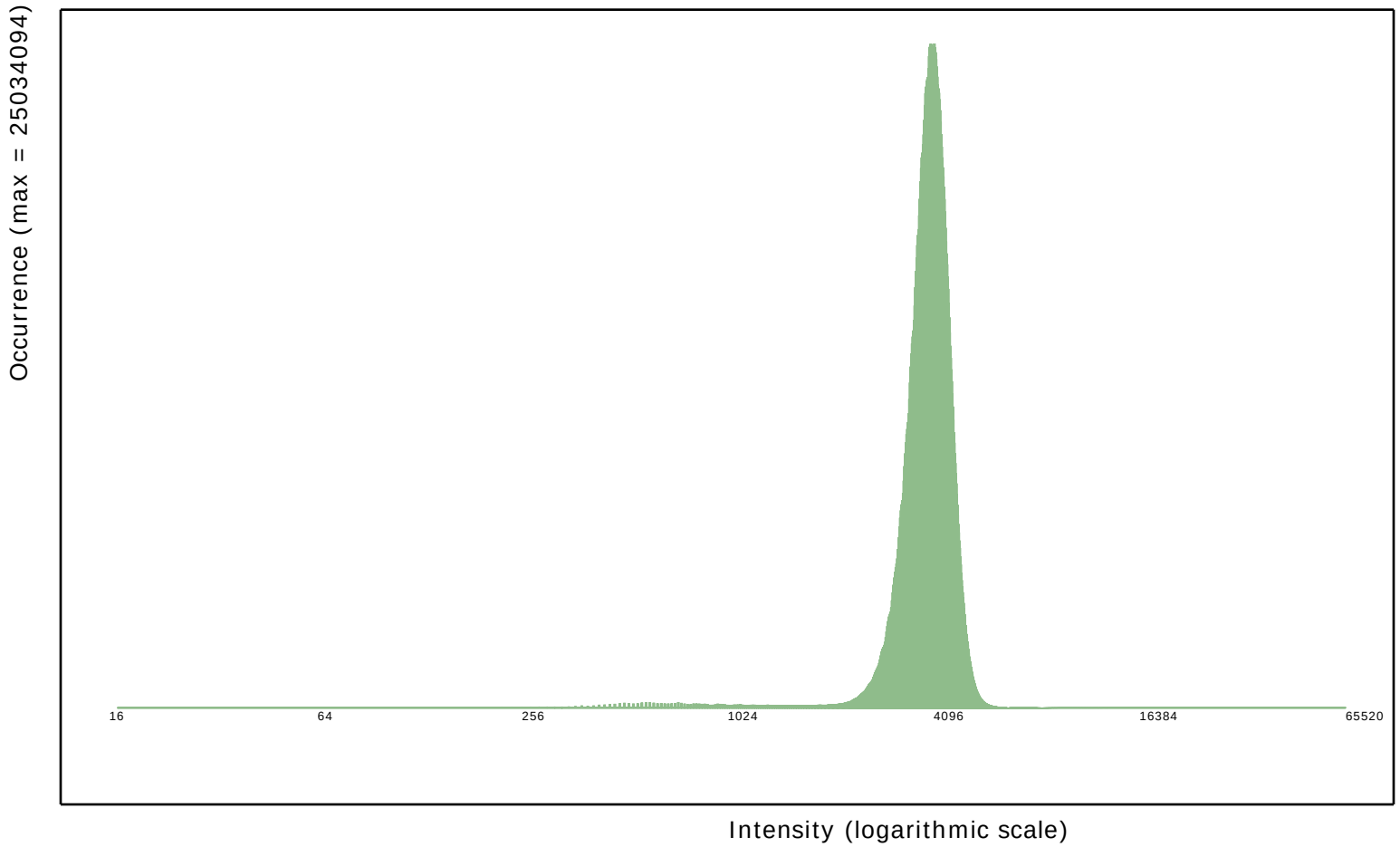
Classified Files - D:\00_CWCB\Block_5\Client_LAS

File	Minimum	Maximum	Mean	Median	Mode
Overall Statistics	16	65,520	4,044	4,064	4,128

C-3 Report on Intensity Values (Tiled Data) - continued

The purpose of this section is to show a frequency distribution chart of intensities throughout all of the lidar tiled files. It is important to understand that 8-bit intensity lidar systems have a valid intensity range from 0-255, and 12-bit intensity lidar systems have a valid intensity range from 0-4095.

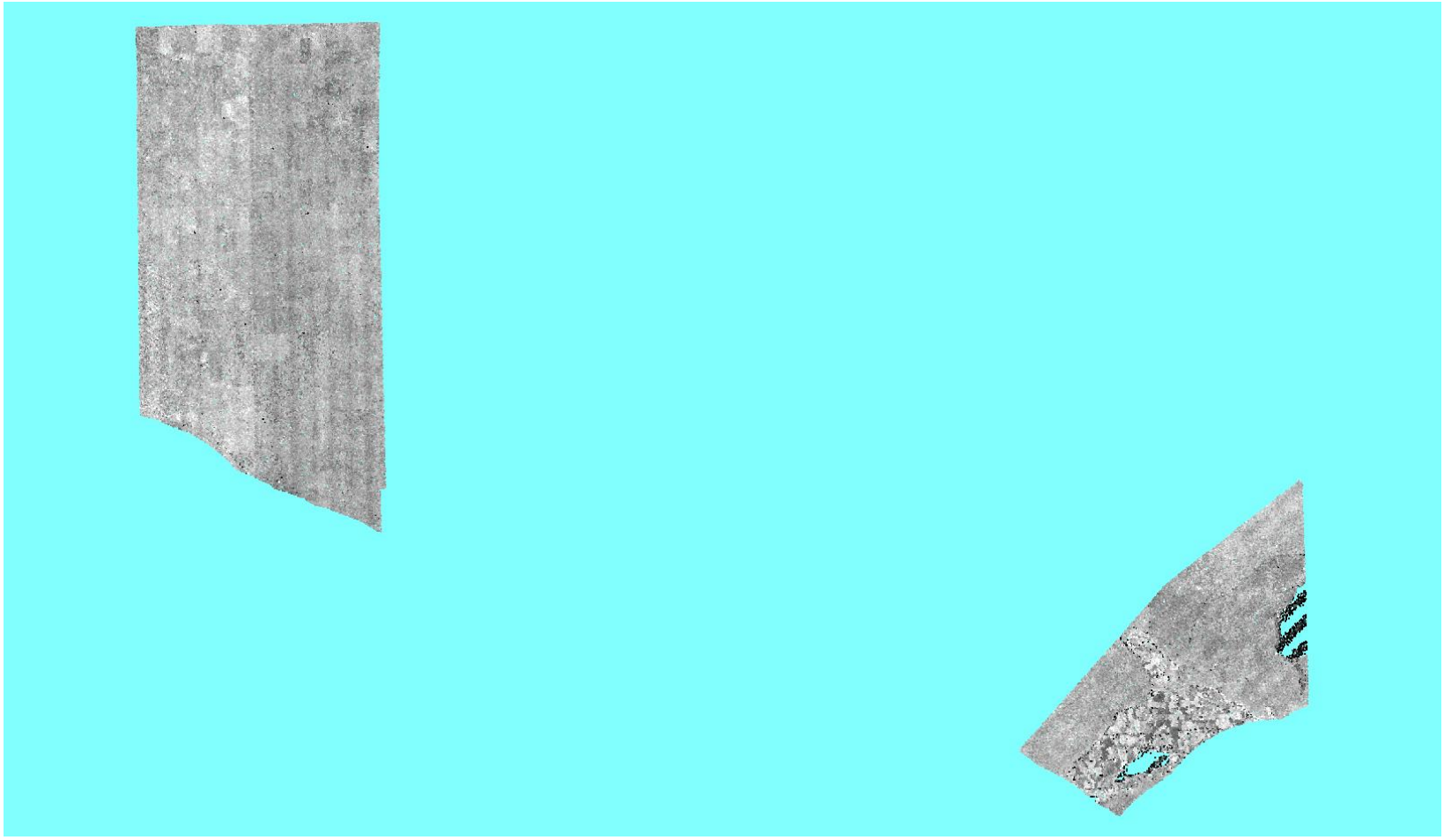
Data Source - D:\00_CWCB\Block_5\Client_LAS



C-3 Report on Intensity Values (Tiled Data) - continued

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

Data Source - D:\00_CWCB\Block_5\Client_LAS
Result Path - D:\00_CWCB\Block_5\Block_5_QC\C_3\ColorByIntensity_Classified.jpg



C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification Version 1.2 states: "Assessment and reporting of the NPS is made against single swath, single instrument, first return only data, including only the geometrically usable part of the swath (typically the center 95 percent) and excluding acceptable data voids. Higher net densities of lidar point measurements are being achieved more often by using multiple coverages, creating a need for a separate new term to prevent confusion 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 table "Aggregate nominal pulse spacing and density, Quality Level 0–Quality Level 3" (table 1) lists the required ANPS and ANPD by QL. 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, Quality Level 0–Quality Level 3.

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

Quality Level (QL)	Aggregate nominal pulse spacing (ANPS) (m)	Aggregate nominal pulse density (ANPD) (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 swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported.

Boresighted Files - D:\00_CWCB\Block_5\Swath

Quality level tested: QL2

Units: US Survey Feet

File	Number of First Returns	Area of Swath	Point Density	NPS
Average			2.476/0.230 pp Square Meter/ pp Square US Survey Foot	0.635/2.083 Meter/ US Survey Feet

C-4 Report on Nominal Pulse Spacing (NPS) - continued

Boundary ID	Number of First Returns	Area of Swath	Point Density	NPS
Aggregate	1,894,393,346	6,349,962,808	3.208/0.298 pp Square Meter/ pp Square US Survey Foot	0.558/1.831 Meter/ US Survey Feet

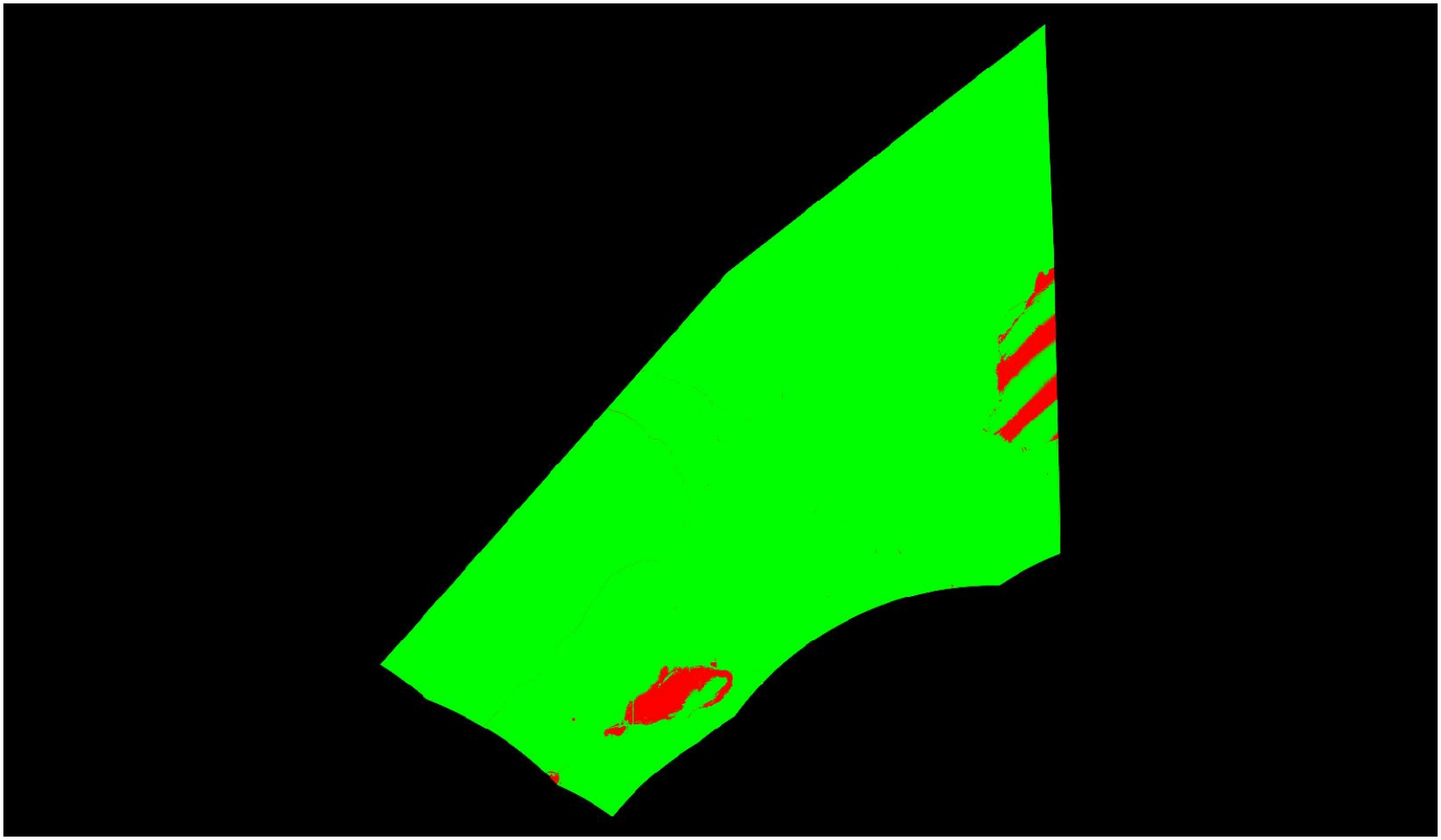
C-5.1 Report on Data Voids

The USGS Lidar Base Specification Version 1.2 states: "Data voids, in lidar, are gaps in the point cloud coverage, caused by surface absorbance or refraction of the lidar pulse (or both absorbance and refraction simultaneously), 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(ANPS2), 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 water bodies.
(2) where caused by areas of low near infrared (NIR) reflectivity such as asphalt or composition roofing, or
(3) 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.

Data Source - D:\00_CWCB\Block_5\Swath
D:\00_CWCB\Block_5\Block_5_QC\C_5\Area1\Boresighted_DataVoids_SingleFile.jp2

C-5.1 Report on Data Voids



Cell size: 9.318 US Survey Feet

Green: Cells containing at least 1 first return lidar point (number of cells = 20,819,479)
Red: Cells containing no first return lidar points (number of cells = 578,194)
Background Color: Null data

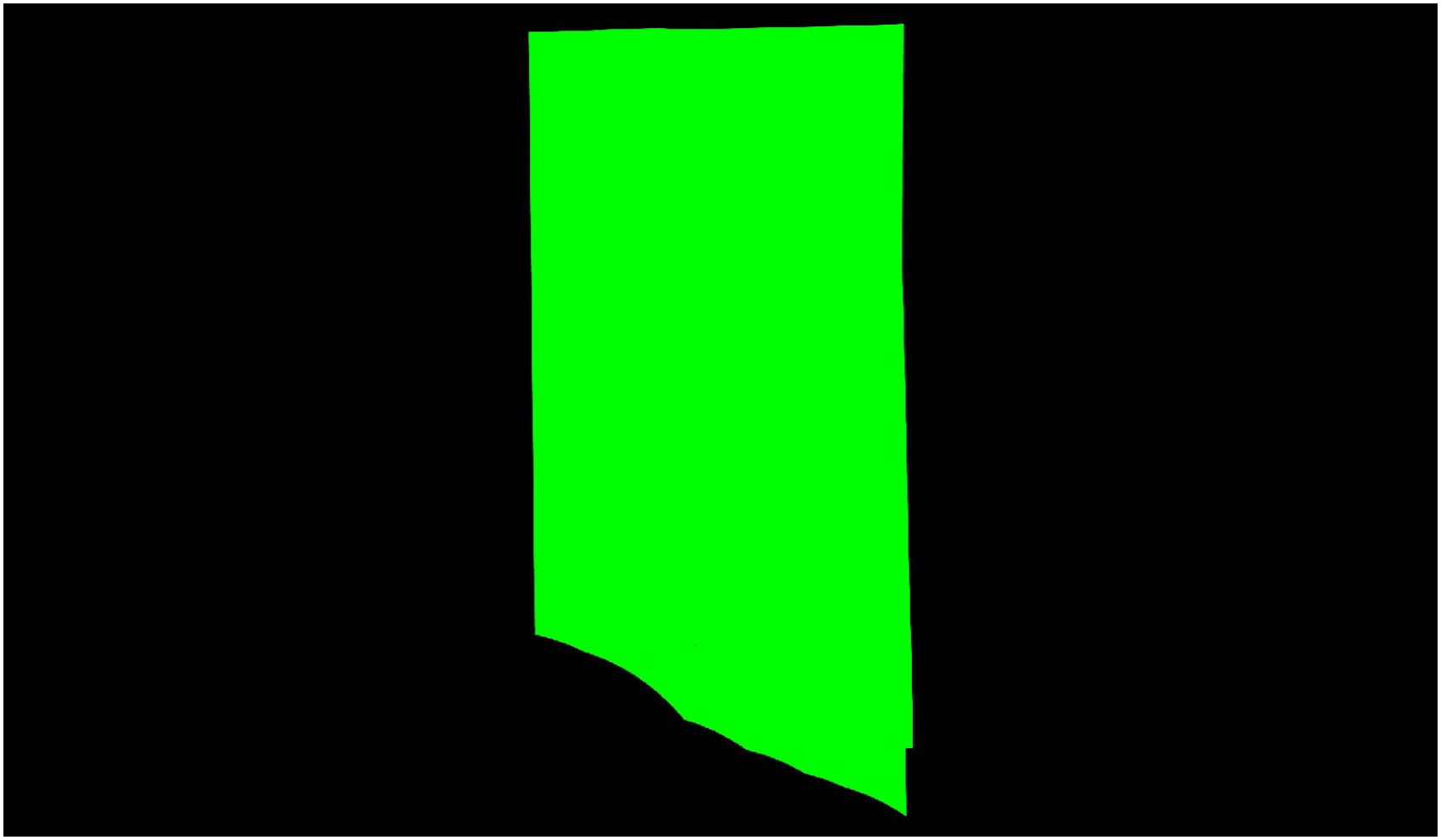
C-5.2 Report on Data Voids

The USGS Lidar Base Specification Version 1.2 states: "Data voids, in lidar, are gaps in the point cloud coverage, caused by surface absorbance or refraction of the lidar pulse (or both absorbance and refraction simultaneously), 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(ANPS2), 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 water bodies.
(2) where caused by areas of low near infrared (NIR) reflectivity such as asphalt or composition roofing, or
(3) 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.

Data Source - D:\00_CWCB\Block_5\Swath
D:\00_CWCB\Block_5\Block_5_QC\C_5\Area2\Boresighted_DataVoids_SingleFile.jp2

C-5.2 Report on Data Voids



Cell size: 9.318 US Survey Feet

- Green: Cells containing at least 1 first return lidar point (number of cells = 51,769,257)
- Red: Cells containing no first return lidar points (number of cells = 233)
- Background Color: Null data

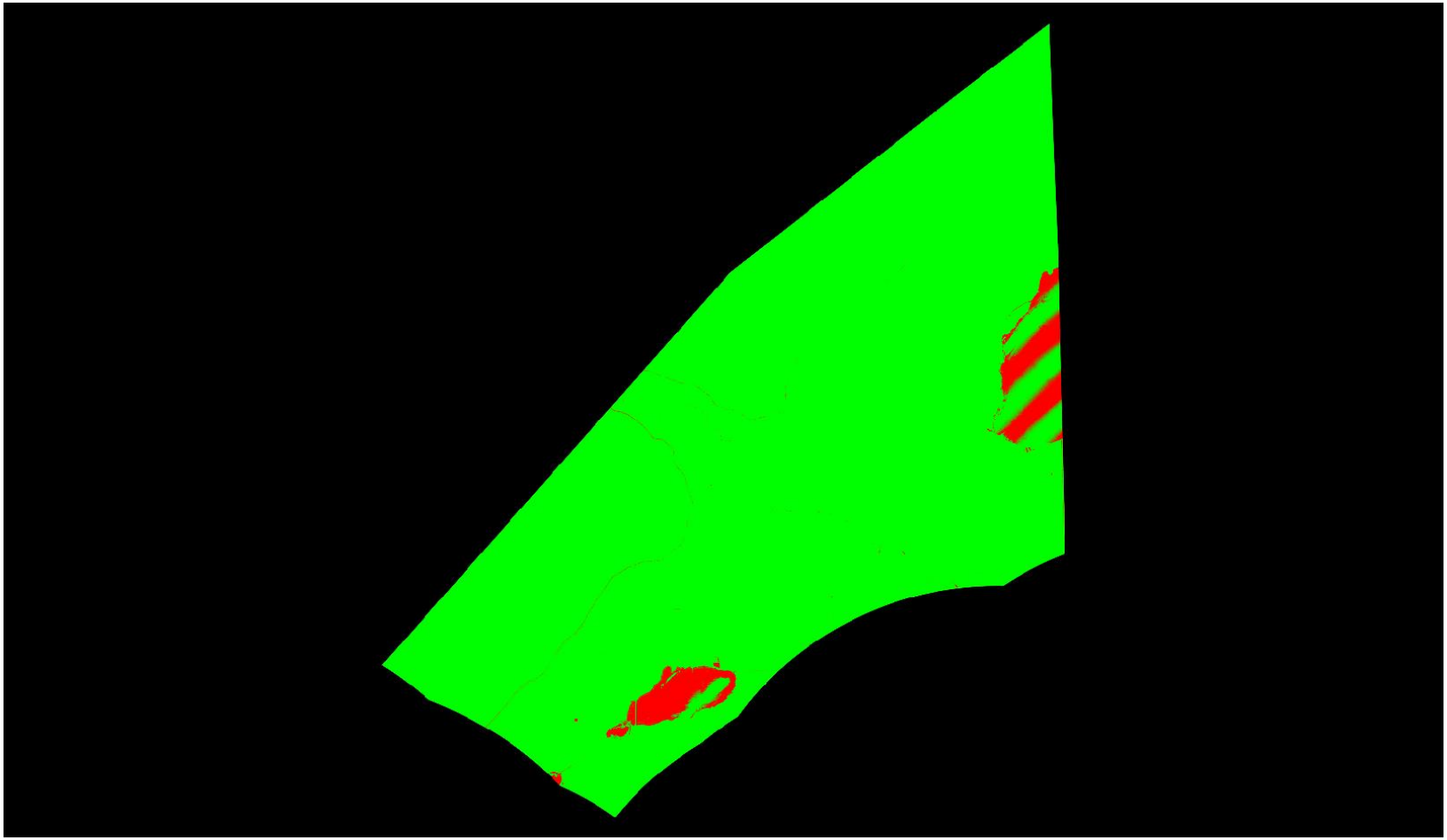
C-6.1.1 Report on Spatial Distribution and Regularity

The USGS Lidar Base Specification Version 1.2 states: "The spatial distribution of geometrically usable points will be uniform and regular. Although lidar instruments do not produce regularly gridded points, collections shall be planned and executed to produce an aggregate first return point cloud that approaches a regular lattice of points, rather than a collection of widely spaced, high-density profiles of the terrain. The regularity of the point pattern and density throughout the dataset is important and will be assessed by using the following steps:
(1) Generating a density grid from the data with cell sizes equal to twice the design ANPS and a radius equal to the design ANPS.
(2) Ensuring at least 90 percent of the cells in the grid contain at least one lidar point.
(3) Using individual (single) swaths, with only the first return points located within the geometrically usable center part (typically 95 percent) of each swath.
(4) Excluding acceptable data voids previously identified in this specification.
The process described in this section relates only to regular and uniform point distribution. The process does not relate to, nor can it be used for, the assessment of NPS or ANPS. The USGS–NGP may allow lower passing thresholds for this requirement in areas of substantial relief where maintaining a regular and uniform point distribution is impractical."

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), 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 lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications.

Data Source - D:\00_CWCB\Block_5\Swath
D:\00_CWCB\Block_5\Block_5_QC\C_6\Area1\Boresighted_SpatialDistribution_SingleFile.jp2

C-6.1.1 Report on Spatial Distribution and Regularity - continued



Cell size: 4.659 US Survey Feet

Green: Cells containing at least one first return lidar point (number of cells = 82,905,968)
Red: Cells not containing at least one first return lidar point (number of cells = 2,664,707)
Background Color: Null data

Percentage of cells in the grid that contain at least one first return lidar point = 96.89% (Requirement is typically 90%)
See JPG2000 file for full resolution results

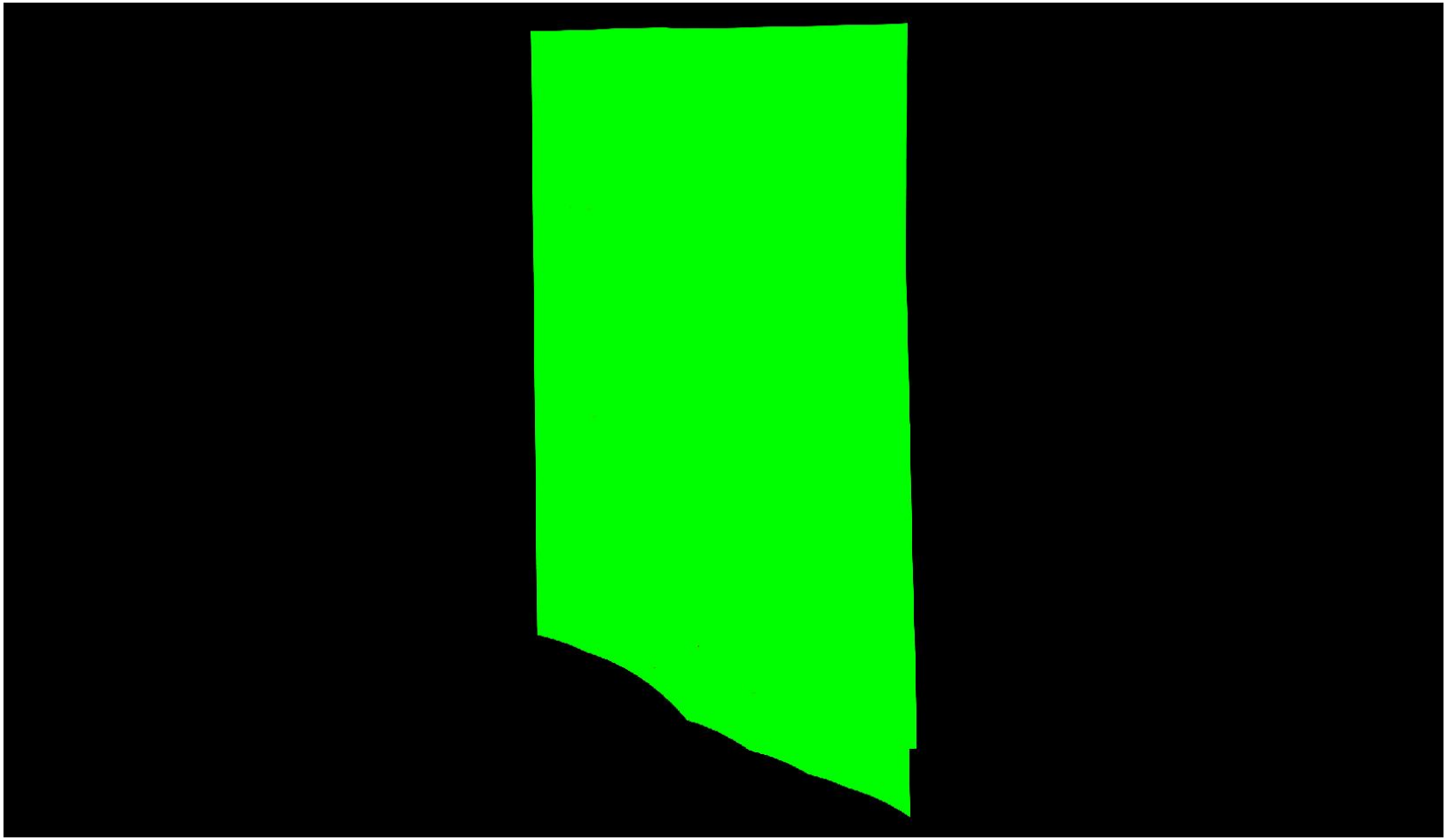
C-6.1.2 Report on Spatial Distribution and Regularity

The USGS Lidar Base Specification Version 1.2 states: "The spatial distribution of geometrically usable points will be uniform and regular. Although lidar instruments do not produce regularly gridded points, collections shall be planned and executed to produce an aggregate first return point cloud that approaches a regular lattice of points, rather than a collection of widely spaced, high-density profiles of the terrain. The regularity of the point pattern and density throughout the dataset is important and will be assessed by using the following steps:
(1) Generating a density grid from the data with cell sizes equal to twice the design ANPS and a radius equal to the design ANPS.
(2) Ensuring at least 90 percent of the cells in the grid contain at least one lidar point.
(3) Using individual (single) swaths, with only the first return points located within the geometrically usable center part (typically 95 percent) of each swath.
(4) Excluding acceptable data voids previously identified in this specification.
The process described in this section relates only to regular and uniform point distribution. The process does not relate to, nor can it be used for, the assessment of NPS or ANPS. The USGS–NGP may allow lower passing thresholds for this requirement in areas of substantial relief where maintaining a regular and uniform point distribution is impractical."

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), 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 lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications.

Data Source - D:\00_CWCB\Block_5\Swath
D:\00_CWCB\Block_5\Block_5_QC\C_6\Area2\Boresighted_SpatialDistribution_SingleFile.jp2

C-6.1.2 Report on Spatial Distribution and Regularity - continued



Cell size: 4.659 US Survey Feet

Green: Cells containing at least one first return lidar point (number of cells = 207,042,652)
Red: Cells not containing at least one first return lidar point (number of cells = 4,808)
Background Color: Null data

Percentage of cells in the grid that contain at least one first return lidar point = 100.00% (Requirement is typically 90%)
See JPG2000 file for full resolution results

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

Swath	Percentage of Cells that Contain >= 1

Pass: 47 files (percentage >= 90%)
Fail: 1 files (percentage < 90%)

C-7 Report on Collection Conditions

The USGS Lidar Base Specification Version 1.2 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 in special cases, 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 are unable to 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: 05/06/2018
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=38.2948343724475+N%2C+103.814696130923+W&ql=station&var=ssm_depth&dy=2018&dm=5&dd=6&dh=9&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-104.258536186165&min_y=38.072330065267&max_x=-103.37085607568&max_y=38.5173386796279&coord_x=-103.814696130923&coord_y=38.2948343724475&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: 05/16/2018
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=38.2948343724475+N%2C+103.814696130923+W&ql=station&var=ssm_depth&dy=2018&dm=5&dd=16&dh=17&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-104.258536186165&min_y=38.072330065267&max_x=-103.37085607568&max_y=38.5173386796279&coord_x=-103.814696130923&coord_y=38.2948343724475&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: 05/17/2018
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=38.2948343724475+N%2C+103.814696130923+W&ql=station&var=ssm_depth&dy=2018&dm=5&dd=17&dh=18&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-104.258536186165&min_y=38.072330065267&max_x=-103.37085607568&max_y=38.5173386796279&coord_x=-103.814696130923&coord_y=38.2948343724475&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: 06/07/2018
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=38.2948343724475+N%2C+103.814696130923+W&ql=station&var=ssm_depth&dy=2018&dm=6&dd=7&dh=13&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-104.258536186165&min_y=38.072330065267&max_x=-103.37085607568&max_y=38.5173386796279&coord_x=-103.814696130923&coord_y=38.2948343724475&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: 06/12/2018
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=38.2948343724475+N%2C+103.814696130923+W&ql=station&var=ssm_depth&dy=2018&dm=6&dd=12&dh=19&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-104.258536186165&min_y=38.072330065267&max_x=-103.37085607568&max_y=38.5173386796279&coord_x=-103.814696130923&coord_y=38.2948343724475&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: 06/13/2018
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=38.2948343724475+N%2C+103.814696130923+W&ql=station&var=ssm_depth&dy=2018&dm=6&dd=13&dh=14&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-104.258536186165&min_y=38.072330065267&max_x=-103.37085607568&max_y=38.5173386796279&coord_x=-103.814696130923&coord_y=38.2948343724475&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: 07/15/2018
http://www.nohrsc.noaa.gov/interactive/html/map.html?mode=pan&extents=us&zoom=&loc=38.2948343724475+N%2C+103.814696130923+W&ql=station&var=ssm_depth&dy=2018&dm=7&dd=15&dh=12&snap=1&o5=1&o6=1&o11=1&o9=1&o13=1&lbl=m&o7=1&min_x=-104.258536186165&min_y=38.072330065267&max_x=-103.37085607568&max_y=38.5173386796279&coord_x=-103.814696130923&coord_y=38.2948343724475&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 (Swath Data) - Compliance

The USGS Lidar Base Specification Version 1.2 states: "All processing will be carried out with the understanding that all point deliverables are required to be fully compliant with ASPRS LAS Specification, version 1.4, using Point Data Record Format 6, 7, 8, 9 or 10. Data producers are encouraged to review the LAS Specification version 1.4 in detail (American Society for Photogrammetry and Remote Sensing, 2011)."

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

Boresighted Files - D:\00_CWCB\Block_5\Swath

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

Pass: 48 files
Fail: 0 files

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

The USGS Lidar Base Specification Version 1.2 states: "All processing will be carried out with the understanding that all point deliverables are required to be fully compliant with ASPRS LAS Specification, version 1.4, using Point Data Record Format 6, 7, 8, 9 or 10. Data producers are encouraged to review the LAS Specification version 1.4 in detail (American Society for Photogrammetry and Remote Sensing, 2011)."

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

Classified Files - D:\00_CWCB\Block_5\Client_LAS

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: 813 files
Fail: 0 files

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

The purpose of this section is to show a table of LAS 1.4 file integrity test results for each swath 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: 48 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: 813 files
Fail: 0 files

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

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

File	(Xmin, Ymin, Zmin)	(Xmax, Ymax, Zmax)	Extended Scan Angle	Scan Angle Rank	Scanner Channel	Scan Direction	Edge of Flight Line	User Data	Counts for Synthetic	Key-points	Withheld	Overlap
	(3357366.15,1514209.205,1522.566)	(3609163.974,1680836.876,11166.874)	[-4650, 3571]	[-27.9, 21.426]	[0, 0]	[0, 1]	[0, 1]	[0, 0]	0	0	11202136	889676608

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	(Xmin, Ymin, Zmin)	(Xmax, Ymax, Zmax)	Extended Scan Angle	Scan Angle Rank	Scanner Channel	Scan Direction	Edge of Flight Line	User Data	Counts for Synthetic	Key-points	Withheld	Overlap
	(3364193.985,1516467.345,1522.566)	(3604720.8,1679185.513,11166.874)	[-4650, 3571]	[-27.9, 21.426]	[0, 0]	[0, 1]	[0, 1]	[0, 0]	0	0	9513637	662929669

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 the tiled files.

File	Class	Z Min	Z Max
	1	3701.905	5707.161
	2	4054.027	5462.492
	7	1522.566	5424.684
	9	4107.518	4126.622
	10	4107.817	4184.473
	17	4113.824	4188.272
	18	4352.137	11166.874

DPH-2 Report on Full Waveform (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "If full waveform data are recorded during collection, the waveform packets shall be delivered. LAS Specification version 1.4 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 for additional information (American Society for Photogrammetry and Remote Sensing, 2011)."

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

Boresighted Files - D:\00_CWCB\Block_5\Swath

All LAS swath files have no waveform data present.

DPH-2 Report on Full Waveform (Tiled Data)

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

Classified Files - D:\00_CWCB\Block_5\Client_LAS

All LAS tiled files have no waveform data present.

DPH-3 Report on Time of Global Positioning System Data (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "The time of global positioning system (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 109. See the LAS Specification version 1.4 for additional information (American Society for Photogrammetry and Remote Sensing, 2013)."

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

Boresighted Files - D:\00_CWCB\Block_5\Swath

All LAS swath files are formatted as Adjusted GPS Time.

DPH-3 Report on Time of Global Positioning System Data (Tiled Data)

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

Classified Files - D:\00_CWCB\Block_5\Client_LAS

All LAS tiled files are formatted as Adjusted GPS Time.

DPH-4 Report on Datums (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "All data collected shall be tied to the datums listed below: For the Conterminous United States (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 published adjustment of the National Geodetic Survey (NGS) (currently NAD 83, epoch 2010.00). 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 GEOID12B model)."

The purpose of this section is to show the datums of the LAS files for the lidar swath data.

Boresighted Files - D:\00_CWCB\Block_5\Swath

All LAS swath 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-4 Report on Datums (Tiled Data)

The purpose of this section is to show the datums of the LAS files for the lidar tiled data.

Classified Files - D:\00_CWCB\Block_5\Client_LAS

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 (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "Lidar data for CONUS will be processed and delivered in the most accurate Coordinate Reference System (CRS) available for a project location, usually State Plane Coordinate System (SPCS) or a state system. Universal Transverse Mercator (UTM) also may be used, particularly when a single suitable local SPCS is not available, UTM is needed for compatibility with existing data for the area, or is needed for other reasons. Other CRSs may be used with prior approval from the USGS–NGP. For Alaska, American Samoa, Commonwealth of the Northern Mariana Islands, Guam, Hawaii, Puerto Rico, U.S. Virgin Islands, and other areas, the horizontal and vertical CRS (specifically including the units) shall be specified and agreed to in advance of collection by the USGS–NGP and all collection partners. In all cases, the CRS that is used shall be recognized and published by the European Petroleum Survey Group (EPSG) and correctly recognized by industry standard geographic information system (GIS) software applications."

The purpose of this section is to show the coordinate reference systems of the LAS files for the lidar swath data.

Boresighted Files - D:\00_CWCB\Block_5\Swath

All LAS swath files are defined as:

EPSG Code = 6432
Coordinate Reference System = NAD83(2011) / Colorado South (ftUS)

DPH-5 Report on Coordinate Reference System (Tiled Data)

The purpose of this section is to show the projections of the LAS files for the lidar tiled data.

Classified Files - D:\00_CWCB\Block_5\Client_LAS

All LAS tiled files are defined as:

EPSG Code = 6432
Coordinate Reference System = NAD83(2011) / Colorado South (ftUS)

DPH-6 Report on Units of Reference (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "All references to the unit of measure 'Feet' or '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 swath data.

Boresighted Files - D:\00_CWCB\Block_5\Swath

All LAS swath files are defined as:

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

DPH-6 Report on Units of Reference (Tiled Data)

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data.

Classified Files - D:\00_CWCB\Block_5\Client_LAS

All LAS tiles files are defined as:

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

DPH-7 Report on Swath Identification

The USGS Lidar Base Specification Version 1.2 states: "At the time of its creation and prior to any further processing, each swath shall be assigned a unique File Source Identification (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 will be persisted unchanged throughout all processing and delivery. See the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011)."

The purpose of this section is to report on the File Source ID and Point Source ID values for the lidar swath data. Note that sub-swaths of original swaths (see DPH-9) may violate the unique values specification described in this test.

Boresighted Files - D:\00_CWCB\Block_5\Swath

There are 48 unique Point Source IDs.
There are 48 unique File Source IDs.
0 files are in violation with duplicated File Source ID or Point Source ID values.

DPH-8 Report on Point Families (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "Point families (multiple return 'children' of a single 'parent' pulse) will be maintained throughout all processing before tiling. Multiple returns from a given pulse will be stored in sequential (collected) order."

The purpose of this section is to report on the presence and integrity of point families for the lidar swath data.

Boresighted Files - D:\00_CWCB\Block_5\Swath

All LAS swath files have point families present.

DPH-8 Report on Point Families (Tiled Data)

The purpose of this section is to report on the presence and integrity of point families for the lidar tiled data.

Classified Files - D:\00_CWCB\Block_5\Client_LAS

All LAS tiled files have point families present.

DPH-9 Report on Swath Size and Segmentation (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "The widespread adoption of 64-bit operating systems in mainstream computing (most notably Windows-7, 64-bit or newer operating systems) has obviated the earlier need for 2 GB limits on swath file sizes. Unless otherwise required by the data producer, lidar swaths may be of any file size supported within a 64-bit computing system. In cases where segmentation of the swaths is required by the data producer, the following requirements apply:

(1) Subswath segments of a given original swath will be of comparable size.
(2) Each subswath shall retain the File Source ID of the original complete swath.
(3) Points within each subswath shall retain the Point Source ID of the original complete swath.
(4) Each subswath file shall be named identically to the original complete swath, with the addition of an ordered alphabetic suffix to the name ("-a," "-b," …, "-n"). The order of the named subswaths shall be consistent with the collection order of the points ("-a" will be the first subswath; "-n" will be the last subswath).
(5) Point families will be maintained intact within each subswath.
(6) Subswaths will be broken at the edge of the scan line."

The purpose of this section is to show the file sizes of the LAS files for the lidar swath data.

Boresighted Files - D:\00_CWCB\Block_5\Swath

File	File Size (bytes)	MB	GB
01035.las	196,869,123	187.749	0.183
01164.las	509,093,095	485.509	0.474
02001.las	1,388,282,055	1323.969	1.293
02003.las	3,225,268,357	3075.856	3.004
02011.las	324,011,781	309.002	0.302
02013.las	267,430,609	255.042	0.249
02034.las	3,628,721,049	3460.618	3.380
02035.las	3,590,089,191	3423.776	3.344
02036.las	3,629,207,979	3461.082	3.380
02037.las	3,506,008,185	3343.590	3.265
02038.las	3,478,185,645	3317.056	3.239
02039.las	3,524,219,949	3360.958	3.282
02040.las	3,340,156,489	3185.421	3.111
02050.las	3,208,450,107	3059.816	2.988
02051.las	3,128,714,083	2983.774	2.914
02052.las	2,990,041,021	2851.525	2.785
02053.las	3,016,894,819	2877.135	2.810
02054.las	2,819,354,569	2688.746	2.626
02055.las	2,871,842,543	2738.802	2.675
02056.las	2,444,450,255	2331.209	2.277
02058.las	122,964,063	117.268	0.115
02059.las	203,776,411	194.336	0.190
02060.las	277,769,201	264.901	0.259
02061.las	216,884,457	206.837	0.202
02062.las	299,031,417	285.179	0.278
02063.las	194,002,303	185.015	0.181
02064.las	276,024,885	263.238	0.257
02065.las	69,902,829	66.665	0.065
02066.las	296,674,805	282.931	0.276
02067.las	215,357,391	205.381	0.201
02101.las	260,906,733	248.820	0.243

DPH-9 Report on Swath Size and Segmentation (Swath Data) - continued

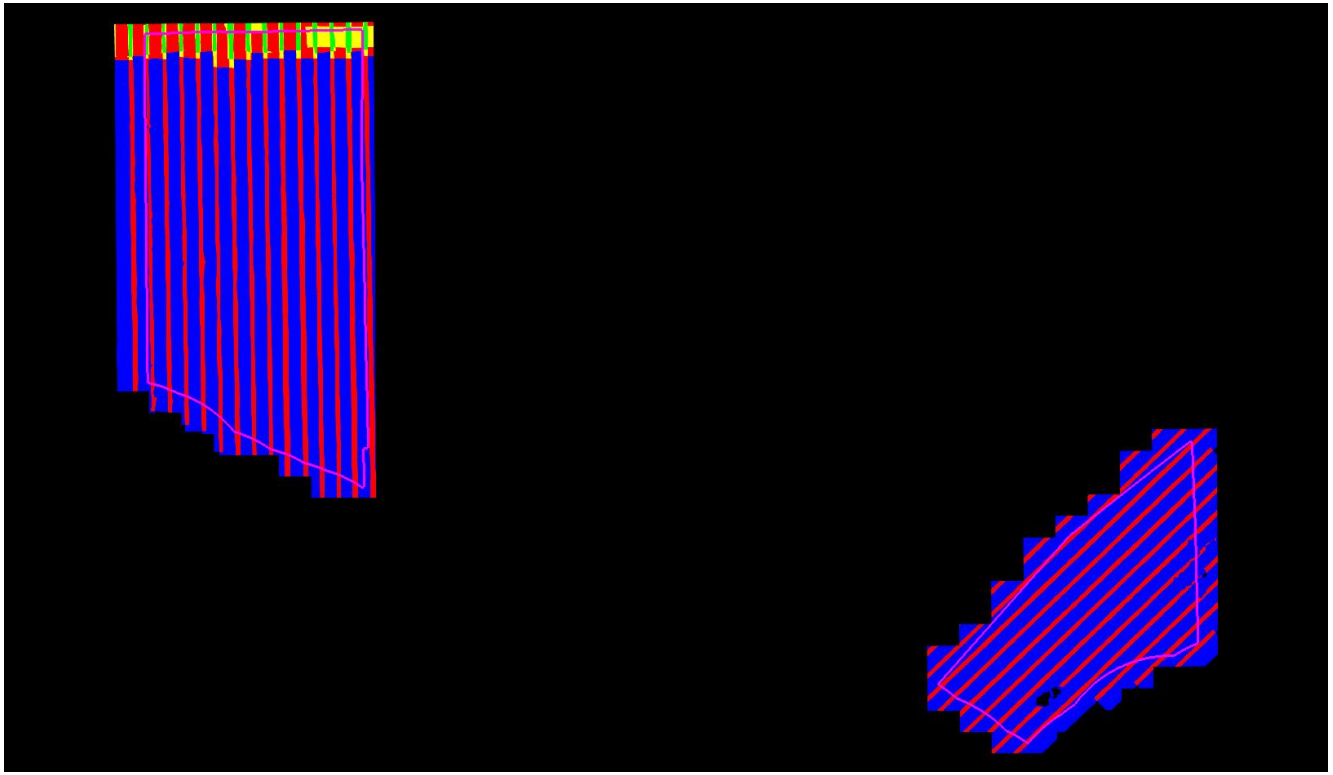
File	File Size (bytes)	MB	GB
02102.las	234,676,409	223.805	0.219
02106.las	236,589,403	225.629	0.220
02107.las	231,350,709	220.633	0.215
02108.las	21,410,065	20.418	0.020
06001.las	277,342,133	264.494	0.258
06002.las	661,146,209	630.518	0.616
06003.las	1,157,090,109	1103.487	1.078
06004.las	1,862,374,235	1776.098	1.734
06005.las	1,838,367,681	1753.204	1.712
06006.las	2,034,291,203	1940.051	1.895
06007.las	2,469,731,659	2355.320	2.300
06008.las	2,733,150,287	2606.535	2.545
06009.las	2,725,965,813	2599.684	2.539
06010.las	2,994,809,789	2856.073	2.789
06011.las	2,735,922,609	2609.179	2.548
06012.las	1,817,841,593	1733.629	1.693
06013.las	392,037,925	373.877	0.365

DPH-10 Report on Scope of Collection

The USGS Lidar Base Specification Version 1.2 states: "All collected swaths shall be delivered as part of the Raw Data Deliverable, including, calibration swaths and cross-ties. All collected returns within each swath shall also be delivered. No points are to be deleted from the swath LAS files. Exceptions to this rule are the extraneous data outside of the BPA (such as aircraft turns, transit between the collection area and airport, and transit between fill-in areas)."

The purpose of this section is to show collection scan overlap. Lack of overlap would be displayed as black polygons or slivers between collection scans.

Data Source - D:\00_CWCB\Block_5\Swath
Result Path - D:\00_CWCB\Block_5\Block_5_QC\DPH_10\Flightline_Coverage_Overlap.jp2



Purple polygon is buffered project area (BPA) boundary

Single Double Triple Quadruple coverage or more

DPH-11.1.1 Report on Smooth Surface Repeatability (intraswath)

The USGS Lidar Base Specification Version 1.2 states: "In ideal theoretical conditions, smooth surface repeatability is a measure of variations documented on a surface that would be expected to be flat and without variation. Users of lidar technology commonly refer to these variations as "noise." Single-swath data will be assessed using only single returns in nonvegetated areas. Repeatability will be evaluated by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns will then be assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). Each sample area will be evaluated using a signed difference raster (maximum elevation - minimum elevation) at a cell size equal to twice the ANPS, rounded up to the next integer. Sample areas will be approximately 50 square meters. The maximum acceptable variations within sample areas at each QL are listed in the table "Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3" (table 2). Isolated noise is expected within the sample areas and will be disregarded."

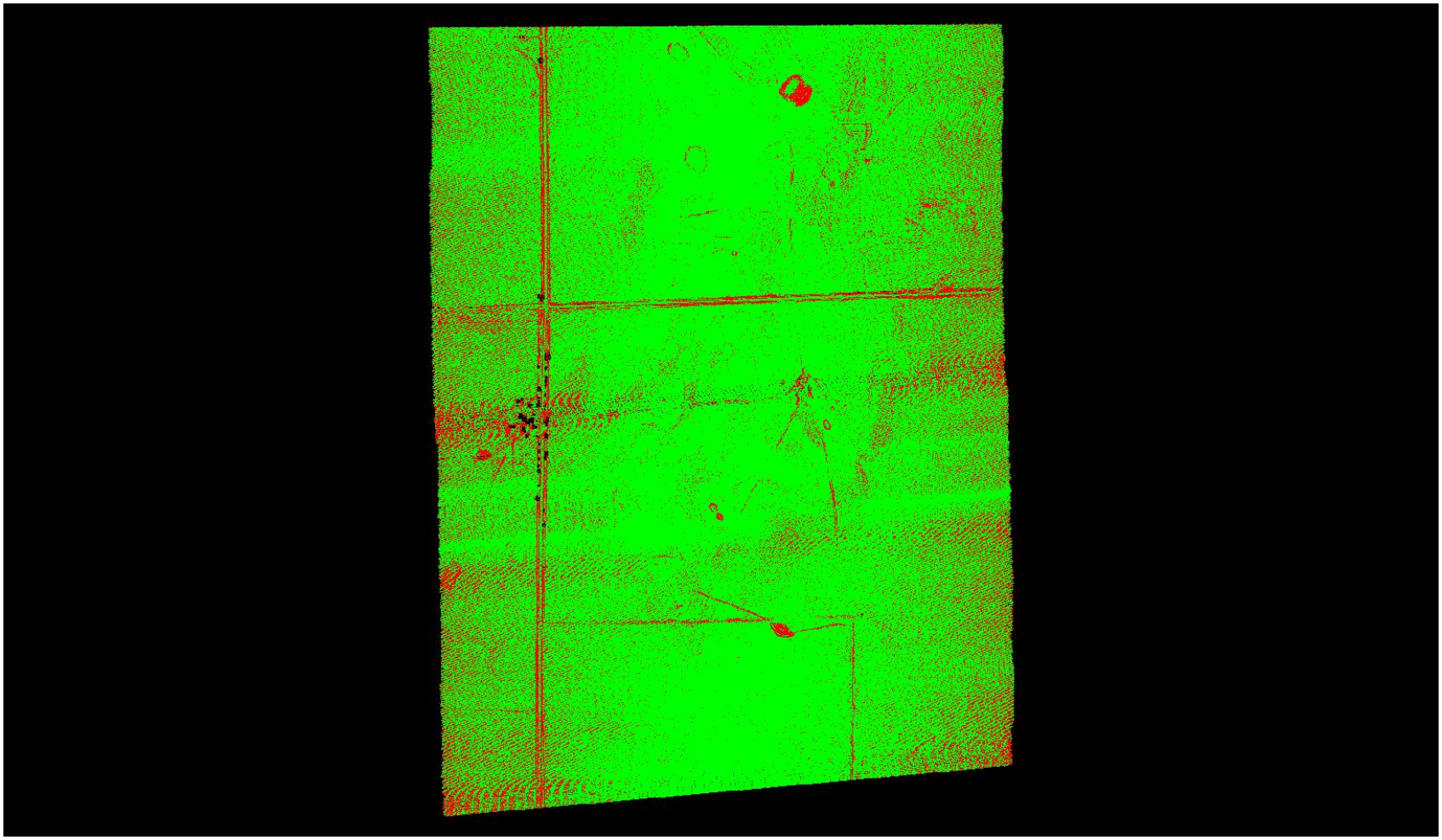
Table 2. Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3.
[cm, centimeter]

Quality Level (QL)	Smooth surface repeatability (cm)
QL0	≤3
QL1	≤6
QL2	≤6
QL3	≤12

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

DPH-11.1.1 Report on Smooth Surface Repeatability (intraswath) - continued

Data Source - D:\00_CWCB\Block_5\Swath
D:\00_CWCB\Block_5\Block_5_QC\DPH_11_1_1\Individual_01035_GRID.jp2



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-11.1.2.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification Version 1.2 states: "Overlap consistency is a measure of geometric alignment of two overlapping swaths; the principles used with swaths can be applied to overlapping lifts and projects as well. Overlap consistency is the fundamental measure of the quality of the calibration or boresight adjustment of the data from each lift, and is of particular importance as the match between the swaths of a single lift is a strong indicator of the overall geometric quality of the data, establishing the quality and accuracy limits of all downstream data and products.
Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns. 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 the intersecting project swaths, and
(3) Adjacent, overlapping lifts.
Each overlap area will be evaluated using a signed difference raster with a cell size equal to twice the ANPS, rounded up to the next integer. The difference rasters will be visually examined using a bicolor ramp from the negative acceptable limit to the positive acceptable limit. Although isolated excursions beyond the limits are expected and accepted, differences in the overlaps shall not exceed the limits listed in table 2 for the QL of information that is being collected. The difference rasters will be statistically summarized to verify that root mean square difference in z (RMSDz) values do not exceed the limits set forth in the table "Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3" (table 2) for the QL of information that is being collected. Consideration will be given for the effect of the expected isolated excursions over limits."

Table 2. Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3.

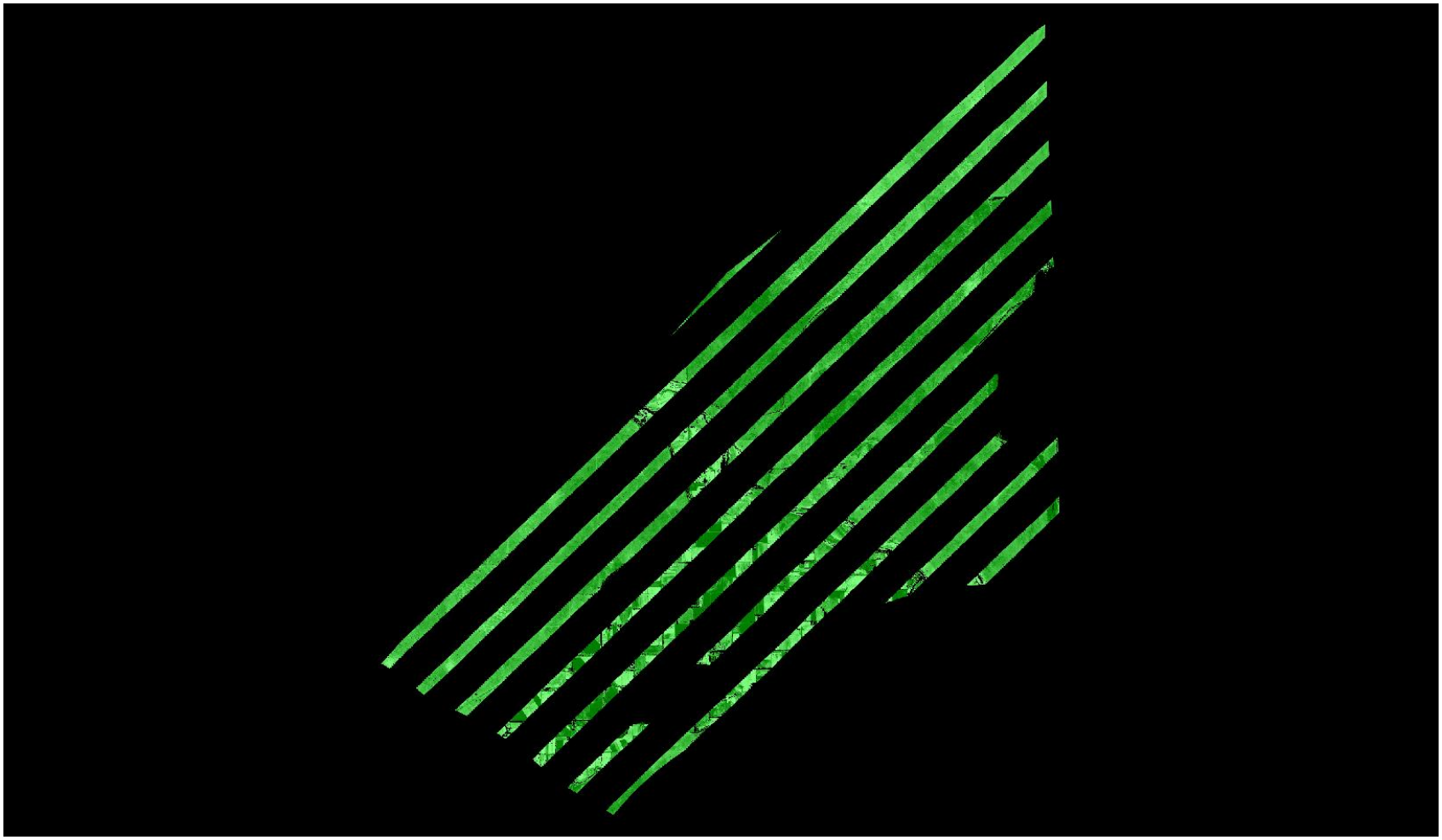
[cm, centimeter; $RMSD_z$, root mean square difference in z; ≤, less than or equal to; ±, plus or minus]

Quality Level (QL)	Swath overlap difference, $RMSD_z$ (cm)	Swath overlap difference, maximum (cm)
QL0	≤4	±8
QL1	≤8	±16
QL2	≤8	±16
QL3	≤16	±32

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. Only overlap areas are shown in the raster.

DPH-11.1.2.1 Report on Overlap Consistency (interswath) - continued

Data Source - D:\00_CWCB\Block_5\Swath
D:\00_CWCB\Block_5\Block_5_QC\DPH_11_1_2\Area1\Boresighted_FlightlineSeparation_SingleFile_Measurable_GRID.jp2



0	0.050	0.100	0.150	0.500 (Meter)
0	0.164	0.328	0.492	1.640 (US Survey Feet)

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-11.1.2.2 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification Version 1.2 states: "Overlap consistency is a measure of geometric alignment of two overlapping swaths; the principles used with swaths can be applied to overlapping lifts and projects as well. Overlap consistency is the fundamental measure of the quality of the calibration or boresight adjustment of the data from each lift, and is of particular importance as the match between the swaths of a single lift is a strong indicator of the overall geometric quality of the data, establishing the quality and accuracy limits of all downstream data and products.
Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns. 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 the intersecting project swaths, and
(3) Adjacent, overlapping lifts.
Each overlap area will be evaluated using a signed difference raster with a cell size equal to twice the ANPS, rounded up to the next integer. The difference rasters will be visually examined using a bicolor ramp from the negative acceptable limit to the positive acceptable limit. Although isolated excursions beyond the limits are expected and accepted, differences in the overlaps shall not exceed the limits listed in table 2 for the QL of information that is being collected. The difference rasters will be statistically summarized to verify that root mean square difference in z (RMSDz) values do not exceed the limits set forth in the table "Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3" (table 2) for the QL of information that is being collected. Consideration will be given for the effect of the expected isolated excursions over limits."

Table 2. Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3.

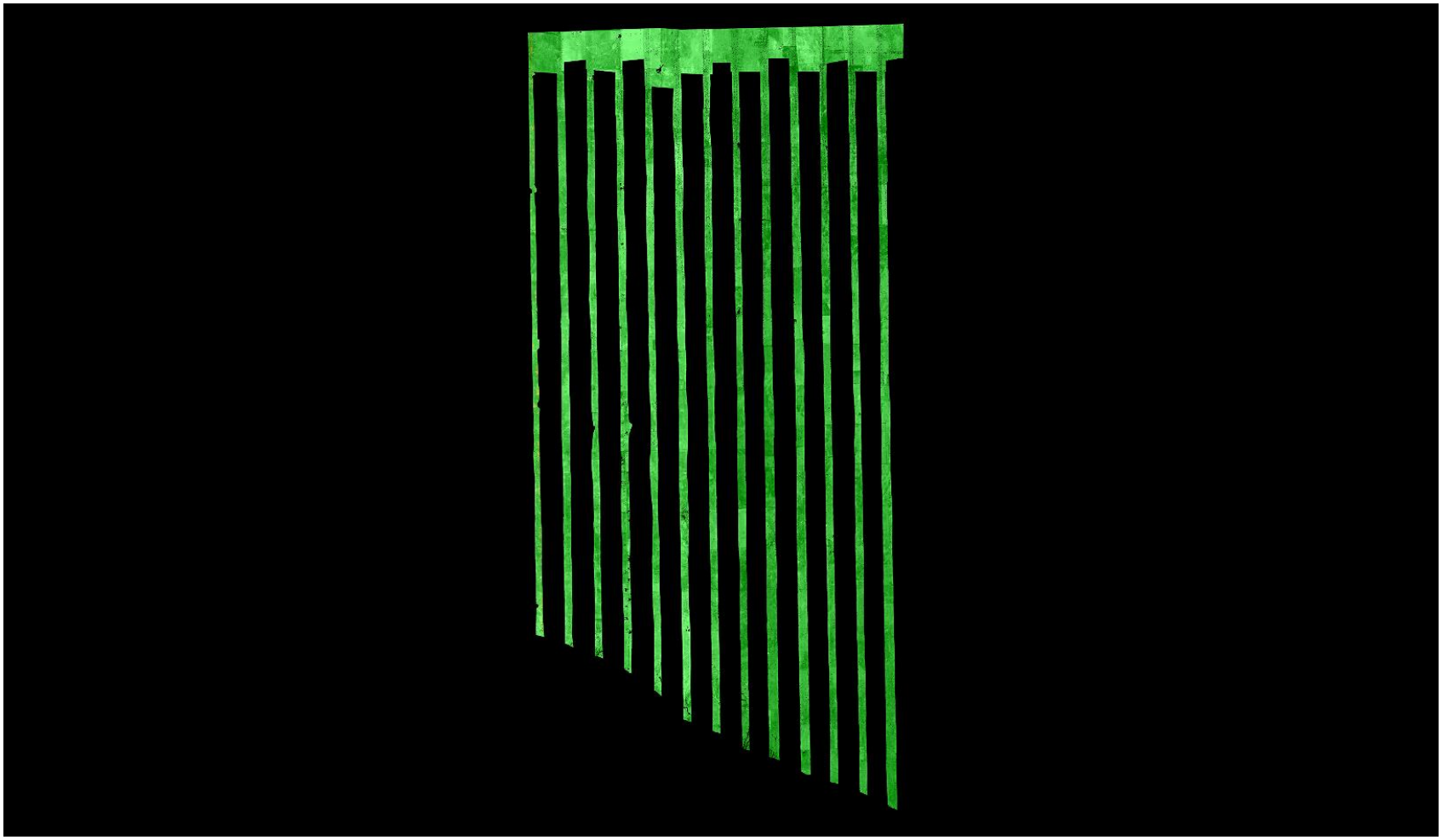
[cm, centimeter; $RMSD_z$, root mean square difference in z; ≤, less than or equal to; ±, plus or minus]

Quality Level (QL)	Swath overlap difference, $RMSD_z$ (cm)	Swath overlap difference, maximum (cm)
QL0	≤4	±8
QL1	≤8	±16
QL2	≤8	±16
QL3	≤16	±32

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. Only overlap areas are shown in the raster.

DPH-11.1.2.2 Report on Overlap Consistency (interswath) - continued

Data Source - D:\00_CWCB\Block_5\Swath
D:\00_CWCB\Block_5\Block_5_QC\DPH_11_1_2\Area2\Boresighted_FlightlineSeparation_SingleFile_Measurable_GRID.jp2



0	0.050	0.100	0.150	0.500 (Meter)
0	0.164	0.328	0.492	1.640 (US Survey Feet)

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-11.2 Report on Check Points

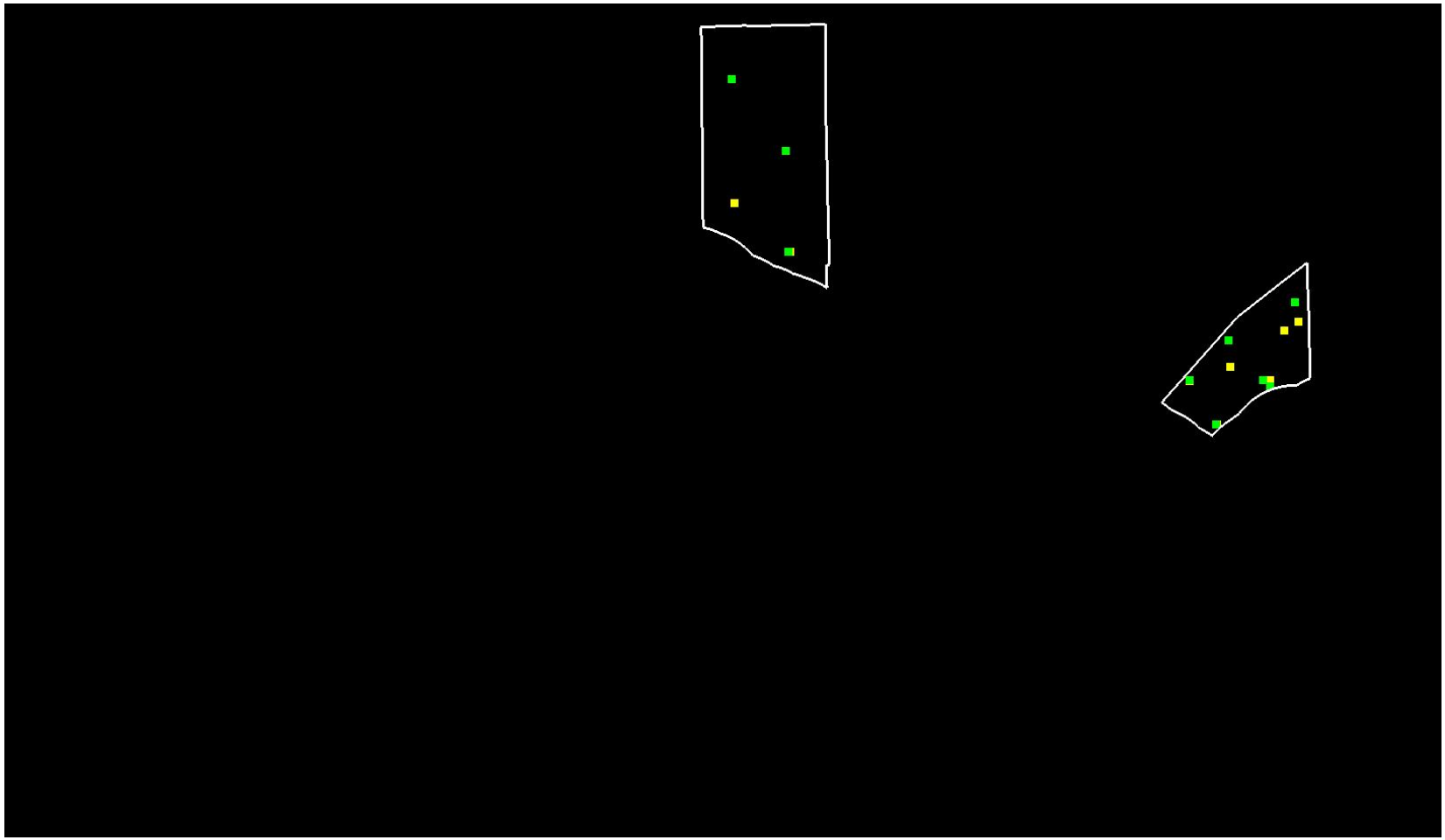
The USGS Lidar Base Specification Version 1.2 states: "The Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014) ties the required number of check points for vertical accuracy assessment to the areal extent of the project. Data producers are encouraged to carefully review the new and revised requirements in that document. 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 cloud 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 (NSSDA) (Federal Geographic Data Committee, 1998) and reiterated in the ASPRS Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014), it is unrealistic to prescribe detailed requirements for check point locations, as many unpredictable factors will affect field operations and decisions, and the data producer must often have 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–NGP 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 the glossary 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 (American Society for Photogrammetry and Remote Sensing, 2014)."

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

DPH-11.2 Report on Check Points - continued

Data Source - D:\00_CWCB\Block_5\Client_Shapes\CWCB_Block5_74NVA_43VVA_CO_S.shp
Check Point Path - D:\00_CWCB\Block_5\Block_5_QC\DPH_11_2\CheckPoints.jpg



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

DPH-11.2 Report on Check Points - continued

Total check points: 117

Check points in defined project area (DPA): 24

Total NVA check points in defined project area (DPA): 15

Total VVA check points in defined project area (DPA): 9

Total defined project area (DPA): 589.933 square KM

Density of check points in defined project area (DPA): 0.041 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-11.3 Report on Absolute Vertical Accuracy

The USGS Lidar Base Specification Version 1.2 states: "Absolute vertical accuracy of the lidar data and the derived DEM will be assessed and reported in accordance with the ASPRS Positional Accuracy Standards for Digital Geospatial Data (American Society for Photogrammetry and Remote Sensing, 2014). Two broad land cover types shall be assessed: vegetated and nonvegetated. Three absolute accuracy values shall be assessed and reported: NVA for the point cloud, NVA for the DEM, and VVA for the DEM. The minimum NVA and VVA requirements for all data, using the ASPRS methodology, are listed in the tables 'Absolute vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3' (table 4) and 'Absolute vertical accuracy for digital elevation models, Quality Level 0–Quality Level 3' (table 5). Both the NVA and VVA required values shall be met. For projects dominated by dense forests, the USGS–NGP may accept higher VVA values."

Table 4. Absolute vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3.

[$RMSE_z$, root mean square error in z; cm, centimeter; NVA, nonvegetated vertical accuracy; ≤, less than or equal to]

Quality Level (QL)	$RMSE_z$ (nonvegetated) (cm)	NVA at 95-percent confidence level (cm)
QL0	≤5.0	≤9.8
QL1	≤10.0	≤19.6
QL2	≤10.0	≤19.6
QL3	≤20.0	≤39.2

Table 5. Absolute vertical accuracy for digital elevation models, Quality Level 0–Quality Level 3.

[$RMSE_z$, root mean square error in z; cm, centimeter; NVA, nonvegetated vertical accuracy; VVA, vegetated vertical accuracy; ≤, less than or equal to]

Quality Level (QL)	$RMSE_z$ (nonvegetated) (cm)	NVA at 95-percent confidence level (cm)	VVA at 95th percentile (cm)
QL0	≤5.0	≤9.8	≤14.7
QL1	≤10.0	≤19.6	≤29.4
QL2	≤10.0	≤19.6	≤29.4
QL3	≤20.0	≤39.2	≤58.8

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

DPH-11.3 Report on Absolute Vertical Accuracy - continued

D:\00_CWCB\Block_5\Client_Shapes\CWCB_Block5_74NVA_43VVA_CO_S.shp
Units: Meter (/US Survey Feet)

Vertical Accuracy Class tested: 10-cm

Check Points in defined project area (DPA):	24
Check Points with Lidar Coverage	24
Check Points with Lidar Coverage (NVA)	15
Check Points with Lidar Coverage (VVA)	9
Average Z Error (NVA)	-0.012/-0.041
Maximum Z Error (NVA)	0.044/0.144
Median Z Error (NVA)	-0.017/-0.055
Minimum Z Error (NVA)	-0.066/-0.217
Standard deviation of Vertical Error (NVA)	0.036/0.117
Skewness of Vertical Error (NVA)	0.222
Kurtosis of Vertical Error (NVA)	-1.177
Non-vegetated Vertical Accuracy (NVA) RMSE(z) [1]	0.036/0.120 PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level +/- [1]	0.071/0.235 PASS
FGDC/NSSDA Vertical Accuracy at the 95% Confidence Level +/-	0.071/0.235
Non-vegetated Vertical Accuracy (NVA) RMSE(z) (DEM) [2]	0.035/0.116 PASS
Non-vegetated Vertical Accuracy (NVA) at the 95% Confidence Level (DEM) +/- [2]	0.069/0.227 PASS
Vegetated Vertical Accuracy (VVA) at the 95th Percentile (DEM) +/- [2]	0.145/0.475 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 = 3.647cm, equating to +/- 7.149cm at the 95% confidence level. Actual VVA accuracy was found to be +/- 14.477cm at the 95th percentile.

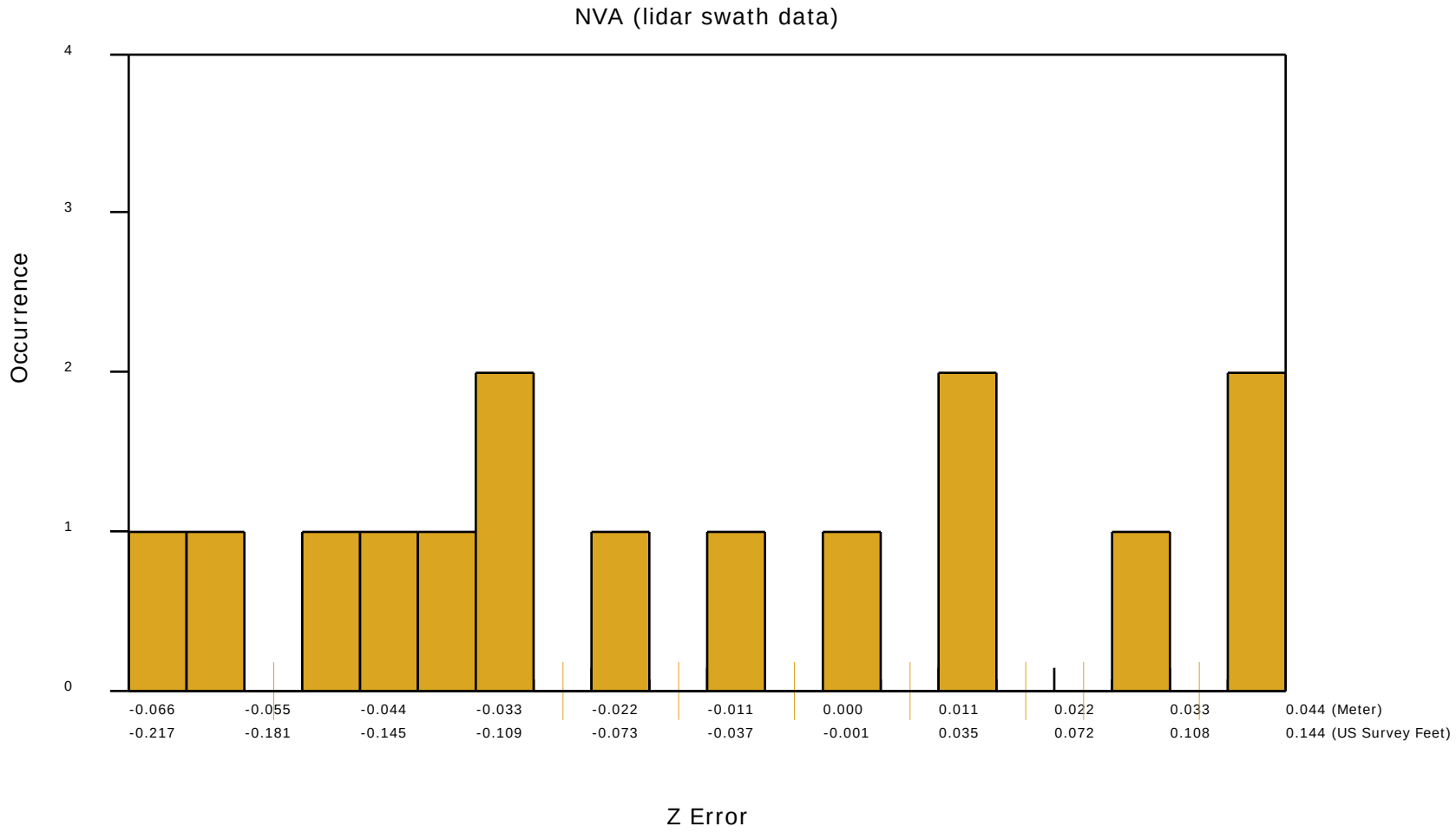
[1] This value is calculated from TIN-based testing of the raw swath lidar point cloud data.

[2] This value is calculated from RAM-based grid testing of the classified tiled lidar data. The grid cells are sized according to the Quality Level selected, and are defined in the USGS NGP Lidar Base Specification Version 1.2 (page 15, Table 7).

DPH-11.3 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.

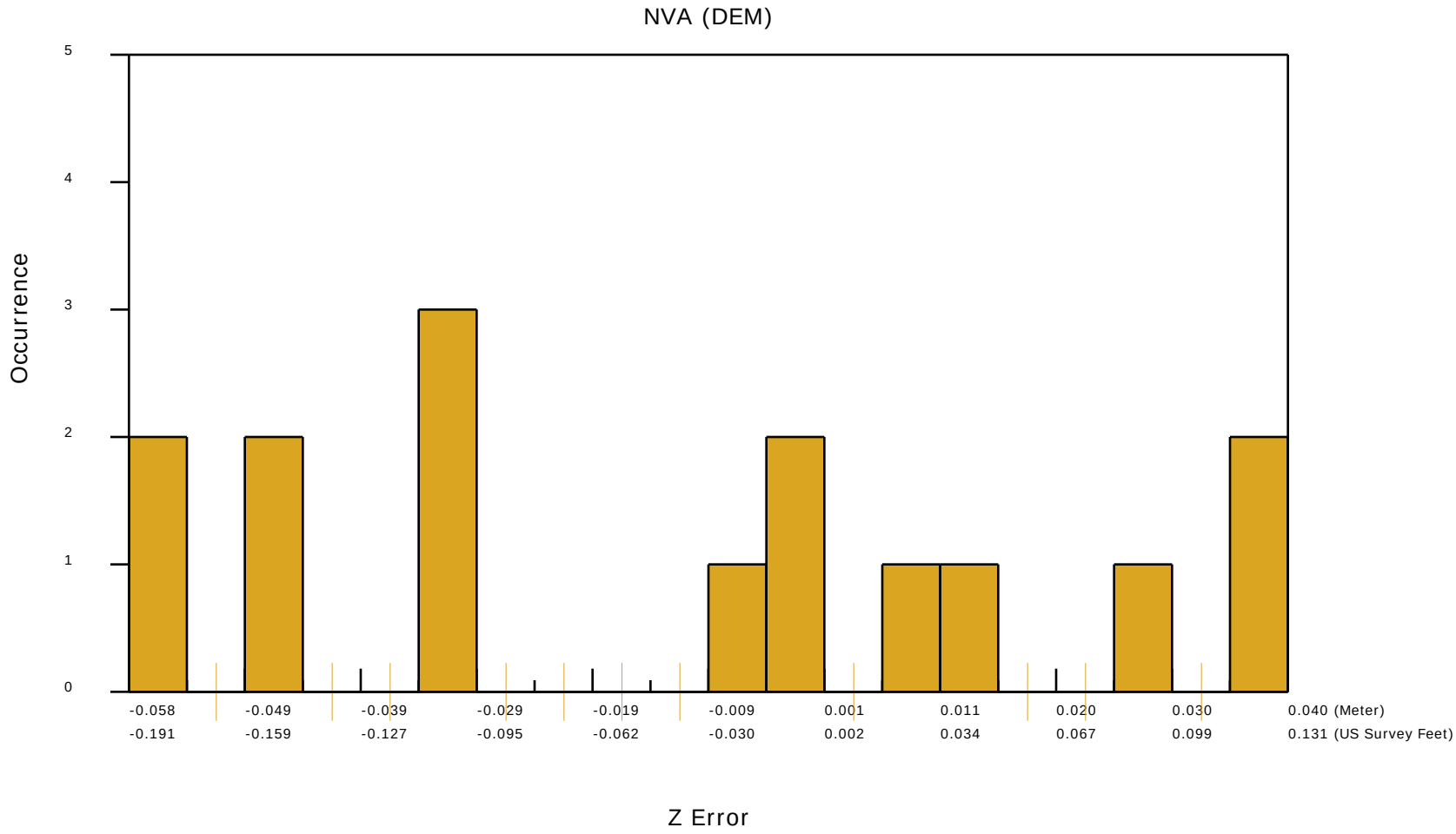
Data Source - D:\00_CWCB\Block_5\Swath



DPH-11.3 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.

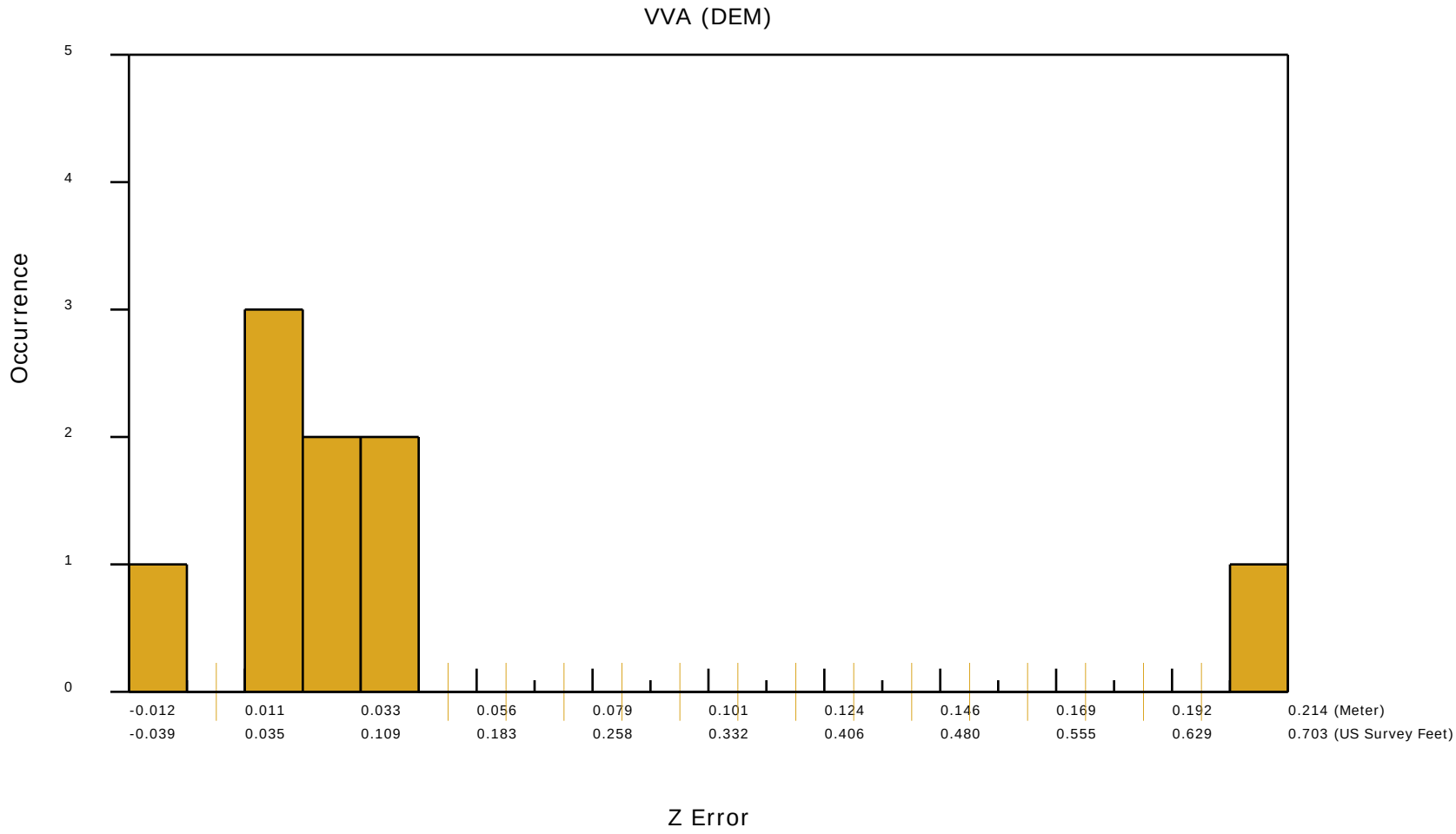
Data Source - D:\00_CWCB\Block_5\Client_LAS



DPH-11.3 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.

Data Source - D:\00_CWCB\Block_5\Client_LAS



DPH-12 Report on Use of the LAS Withheld Flag (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "Outliers, blunders, noise points, geometrically unreliable points near the extreme edge of the swath, and other points the data producer deems unusable are to be identified using the Withheld Flag, as defined in the LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011). The Withheld Flag is primarily used to denote points identified during preprocessing or through automated post-processing routines as geometrically unusable. 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."

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

Boresighted Files - D:\00_CWCB\Block_5\Swath

Total Withheld points (all classes, all swaths)	11202136

DPH-12 Report on Use of the LAS Withheld Flag (Tiled Data)

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

Classified Files - D:\00_CWCB\Block_5\Client_LAS

Total Withheld points (all classes, all tiles)	9513637

DPH-13 Report on Use of the LAS Overlap Flag (Swath Data)

The USGS Lidar Base Specification Version 1.2 states: "The LAS Specification version 1.4 (American Society for Photogrammetry and Remote Sensing, 2011) includes a new overlap flag. Although strictly speaking, the term "overlap" means all lidar points lying within any overlapping areas of two or more swaths, the flag is intended to identify overage points, which are only a subset of overlap points. See the glossary for more information on the difference between overlap and overage. Having overage points identified allows for their easy exclusion from subsequent processes where the increased density and elevation variability they introduce is unwanted (for example, DEM generation). Overage points have commonly been identified using Class 12, precluding other valuable classification (for example, bare earth, water). The overlap 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 flag in all point cloud deliverables."

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

Boresighted Files - D:\00_CWCB\Block_5\Swath

Total Overlap points (all classes, all swaths)	889676608

DPH-13 Report on Use of the LAS Overlap Flag (Tiled Data)

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

Classified Files - D:\00_CWCB\Block_5\Client_LAS

Total Overlap points (all classes, all tiles)	662929669

DPH-14 Report on Point Classification

The USGS Lidar Base Specification Version 1.2 states: "The minimum scheme required for lidar point clouds is listed in the table 'Minimum classified pointcloud classification scheme' (table 6). All points not identified as Withheld (WH) shall be classified. "

Table 6. Minimum classified point cloud classification scheme.

Code	Description
1	Processed, but unclassified.
2	Bare earth.
7	Low noise.
9	Water.
10	Ignored ground (near a breakline).
17	Bridge decks.
18	High noise.

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

Classified Files - D:\00_CWCB\Block_5\Client_LAS

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	35,589,365	00	9,513,637	65	00	00	00	129	00	00	00	193	00	00	00
2	1,911,168,054	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	5,026	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	5,876,193	00	00	73	00	00	00	137	00	00	00	201	00	00	00
10	47,544	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	3,889	00	00	81	00	00	00	145	00	00	00	209	00	00	00
18	2,221	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	00	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

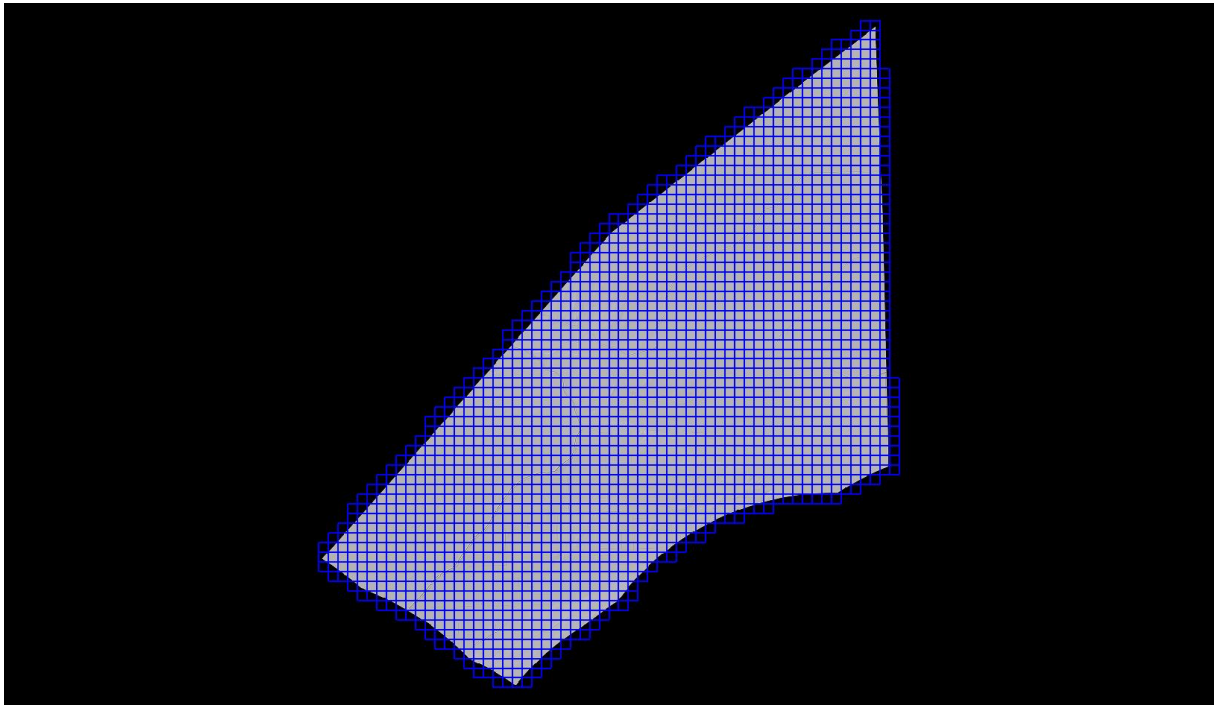
– not all Class 0 points flagged as Withheld

DPH-15.1 Report on Classification Accuracy

The USGS Lidar Base Specification Version 1.2 states: "Following classification processing, no nonwithheld points will remain in Class 0.
• For QL3 data, within any 1 square km, no more than 2 percent of nonwithheld points will have demonstrable errors in the classification value.
• For QL2 data, within any 1 square km, no more than 1 percent of nonwithheld points will have demonstrable errors in the classification value.
• For QL1 and QL0 data, within any 1 square km, no more than 0.5 percent of nonwithheld points will have demonstrable errors in the classification value.
• Points remaining in Class 1 that should be classified in any other required class are subject to these accuracy requirements and will be counted towards the percentage thresholds."
The USGS-NGP may relax these requirements to accommodate collections in areas where classification is particularly difficult.

The purpose of this section is to overlay a 1km x 1km tile scheme over the bare earth surface hillshade product to use for ground filter QC inspection.

Data Source - D:\00_CWCB\Block_5\Client_LAS
Result Path - D:\00_CWCB\Block_5\Block_5_QC\DPH_15_16\Area1\Hillshade_SingleFile.jp2
Tile Shapefile - D:\00_CWCB\Block_5\Block_5_QC\DPH_15_16\Area1\tile.shp

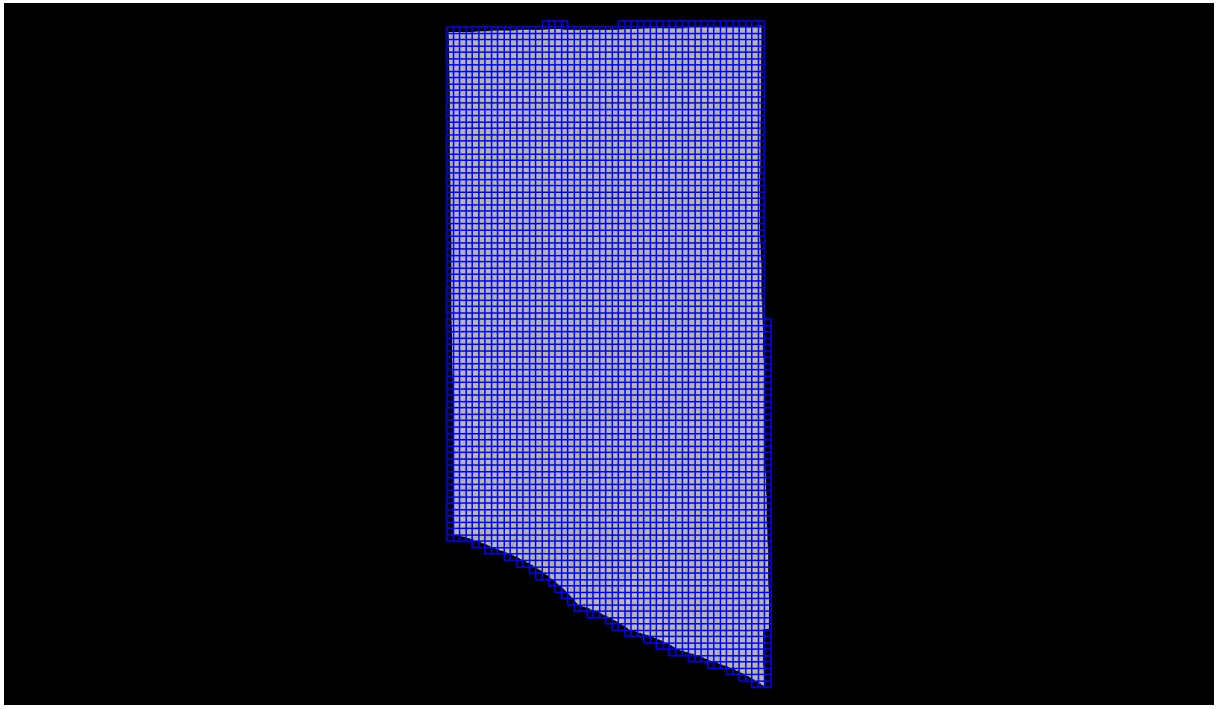


DPH-15.2 Report on Classification Accuracy

The USGS Lidar Base Specification Version 1.2 states: "Following classification processing, no nonwithheld points will remain in Class 0.
• For QL3 data, within any 1 square km, no more than 2 percent of nonwithheld points will have demonstrable errors in the classification value.
• For QL2 data, within any 1 square km, no more than 1 percent of nonwithheld points will have demonstrable errors in the classification value.
• For QL1 and QL0 data, within any 1 square km, no more than 0.5 percent of nonwithheld points will have demonstrable errors in the classification value.
• Points remaining in Class 1 that should be classified in any other required class are subject to these accuracy requirements and will be counted towards the percentage thresholds."
The USGS-NGP may relax these requirements to accommodate collections in areas where classification is particularly difficult.

The purpose of this section is to overlay a 1km x 1km tile scheme over the bare earth surface hillshade product to use for ground filter QC inspection.

Data Source - D:\00_CWCB\Block_5\Client_LAS
Result Path - D:\00_CWCB\Block_5\Block_5_QC\DPH_15_16\Area2\Hillshade_SingleFile.jp2
Tile Shapefile - D:\00_CWCB\Block_5\Block_5_QC\DPH_15_16\Area2\tile.shp

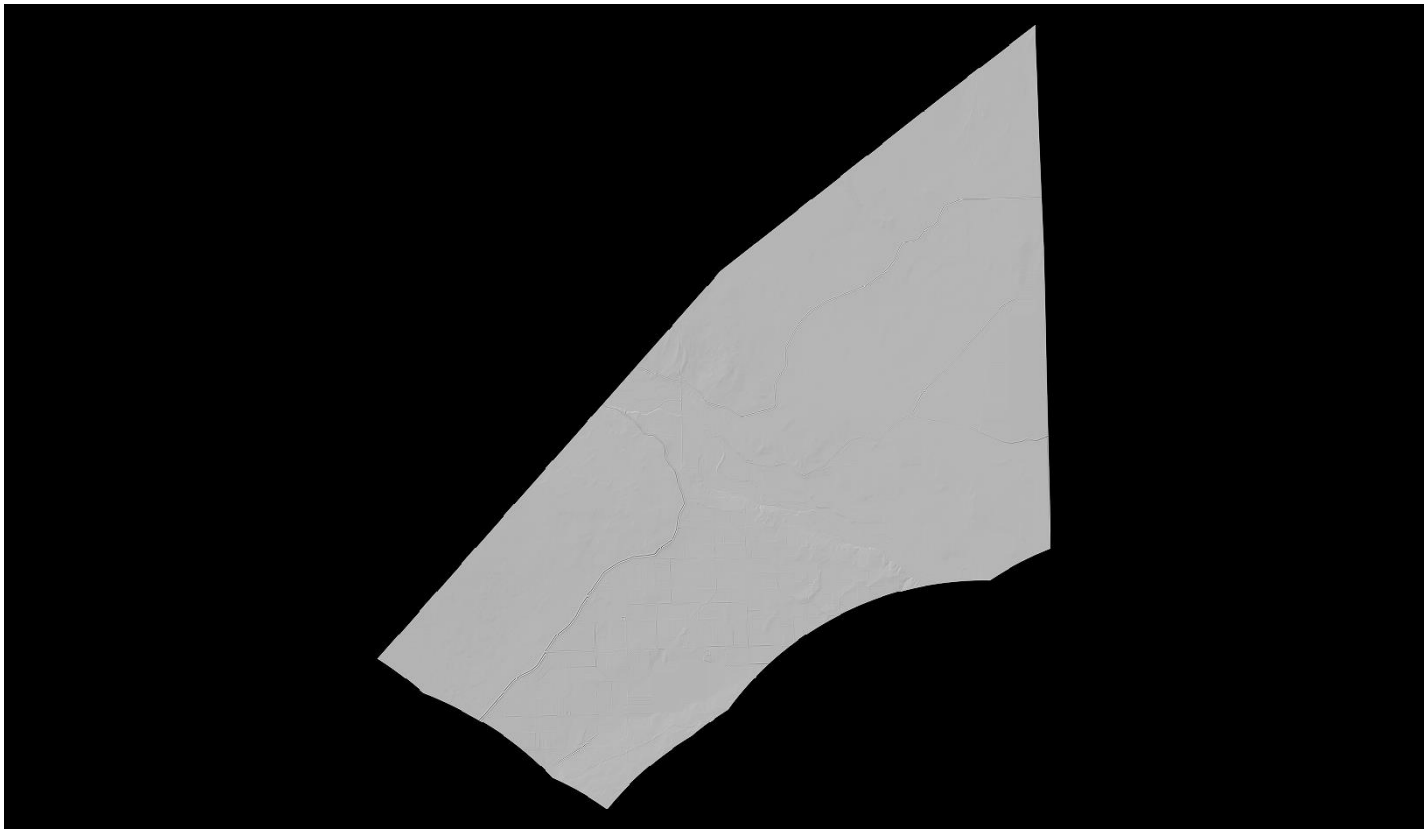


DPH-16.1 Report on Classification Consistency

The USGS Lidar Base Specification Version 1.2 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.

Data Source - D:\00_CWCB\Block_5\Client_LAS
Result Path - D:\00_CWCB\Block_5\Block_5_QC\DPH_15_16\Area1\Hillshade_SingleFile.jp2

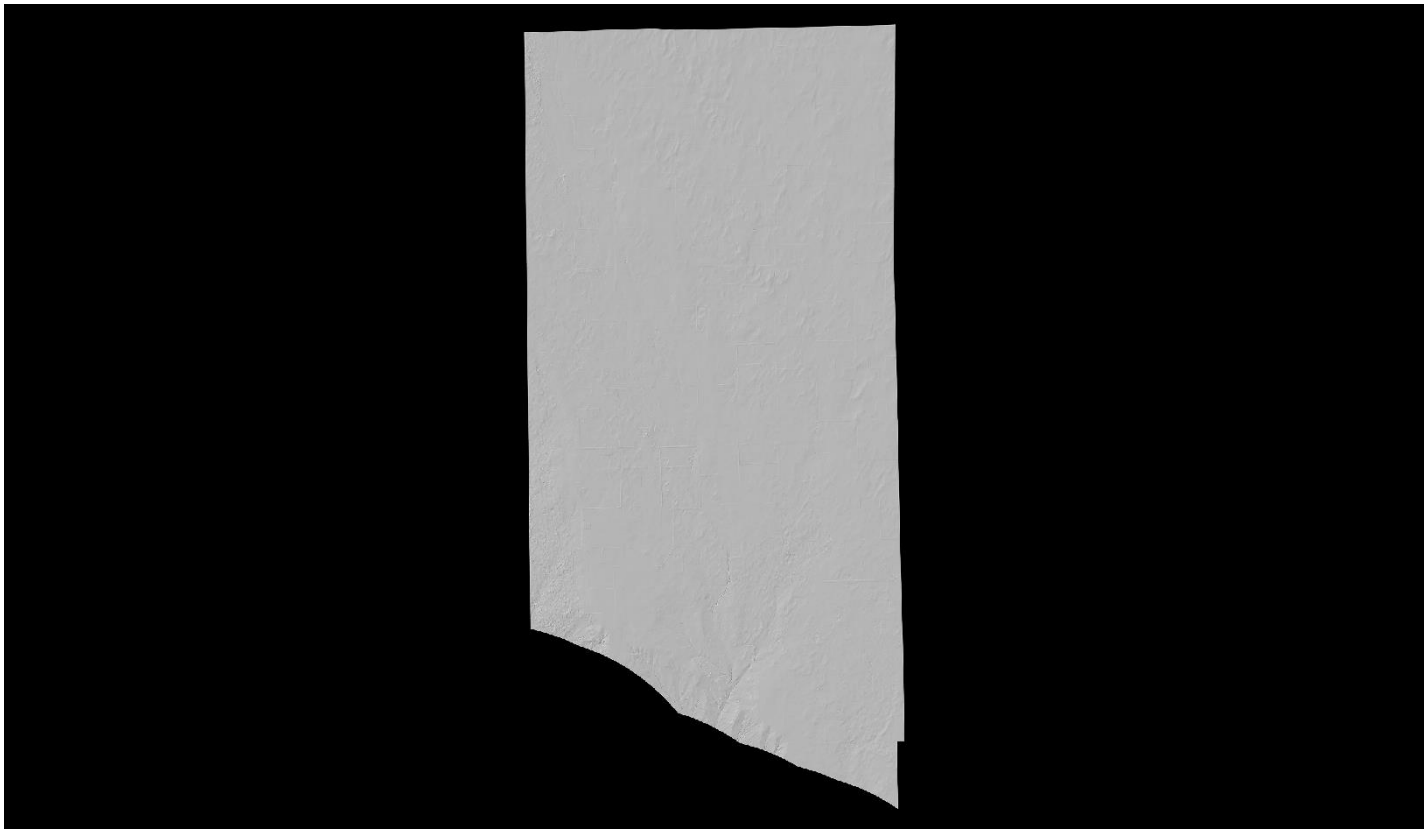


DPH-16.2 Report on Classification Consistency

The USGS Lidar Base Specification Version 1.2 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.

Data Source - D:\00_CWCB\Block_5\Client_LAS
Result Path - D:\00_CWCB\Block_5\Block_5_QC\DPH_15_16\Area2\Hillshade_SingleFile.jp2



DPH-17 Report on Tiles

The USGS Lidar Base Specification Version 1.2 states: "A single non-overlapping 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.

Tile File: D:\00_CWCB\Block_5\Client_Shapes\Block_5_Client_Tiles_North.shp
Units: US Survey Feet

The following lists tiles that are overlapped.

Tile	Width	Height	Overlap

NONE

The following lists tile widths/heights in the project.

3000.000/3000.000