March 18, 2025

Coastal Communities, Alaska

3DEP Lidar Mapping Projects: NC-NA0000-23-01327

Lidar Technical Data Report NOAA Contract: 1305M221DNCNP0018, Task Order: 1305M223FNCNP0305

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Cover Photo: A view looking northwest at The Goodnews Bay community. The image was created from the lidar bare earth model colored by satellite images.

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INTRODUCTION

This photo was taken by the NV5 Acquisition crew in route to acquire lidar data for Coastal Communities sites in Alaska.

In July 2023, NV5 was contracted by the National Oceanic and Atmospheric Administration (NOAA) to collect Light Detection and Ranging (lidar) data in the summer of 2023, and the spring, summer, and fall of 2024 for the Coastal Communities sites in Alaska. The 2023 and 2024 lidar collection includes the communities of Eek, Quinhagak, Goodnews Bay, Togiak, Nelson Lagoon located in UTM Zone 4, and Kachemak located in UTM Zone 5. Data was collected to support coastal resource managers, watershed managers, and various stakeholders in their decision-making processes.

This report accompanies the delivered lidar data and documents contract specifications, data acquisition procedures, processing methods, and analysis of the final dataset including lidar accuracy and density. Acquisition dates and acreage are shown in Table 1, deliverable projection information is shown in Table 2, a complete list of contracted deliverables provided to NOAA is shown in Table 3, and the project extent is shown in Figure 1.

Table 1: Acquisition dates, acreage, and data types collected on the Coastal Communities sites

UTM	Project Site	Contacted Acres	Aerial Acquisition Dates	Data Type
Zone 4	**Eek, Alaska**	1,044	9/21/2024	NIR - Lidar
Zone 4	**Quinhagak, Alaska**	20,672	9/22/2024	NIR - Lidar
Zone 4	**Goodnews Bay, Alaska**	2,954	9/21/2024	NIR - Lidar
Zone 4	**Togiak, Alaska**	40,266	10/2/2023 & 7/31/2024	NIR - Lidar
Zone 4	**Nelson Lagoon, Alaska**	27,500	8/20/2024	NIR - Lidar
Zone 5	**Kachemak, Alaska**	286,326	8/1/2023 – 8/2/2023, 6/15/2024 – 6/17/2024 & 9/21/2024	NIR - Lidar

Deliverable Products

Table 2: Deliverable product projection information

Projections	Horizontal Datum	Vertical Datum	Units
UTM Zone 4 and Zone 5	NAD83 (2011)	NAVD88 (GEOID12B)	Meters

Table 3: Products delivered to NOAA for the Coastal Communities sites

Product Type	File Type	Product Details
Points	LAZ v.1.4 (*.laz)	• All Classified Returns
Rasters	0.5 meter GeoTIFFs (*.tif)	• Hydroflattened Bare Earth Model (DEM) • Intensity Images
Raster	1 meter GeoTIFFs (*.tif)	• Swath Separation Images • Maximum Surface Height Rasters
Vectors	ESRI File Geodatabase (*.gdb)	• Defined Project Area • Master Tile Index • Flightline Index • Flightline Swaths • Hydro-Breaklines • Ground Survey Points • Snow Polygons
Metadata	Extensible Markup Language (*.xml)	• Metadata
Reports	Adobe Acrobat (*.pdf)	• Lidar Technical Data Report • Ground Survey Report

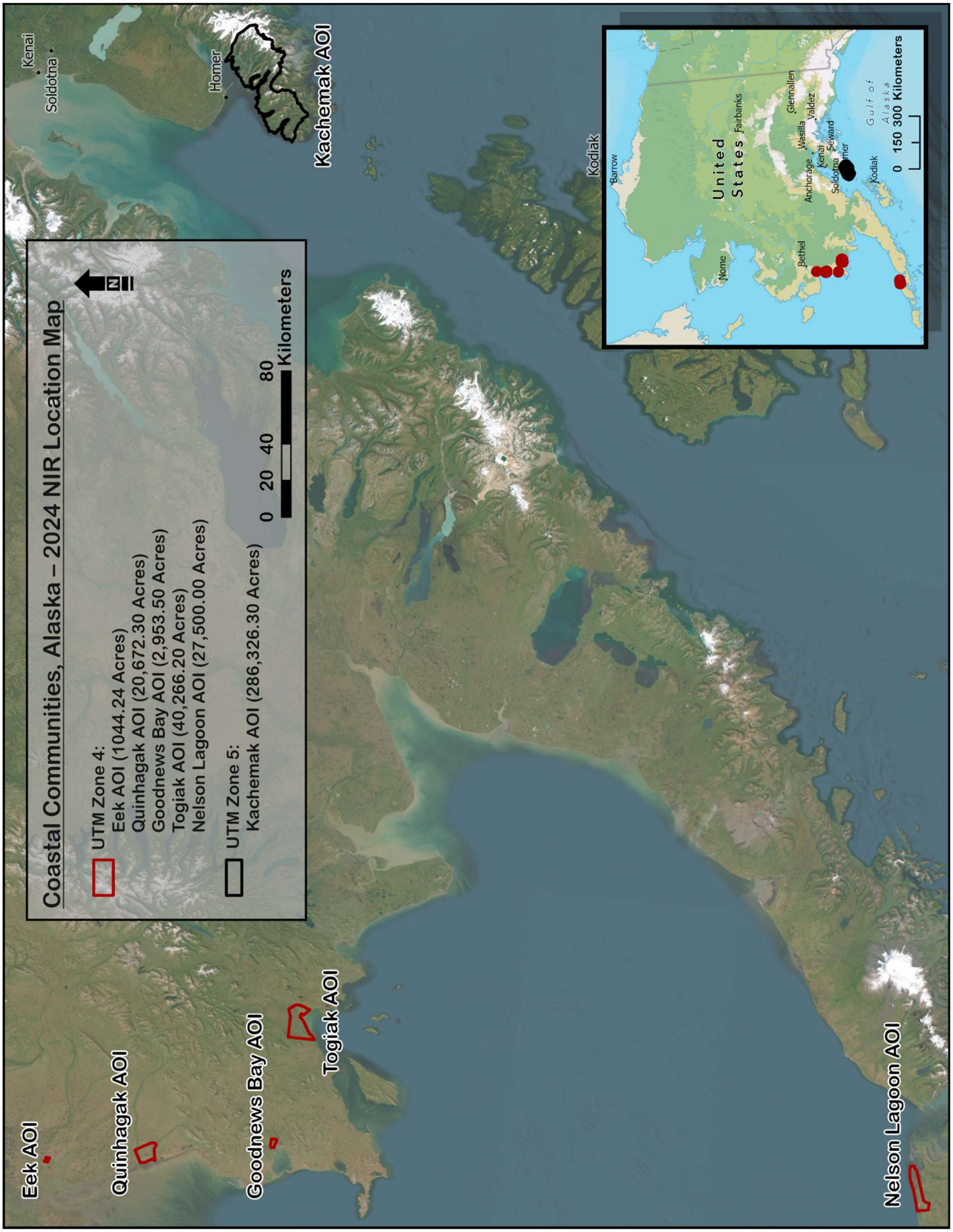


Figure 1: Location map of the Coastal Communities site in Alaska

DOWL's ground acquisition equipment set up in the Coastal Communities Lidar study area.

Planning

In preparation for data collection, NV5 reviewed the project areas and developed a specialized flight plan to ensure complete coverage of the Coastal Communities lidar study areas at the target point density of ≥8.0 points/m^2. Acquisition parameters including orientation relative to terrain, flight altitude, pulse rate, scan angle, and ground speed were adapted to optimize flight paths and flight times while meeting all contract specifications. Figure 2 shows these optimized flight paths and dates.

Factors such as satellite constellation availability and weather windows must be considered during the planning stage. Any weather hazards or conditions affecting the flights were continuously monitored due to their potential impact on the daily success of airborne and ground operations. In addition, logistical considerations including private property access and potential air space restrictions were reviewed.

Table 4: Flight Date Table

UTM	Date	Flight Line Number	Start Time (Adjusted GPS)	End Time (Adjusted GPS)
Zone 5	8/1/2023	101 - 117	374944715	374954049
Zone 5	8/2/2023	205 - 221	374969254	374978526
Zone 5	8/2/2023	300 - 315	375033858	375042881
Zone 5	6/15/2024	1300 - 1316	402527364	402538471
Zone 5	6/16/2024	1400 - 1410	402612775	402618184

UTM	Date	Flight Line Number	Start Time (Adjusted GPS)	End Time (Adjusted GPS)
Zone 5	6/17/2024	1410 - 1424	402617776	402625000
Zone 5	9/21/2024	1900 - 1902	410981666	410982793
Zone 4	10/2/2023	1200 - 1210	380309129	380314250
Zone 4	7/31/2024	1500 - 1506	380309129	406501709
Zone 4	8/20/2024	1600 - 1608	408154792	408159292
Zone 4	9/22/2024	2000 - 2016	411004846	411010537
Zone 4	9/21/2024	2100 - 2110	410991745	410996311

Airborne Survey

Lidar

The lidar survey was accomplished using a Riegl VQ-1560ii-S system mounted in a Cessna Conquest II, and a Riegl VQ-780ii-S system mounted in a Cessna Grand Caravan. Table 5 summarizes the settings used to yield an average pulse density of $\geq$8 pulses/m^2 over the Coastal Communities project areas. The Riegl VQ-1560ii-S and Riegl VQ-780ii-S laser system can record unlimited range measurements (returns) per pulse, however a maximum of 15 returns can be stored due to LAS v1.4 file limitations. The typical number of returns digitized from a single pulse range from 1 to 9 for the Riegl VQ-1560ii-S, and 1 to 12 for Riegl VQ 780ii-S for the Coastal Communities project areas. It is not uncommon for some types of surfaces (e.g., dense vegetation or water) to return fewer pulses to the lidar sensor than the laser originally emitted. The discrepancy between first return and overall delivered density will vary depending on terrain, land cover, and the prevalence of water bodies. All discernible laser returns were processed for the output dataset. Figure 2 shows the flightlines acquired using these lidar specifications.

Table 5: Lidar specifications and aerial survey settings

Parameter	NIR Laser	NIR Laser
Acquisition Dates	8/1-2/2023 & 9/21-22/2024	10/2/2023, 6/15-17/2024, 7/31/2024 & 8/20/2024
Aircraft Used	Cessna Grand Caravan	Cessna Grand Caravan
Sensor	Riegl	Riegl
Laser Channel	VQ-1560ii-S	VQ-780ii-S
Maximum Returns	9	12
Resolution/Density	Average 8 points/m²	Average 8 points/m²
Nominal Pulse Spacing	0.35 m	0.35 m
Survey Altitude (AGL)	2478 m	2058 m
Survey speed	160 knots	145 knots
Field of View	58.5°	58.5°
Mirror Scan Rate	Uniform Point Spacing	Uniform Point Spacing
Target Pulse Rate	829 kHz	1285 kHz
Pulse Length	3 ns	3 ns
Laser Pulse Footprint Diameter	57 cm	47.3 cm
Central Wavelength	1064 nm	1064 nm
Pulse Mode	Multiple Times Around (MTA)	Multiple Times Around (MTA)
Beam Divergence	0.23 mrad	0.23 mrad
Swath Width	2775 m	2305 m
Swath Overlap	57%	57%
Intensity	16-bit	16-bit

All areas were surveyed with an opposing flight line side-lap of ≥50% (≥100% overlap) to reduce laser shadowing and increase surface laser painting. To accurately solve laser point position (geographic coordinates x, y, and z), the positional coordinates of the airborne sensor and the orientation of the aircraft to the horizon (attitude) were recorded continuously throughout the lidar data collection mission. Position of the aircraft was measured twice per second (2 Hz) by an onboard differential GPS unit, and aircraft attitude was measured 200 times per second (200 Hz) as pitch, roll, and yaw (heading) from an onboard inertial measurement unit (IMU). To allow for post-processing correction and calibration, aircraft and sensor position and attitude data are indexed by GPS time.

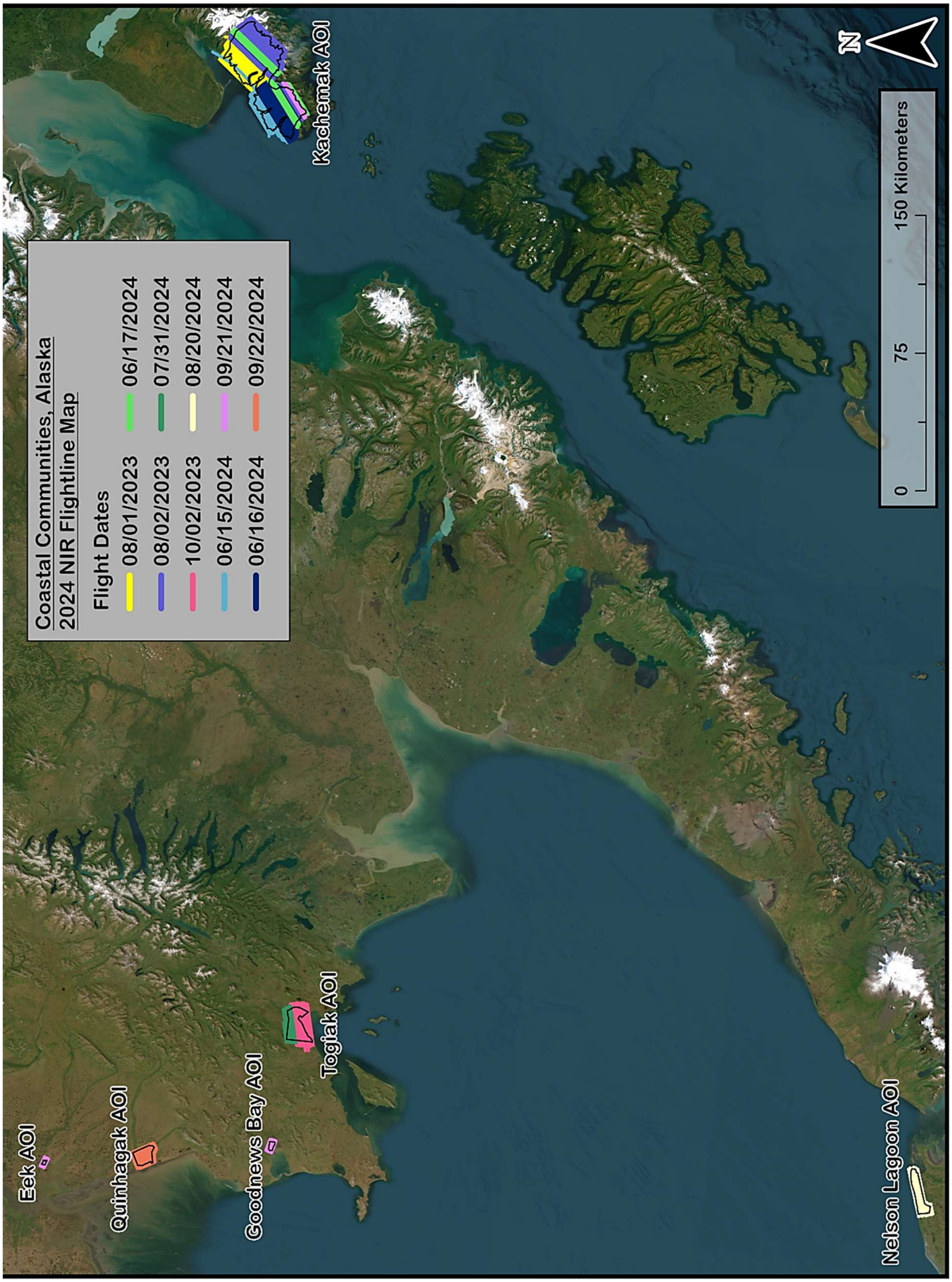


Figure 2: Flightlines map

Ground Survey

Ground control surveys, including monumentation and ground survey points (GSPs), Non-vegetated Vertical Accuracy (NVA) points, and Vegetated Vertical Accuracy (VVA) points were conducted by DOWL to support NV5's airborne acquisition (Figure 4). Ground control data was used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final lidar data. Please reference DOWL's ground survey reports (Appendix B - Ground Survey Reports) for more detailed information on how the survey was conducted and controlled.

Base station locations were selected by DOWL with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. Table 6 and Figure 4 show the location of each base station.

Figure 3: Photo of ground survey base station Qunihagak-401 taken by DOWL

Table 6: Base station positions for the Coastal Communities acquisition. Coordinates are on the NAD83 (2011) datum, epoch 2010.00

Monument ID	Latitude	Longitude	Ellipsoid (meters)
Dillingham-411	59° 14' 10.03021"	-158° 39' 58.15282"	59.562
Aleknagik-412	59° 04' 41.32448"	-158° 35' 10.58851"	62.599
Ekwok-413	59° 21' 08.82551"	-157° 28' 25.44266"	49.077
Koliganek-414	59° 43' 34.00243"	-157° 16' 00.30985"	83.722
Manokotak-415	58° 58' 30.85932"	-159° 03' 03.34850"	26.923
Clark's Point-416	58° 50' 11.55197"	-158° 31' 45.60747"	31.111
New Stuyakok-417	59° 27' 23.51430"	-157° 22' 32.91190"	126.885
KEK A (PID DK2876)	59° 21' 07.10402"	-157° 28' 38.78147"	48.053
JZZ A (PID DP6584)	59° 43' 34.65294"	-157° 15' 47.71846"	85.174
MBA B (PID DL7269)	58° 56' 01.88055"	-158° 53' 45.75903"	44.090
CLARK AZ (PID UV7281)	58° 50' 35.46064"	-158° 33' 16.11370"	19.389
1277-3-84 (PID BBBJ80)	59° 02' 14.75487"	-158° 28' 31.26293"	20.543
TWIN-1	59° 04' 25.61810"	-160 16' 37.93640"	33.639
EEK-401	60° 12' 53.84677"	-162° 02' 28.73977"	17.894
GOODNEWS-401	59° 07' 17.73812"	-161° 34' 22.23699"	51.252
NELSON-1	56° 00' 24.21454"	-161° 10' 00.54450"	17.788
QUNIHAGAK-401	59° 44' 53.93521"	-161° 52' 46.95128"	21.318
TOGIAK-551	59° 03' 10.65380"	-160° 23' 42.11974"	18.177
NANWALEK-401	59° 21' 17.18126"	-151° 55' 19.79701"	17.483
PORT GRAHAM-402	59° 20 42.80205"	-151° 49' 32.35612"	31.518
PORT GRAHAM-403	59° 17' 23.51534"	-151° 40' 41.99750"	88.262
SELDOVIA-404	59° 26' 21.56169"	-151° 42' 59.82336"	27.181

Land Cover Class

In addition to ground survey points, land cover class checkpoints were collected by DOWL throughout the study areas to evaluate vertical accuracy. Vertical accuracy statistics were calculated for all land cover types to assess confidence in the lidar derived ground models across land cover classes (Table 7, see Lidar Accuracy Assessments, page 26).

Table 7: Land Cover Types and Descriptions

Land cover type	Land cover code	Example	Description	Accuracy Assessment Type
Bare Earth	BE		Areas of bare soil, sand, and rocks where there is little or no natural vegetation	NVA
Shrub	SH		Low growth shrub	VVA
Tall Grass	TG		Herbaceous grasslands in advanced stages of growth	VVA
Forest	FR		Forested areas	VVA
Tundra	TU		Terrain with low-lying vegetation like mosses, lichens, small shrubs, and herbs	VVA

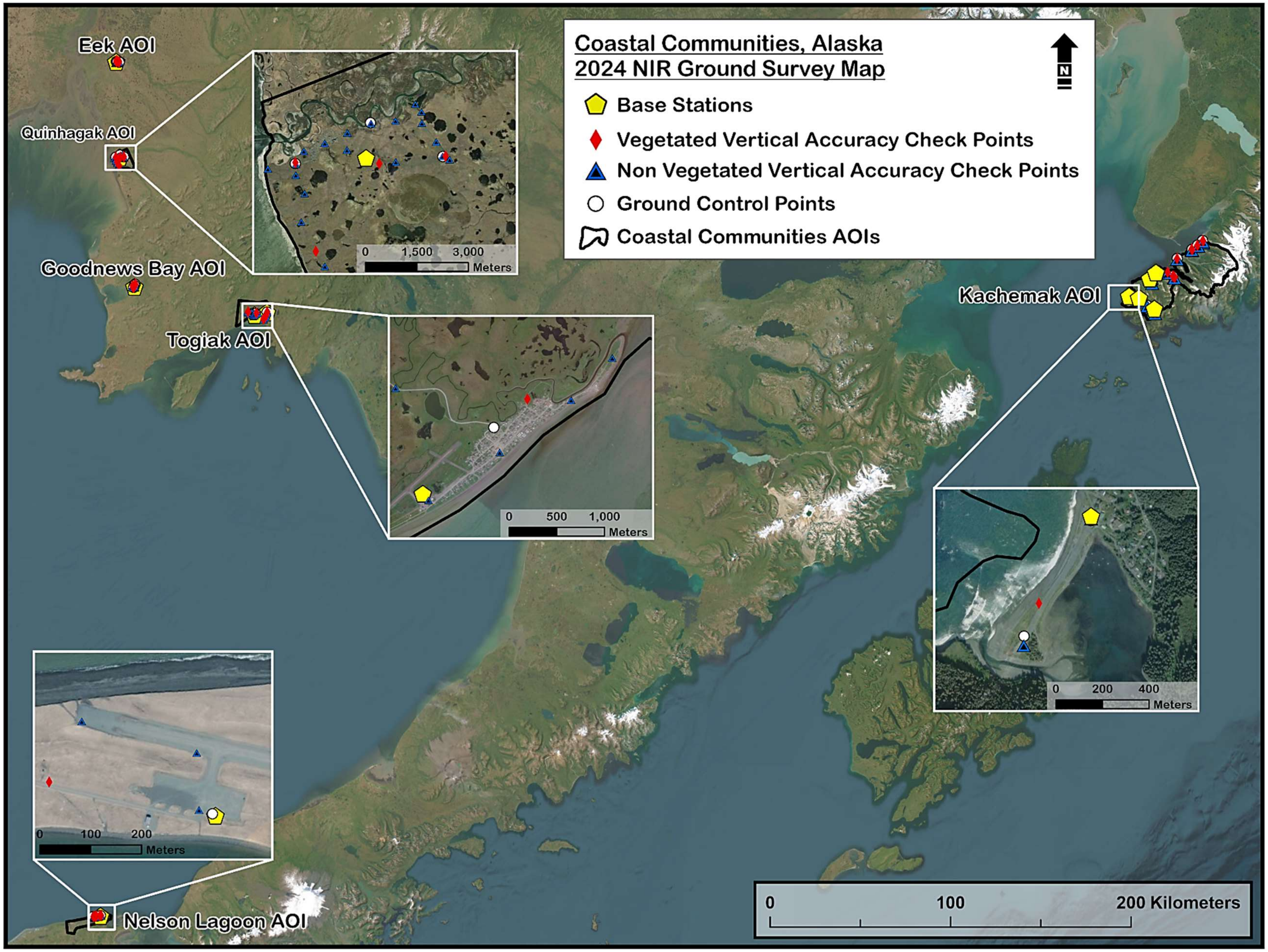


Figure 4: Ground survey location map

This 2 meter lidar cross section shows a view of the river that runs alongside the Twin Hills community in the Togiak AOI, colored by point classification.

NIR Lidar Data

Upon completion of data acquisition, NV5 processing staff initiated a suite of automated and manual techniques to process the data into the requested deliverables. Processing tasks included GPS control computations, smoothed best estimate trajectory (SBET) calculations, kinematic corrections, calculation of laser point position, sensor and data calibration for optimal relative and absolute accuracy, and lidar point classification (Table 8). Processing methodologies were tailored for the landscape. Brief descriptions of these tasks are shown in Table 9.

Table 8: ASPRS LAS classification standards applied to the Coastal Communities dataset

Classification Number	Classification Name	Point Count	Classification Description
1	Default/Unclassified	14,275,311,357	Laser returns that are not included in the ground class, composed of vegetation and anthropogenic features
2	Ground	5,600,824,856	Laser returns that are determined to be ground using automated and manual cleaning algorithms
5	Vegetation	11,062,141,857	2-meter height threshold
6	Buildings	5,465,122	Permanent roofed structures larger than 100 ft^2

Classification Number	Classification Name	Point Count	Classification Description
7W	Noise	85,457,574	Laser returns that are often associated with birds, scattering from reflective surfaces, or artificial points below the ground surface
9	Water	163,385,045	Laser returns that are determined to be water using automated and manual cleaning algorithms
17	Bridge	82,917	Bridge decks
18W	High Noise	15,067,886	Laser returns that are often associated with birds, scattering from reflective surfaces.
20	Ignored Ground	2,756,754	Ground points proximate to water's edge breaklines; ignored for correct model creation
21	Snow	1,246,460,203	Laser returns in the presence of identifiable snow.
22	Temporal Exclusion	422,464,433	Laser returns that are determined to be due to temporal differences in flightlines and are excluded from model creation.

Table 9: Lidar processing workflow

Lidar Processing Step	Software Used
Resolve kinematic corrections for aircraft position data using kinematic aircraft GPS and static ground GPS data. Develop a smoothed best estimate of trajectory (SBET) file that blends post-processed aircraft position with sensor head position and attitude recorded throughout the survey.	POSPac MMS v.9.1
Calculate laser point position by associating SBET position to each laser point return time, scan angle, intensity, etc. Create raw laser point cloud data for the entire survey in *.las (ASPRS v. 1.4) format. Convert data to orthometric elevations by applying a geoid correction.	RiUnite v.1.0.5
Import raw laser points into manageable blocks to perform manual relative accuracy calibration and filter erroneous points. Classify ground points for individual flight lines.	TerraScan v.19.005
Using ground classified points per each flight line, test the relative accuracy. Perform automated line-to-line calibrations for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Calculate calibrations on ground classified points from paired flight lines and apply results to all points in a flight line. Use every flight line for relative accuracy calibration.	StripAlign v.2.24
Classify resulting data to ground and other client designated ASPRS classifications (Table 8). Assess statistical absolute accuracy via direct comparisons of ground classified points to ground control survey data.	TerraScan v.19.005 TerraModeler v.19.003
Generate bare earth models as triangulated surfaces. Generate Maximum Surface Height Rasters as a surface expression of all classified points. Export all surface models as Cloud Optimized GeoTIFFs at a meter pixel resolution.	LAS Product Creator 4.0 (NV5 proprietary)
Export ground surface classified points as point shapefiles to derive TIN models	Las Monkey v.2.6.9 (NV5 proprietary)
Correct intensity values for variability and export intensity images as Cloud Optimized GeoTIFFs at a 0.5 meter pixel resolution.	Las Monkey 2.6.9 (NV5 proprietary) LAS Product Creator 4.0 (NV5 proprietary)

Feature Extraction

Hydroflattening and Water's Edge Breaklines

Water bodies within the project area were flattened to levels consistent with heights observed during collection. These include lakes and other closed-bodies with a surface area greater than 2 acres, streams and rivers nominally wider than 30 meters, all non-tidal and tidal waters bordering the project, and select smaller bodies of water as feasible. The hydroflattening process eliminates artifacts in the digital terrain model caused by both increased variability in ranges and dropouts in laser returns due to the low reflectivity of water.

Hydroflattening was performed through a combination of automated and manual detection and adjustment techniques designed to identify water boundaries and water levels. Boundary polygons were developed using an algorithm which weights lidar-derived slopes, intensities, and return densities to detect the water's edge. The water edges were then manually reviewed and edited as necessary. Specific care was taken to not hydroflatten wetland and marsh habitat found throughout the study site.

Once polygons were developed, the initial ground classified points falling within water polygons were reclassified as water points to omit them from the final ground model. Elevations were then obtained from the filtered lidar returns to create the final breaklines. Lakes were assigned a consistent elevation for an entire polygon while rivers were assigned consistent elevations on opposing banks and smoothed to ensure downstream flow through the entire river channel. Coastal waters were assigned elevations optimized for maximal shoreline exposure. In areas with extreme tidal variation, including Kachemak Bay (>4.5m mean range), this consideration can lead to visible "breaks" in the interpolated water surface.

Water boundary breaklines were then incorporated into the hydroflattened DEM by enforcing triangle edges (adjacent to the breakline) to the elevation values of the breakline. This implementation corrected interpolation along the hard edge. Water surfaces were obtained from a TIN of the 3-D water edge breaklines resulting in the final hydroflattened model (Figure 5).

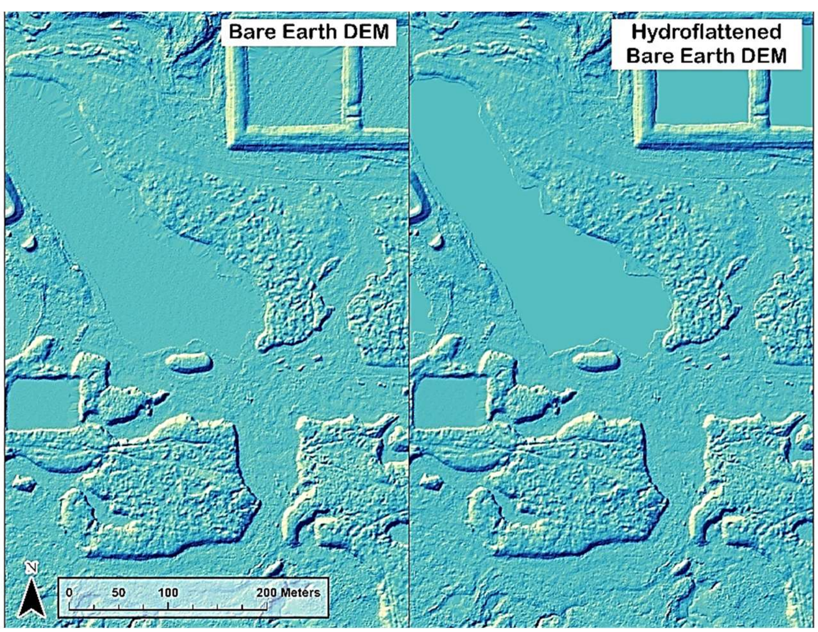


Figure 5: Example of hydroflattening in the Coastal Communities Lidar dataset

Intensity Image Processing

Intensity images represent reflectivity values collected by the lidar sensor during acquisition. NV5 Geospatial proprietary software generates intensity images using all valid first returns and excluding those flagged with a withheld bit. Intensity images are linearly scaled to a value range specific to the project area and sensor to standardize the images and reduce differences between individual flightlines. Appropriate horizontal projection information as well as applicable header values are written during product generation.

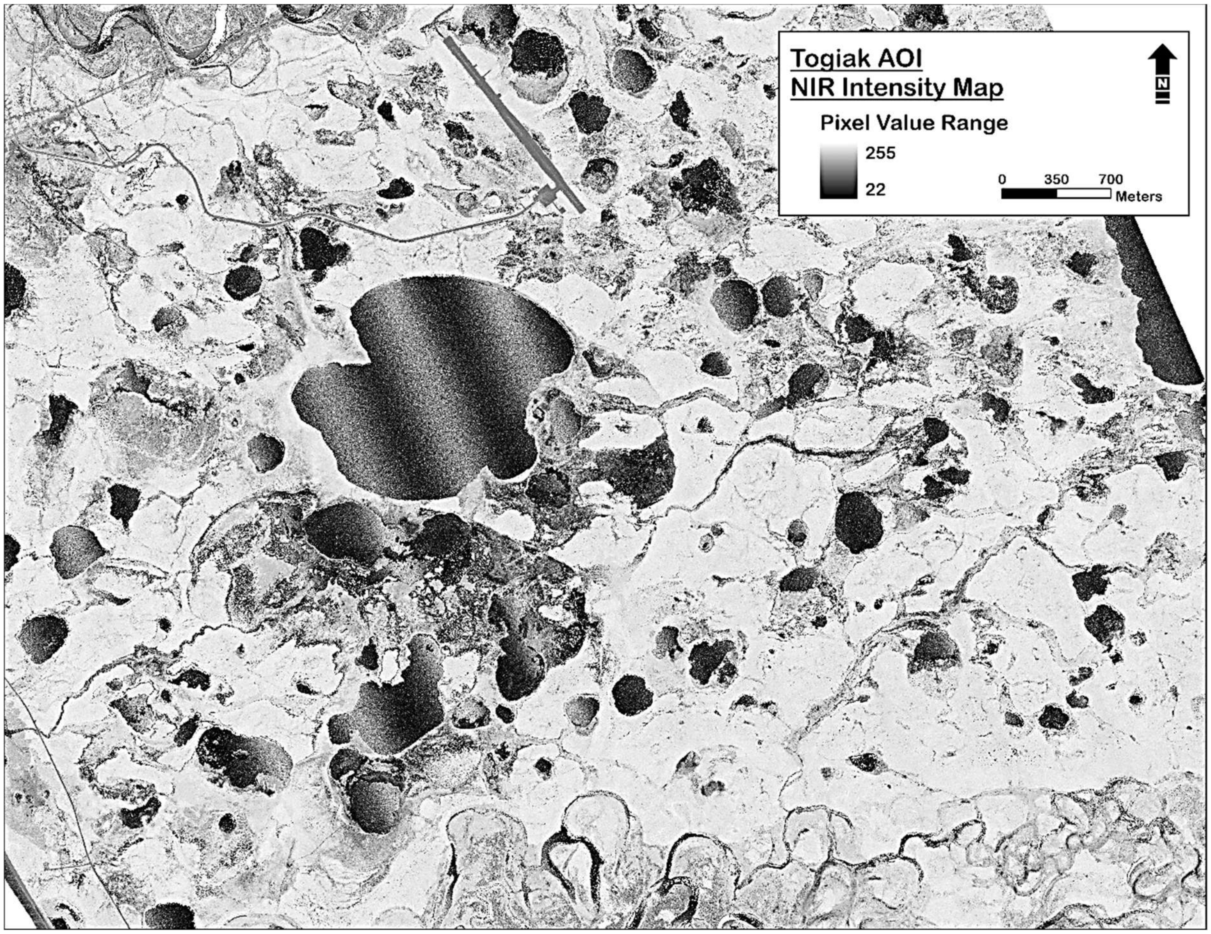


Figure 6: Example of intensity image viewing the Togiak AOI

Swath Separation Raster Processing

Swath Separation Images are rasters that represent the interswath alignment between flight lines and provide a qualitative evaluation of the positional quality of the point cloud. NV5 Geospatial proprietary software generated 1 meter raster images in GeoTIFF format using all returns from all the classes (Figure 7), excluding temporal classification and points flagged with the withheld bit, and using a grid based average algorithm. Images are generated with 50% intensity opacity and four absolute 8 cm intervals (see Figure 7 below for interval coloring). Intensity images are linearly scaled to a value range specific to the project area and sensor to standardize the images and reduce differences between individual flightlines. Appropriate horizontal projection information as well as applicable header values are written to the file during product generation.

(green)	0-8cm
(yellow)	8-16cm
(orange)	16-24cm
(red)	>24cm

Figure 7: Swath separation raster color ramp values used in the Coastal Communities project

Maximum Surface Height Raster (MSHR) Processing

MSHRs (topographic) represent a lidar-derived product illustrating natural and built-up features. NV5 proprietary software was used to take all valid classified lidar points, excluding those flagged with a withheld bit, and create a raster on a tile-by-tile basis. A 32-bit floating point GeoTIFF was generated for each tile with a pixel size of 1 meter, which meets the requirements set by USGS that states that the resolution of the MSRH be twice that of the bare earth DEM. NV5 proprietary software was used to write appropriate horizontal and vertical projection information as well as applicable header values into the file during product generation. Each maximum surface height raster is reviewed in ESRI ArcGIS Pro to check for any anomalies and to ensure a seamless dataset.

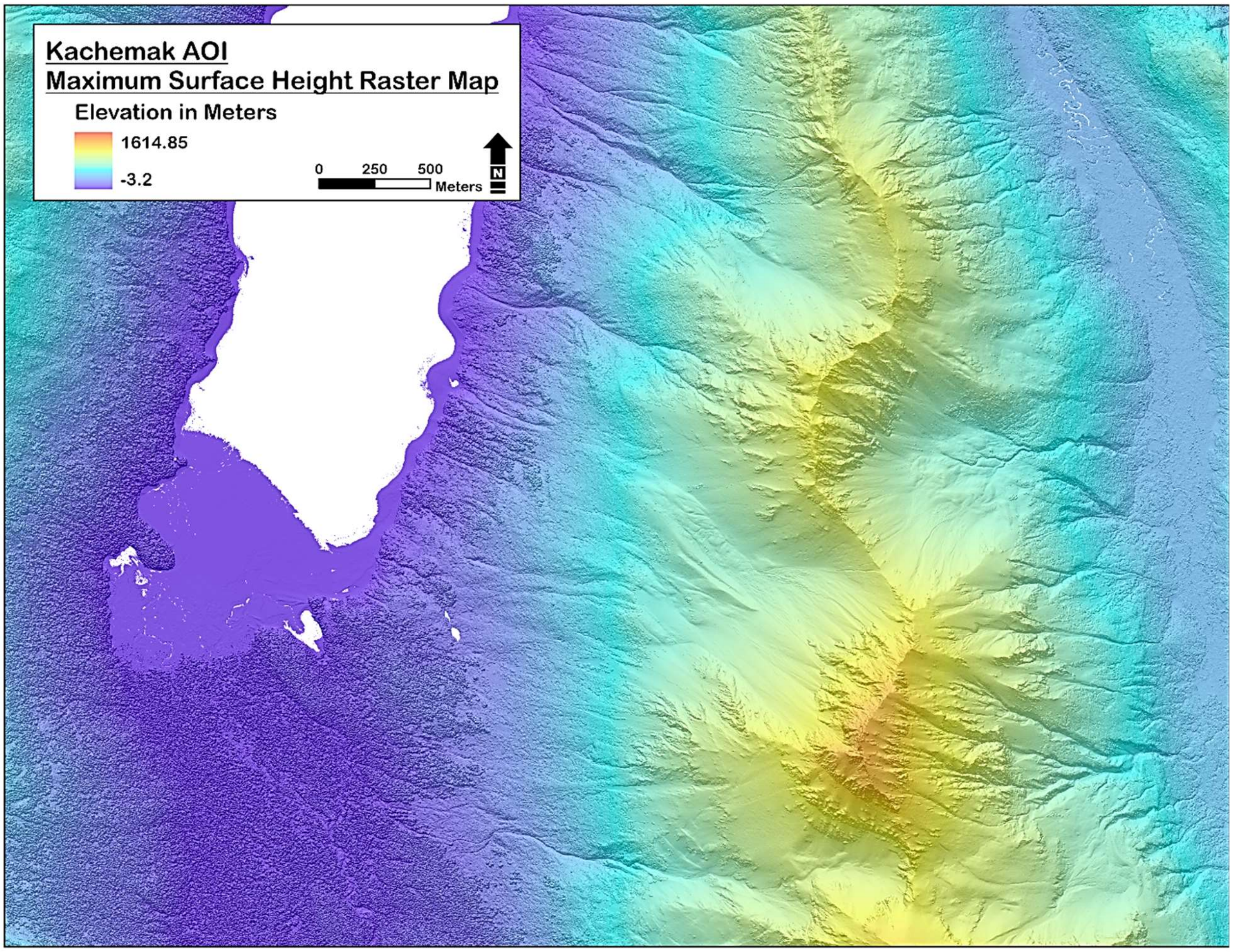


Figure 8: Example of MSHR model viewing the Kachemak AOI with Sadie Peak at 1,317 meters elevation to the southeast

Buildings

Anthropogenic feature classification was performed through a combination of automated algorithms and manual classification. Typically, manual editing of the buildings and other anthropogenic feature classification was necessary where dense canopy was immediately proximate to a given feature. All anthropogenic features > 2m above the surface were classified into the building category (Figure 9).

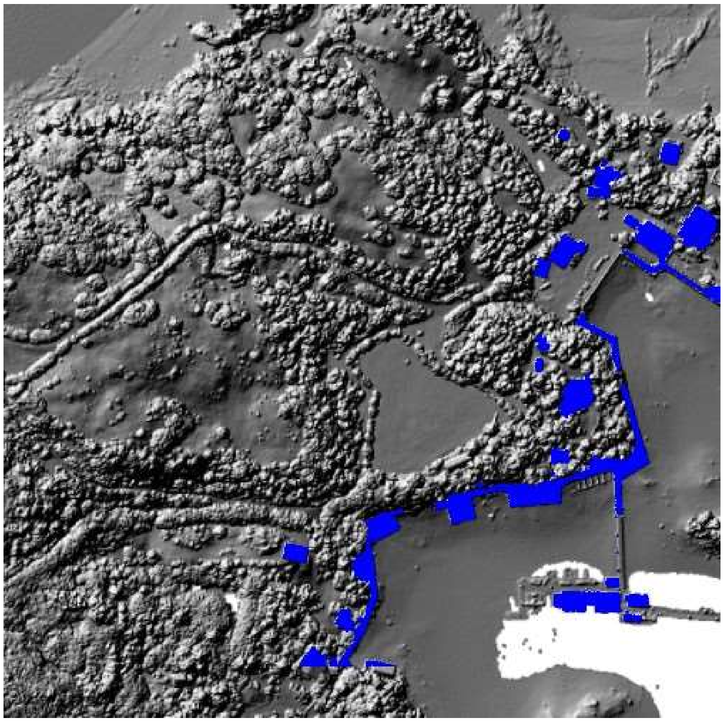
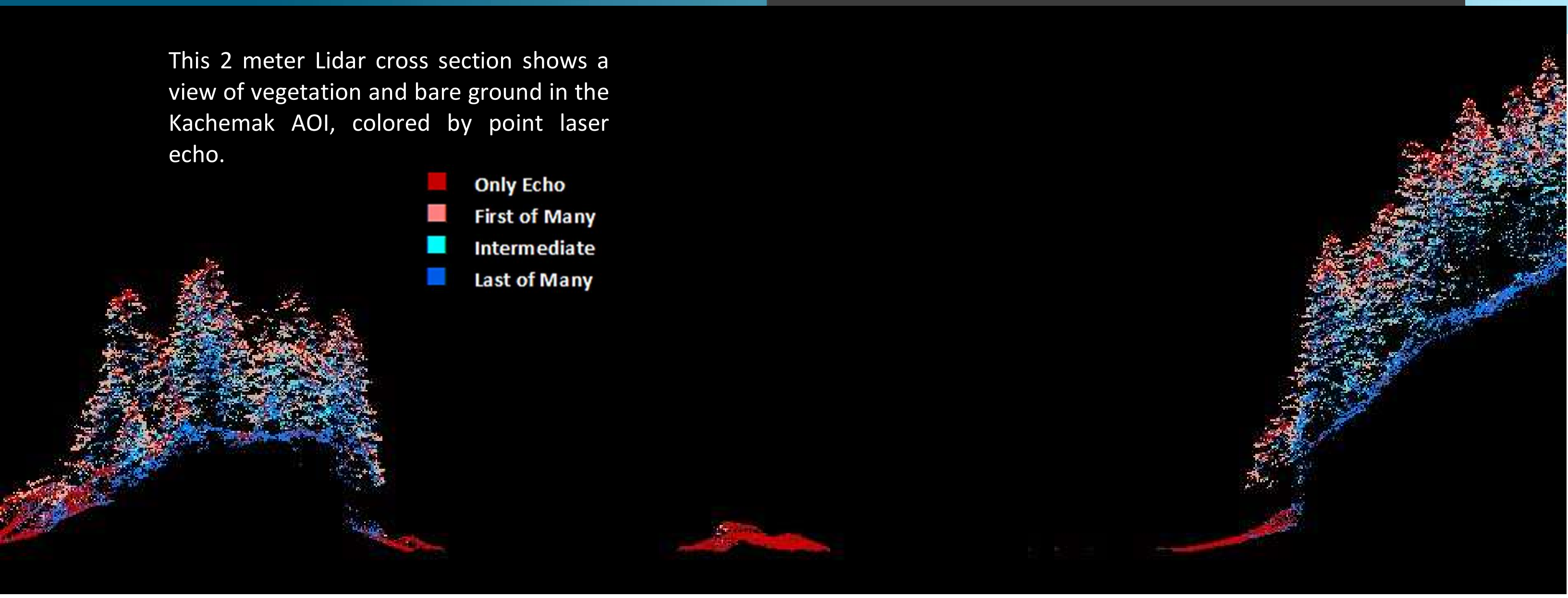


Figure 9: Sample image of building classification on the west Ismailof Island in Halibut Cove part of the Kachemak AOI dataset



This 2 meter Lidar cross section shows a view of vegetation and bare ground in the Kachemak AOI, colored by point laser echo.

Lidar Density

The acquisition parameters were designed to acquire an average first-return density of 8 points/m^2. First return density describes the density of pulses emitted from the laser that return at least one echo to the system. Multiple returns from a single pulse were not considered in first return density analysis. Some types of surfaces (e.g., breaks in terrain, water and steep slopes) may have returned fewer pulses than originally emitted by the laser.

First returns typically reflect off the highest feature on the landscape within the footprint of the pulse. In forested or urban areas, the highest feature could be a tree, building, or power line, while in areas of unobstructed ground, the first return will be the only echo and represents the bare earth surface.

The density of ground-classified lidar returns was also analyzed for this project. Terrain character, land cover, and ground surface reflectivity all influenced the density of ground surface returns. In vegetated areas, fewer pulses may penetrate the canopy, resulting in lower ground density.

The average first-return density of lidar data for UTM Zone 4 of the Coastal Communities project was 11.25 points/m^2 while the average ground classified density was 3.92 points/m^2 (Table 10). The statistical and spatial distributions of first return densities and classified ground return densities per 100 m x 100 m cell are portrayed in Figure 10 through Figure 12.

The average first-return density of lidar data for UTM Zone 5 of the Coastal Communities project was 18.25 points/m^2 while the average ground classified density was 4.71 points/m^2 (Table 11). The statistical and spatial distributions of first return densities and classified ground return densities per 100 m x 100 m cell are portrayed in Figure 13 through Figure 15.

Table 10: Average lidar point densities for UTM Zone 4

Classification	Point Density
First-Return	11.25 points/m^2
Ground Classified	3.92 points/m^2

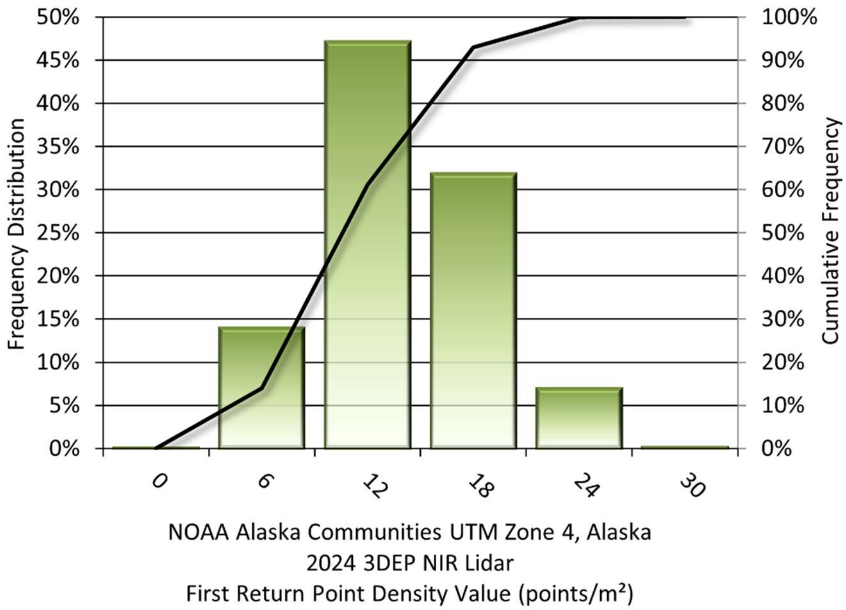


Figure 10: Frequency distribution of first return point density for UTM Zone 4 values per 100 x 100 m cell

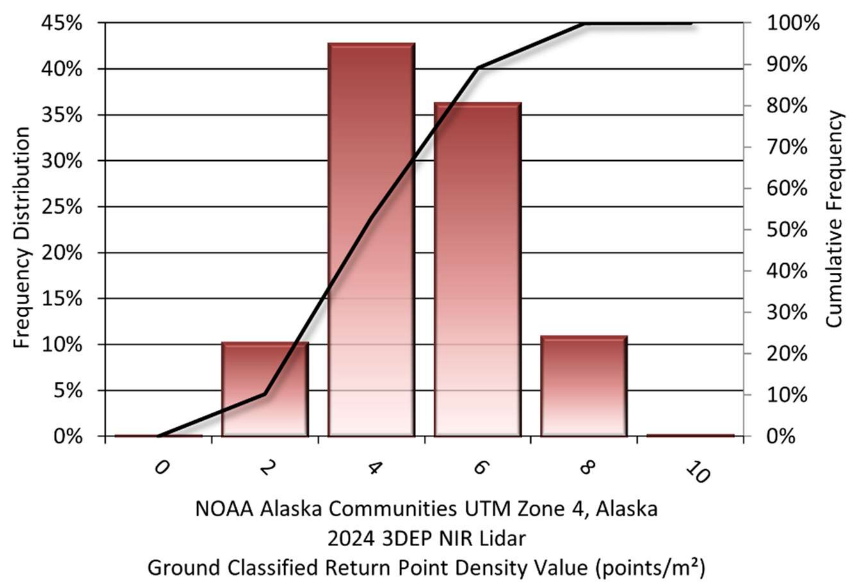


Figure 11: Frequency distribution of ground-classified return point density values for UTM Zone 4 per 100 x 100 m cell

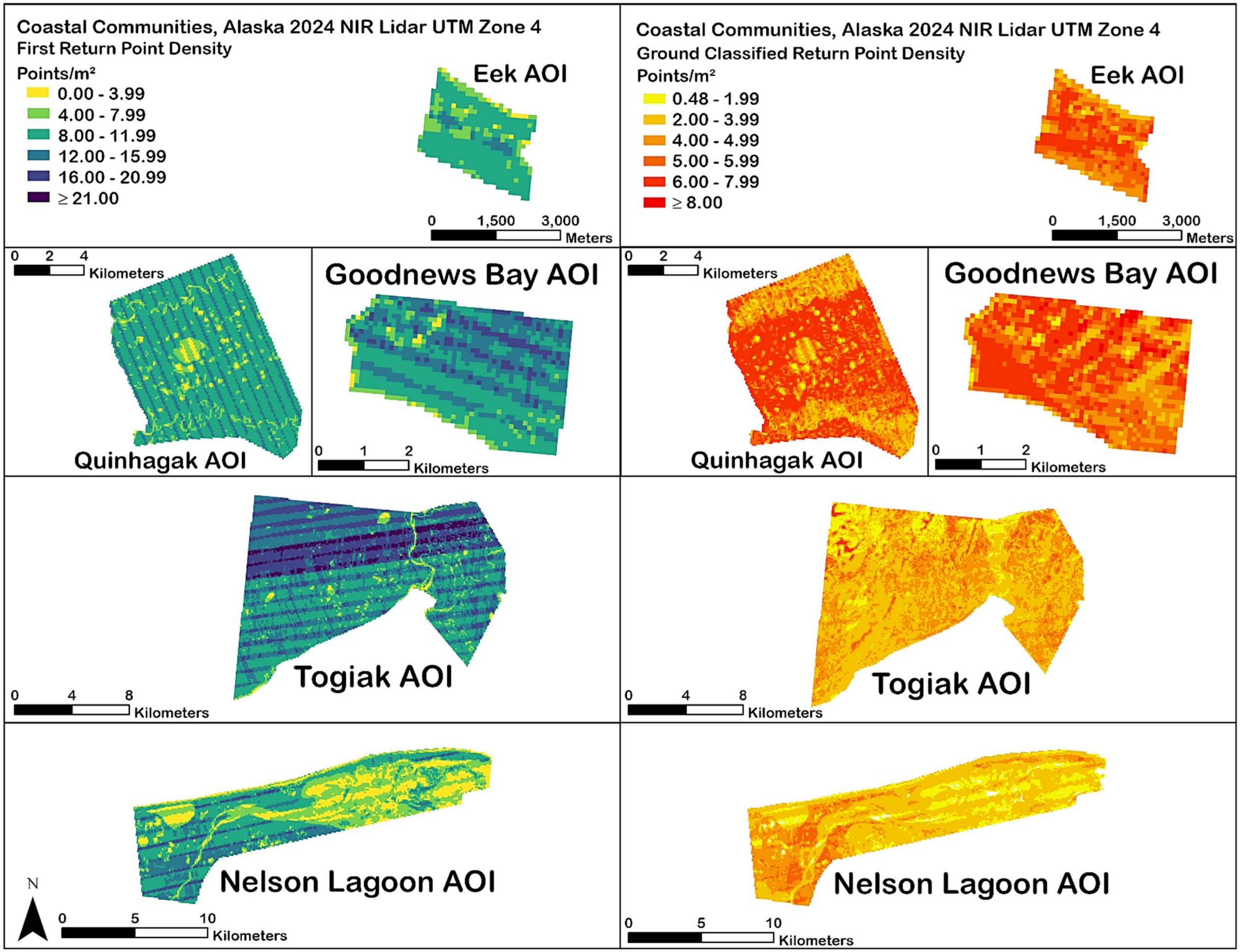


Figure 12: First return and ground-classified point density map of UTM Zone 4 for the Coastal Communities project (100 m x 100 m cells)

Table 11: Average lidar point densities for UTM Zone 5

Classification	Point Density
First-Return	18.25 points/m^2
Ground Classified	4.71 points/m^2

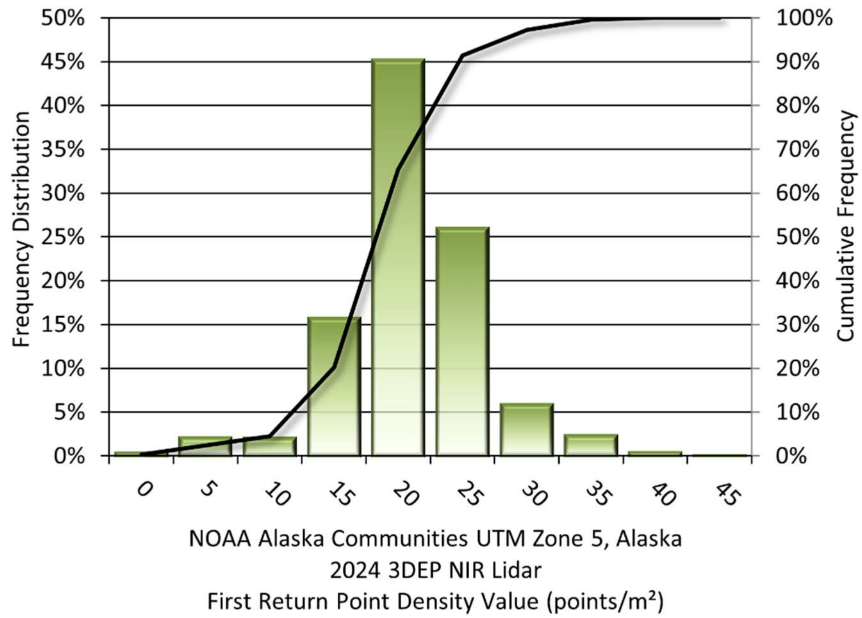


Figure 13: Frequency distribution of first return point density values for UTM Zone 5 per 100 x 100 m cell

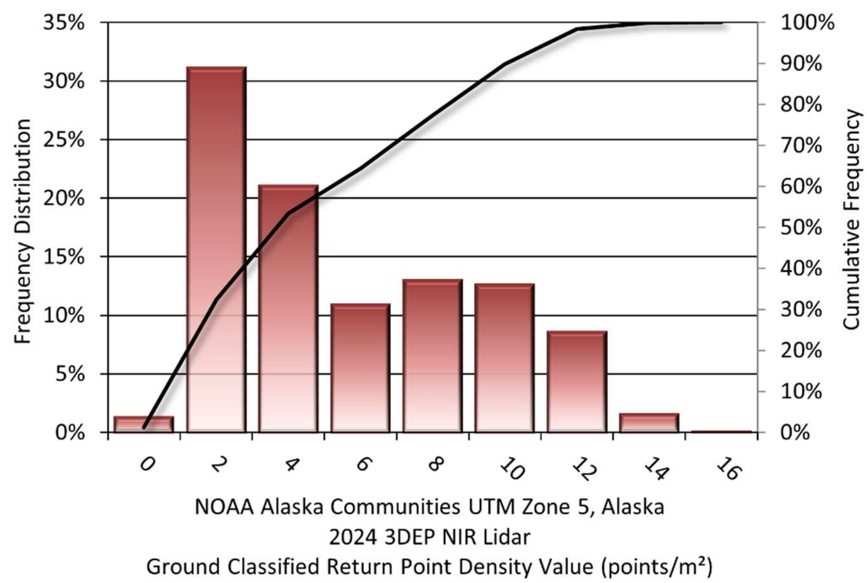


Figure 14: Frequency distribution of ground-classified return point density values for UTM Zone 5 per 100 x 100 m cell

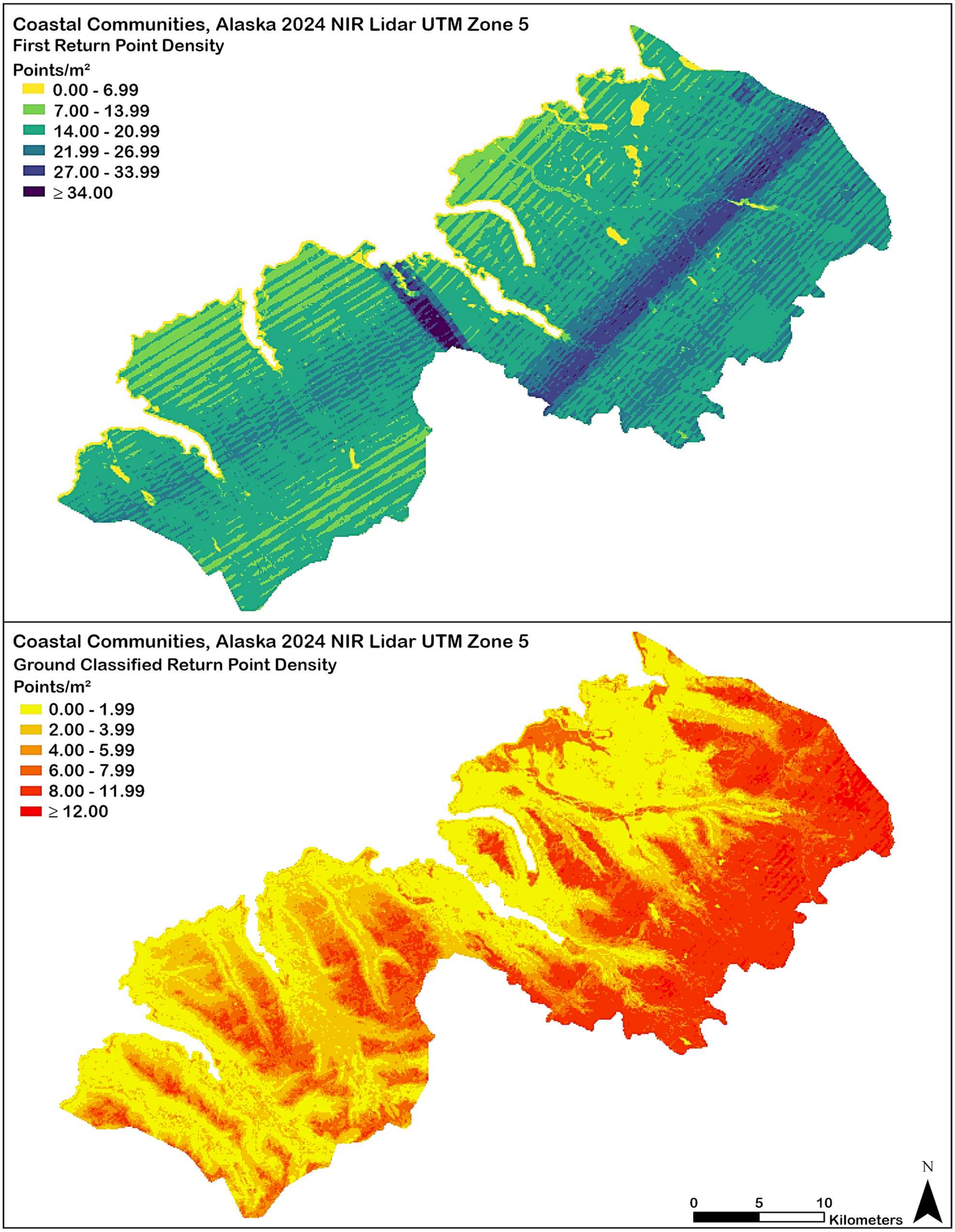


Figure 15: First return and ground-classified point density map for the Coastal Communities site (100 m x 100 m cells)

Lidar Accuracy Assessments

The accuracy of the lidar data collection can be described in terms of absolute accuracy (the consistency of the data with external data sources) and relative accuracy (the consistency of the dataset with itself). See Appendix A for further information on sources of error and operational measures used to improve relative accuracy.

Lidar Non-Vegetated Vertical Accuracy

Absolute accuracy was assessed using Non-Vegetated Vertical Accuracy (NVA) reporting designed to meet guidelines presented in the FGDC National Standard for Spatial Data Accuracy[1]. NVA compares known ground check point data that were withheld from the calibration and post-processing of the lidar point cloud to the triangulated surface generated by the classified lidar point cloud as well as the derived gridded bare earth DEM. NVA is a measure of the accuracy of lidar point data in open areas where the lidar system has a high probability of measuring the ground surface and is evaluated at the 95% confidence interval (1.96 * RMSE). For the Coastal Communities project, NVA statistics were calculated separately for each project site (Table 12) and again for each UTM zone (Table 13 and Table 14).

The mean and standard deviation (sigma, σ) of divergence of the ground surface model from quality assurance point coordinates are also considered during accuracy assessment. The number of points evaluated for NVA is large enough that the error for x, y, and z is approximately normally distributed. The skew and kurtosis of distributions are also considered when evaluating error statistics in order to better evaluate the magnitude and distribution of the estimated error.

For the Coastal Communities UTM Zone 4 survey, 101 ground checkpoints were withheld from the calibration and post processing of the lidar point cloud, with resulting non-vegetated vertical accuracy of 0.061 meters as compared to classified LAS, and 0.060 meters as compared to the bare earth DEM, with 95% confidence (Figure 16, Figure 17).

For the Coastal Communities UTM Zone 5 survey, 43 ground checkpoints were withheld from the calibration and post processing of the lidar point cloud, with resulting non-vegetated vertical accuracy of 0.089 meters as compared to classified LAS, and 0.095 meters as compared to the bare earth DEM, with 95% confidence (Figure 18, Figure 19).

NV5 also assessed absolute accuracy using 15 ground control points for UTM Zone 4 and 17 ground control points for UTM Zone 5. Although these points were used in the calibration and post-processing of the lidar point cloud, they still provide a good indication of the overall accuracy of the lidar dataset, and therefore have been provided in Figure 20 for UTM Zone 4 and Figure 21 for UTM Zone 5.

[1] Federal Geographic Data Committee, ASPRS POSITIONAL ACCURACY STANDARDS FOR DIGITAL GEOSPATIAL DATA EDITION 1, Version 1.0, NOVEMBER 2014. https://www.asprs.org/a/society/committees/standards/Positional_Accuracy_Standards.pdf.

Table 12: Non vegetated vertical accuracy results as compared to the classified LAS per project site

UTM	Project Site	Number of Sample Points	95% Confidence (1.96*RMSE)	Average	Median	RMSE	Standard Deviation
Zone 4	**Eek**	20	0.046 m	-0.017 m	-0.017 m	0.023 m	0.017 m
Zone 4	**Quinhagak**	20	0.077 m	0.008 m	0.012 m	0.039 m	0.039 m
Zone 4	**Goodnews Bay**	20	0.032 m	-0.008 m	-0.006 m	0.016 m	0.015 m
Zone 4	**Togiak**	21	0.074 m	-0.010 m	-0.006 m	0.038 m	0.037 m
Zone 4	**Nelson Lagoon**	20	0.063 m	0.027 m	0.029 m	0.032 m	0.017 m
Zone 5	**Kachemak**	43	0.089 m	0.003 m	0.010 m	0.046 m	0.046 m

Table 13: Absolute accuracy results for UTM Zone 4

Parameter	NVA, as compared to classified LAS	NVA, as compared to bare earth DEM	Ground Control Points
Sample	101 points	101 points	15 points
95% Confidence (1.96*RMSE)	0.061 m	0.060 m	0.036 m
Average	0.000 m	0.000 m	0.001 m
Median	0.003 m	0.000 m	0.003 m
RMSE	0.031 m	0.030 m	0.018 m

Table 14: Absolute accuracy results for UTM Zone 5

Parameter	NVA, as compared to classified LAS	NVA, as compared to bare earth DEM	Ground Control Points
Sample	43 points	43 points	17 points
95% Confidence (1.96*RMSE)	0.089 m	0.095 m	0.087 m
Average	0.003 m	0.004 m	-0.003 m
Median	0.010 m	0.012 m	0.010 m
RMSE	0.046 m	0.048 m	0.044 m

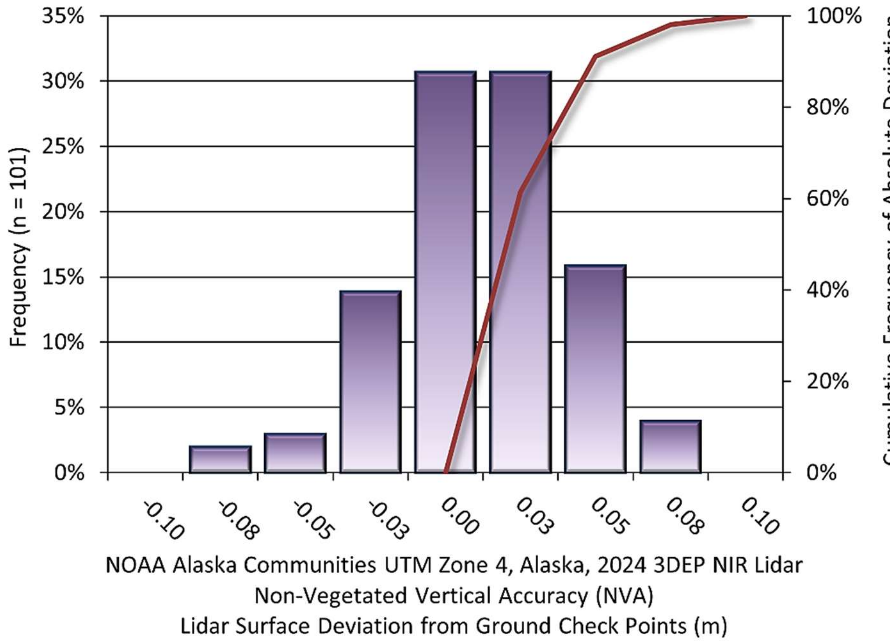


Figure 16: UTM Zone 4 histogram for lidar classified LAS deviation from NVA check points

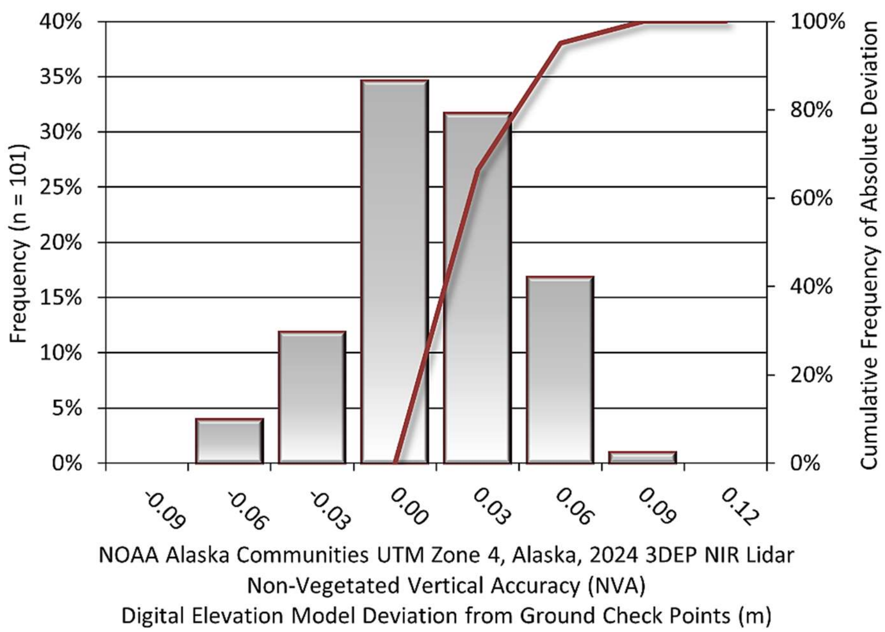


Figure 17: UTM Zone 4 histogram for the lidar bare earth DEM surface deviation from NVA check points

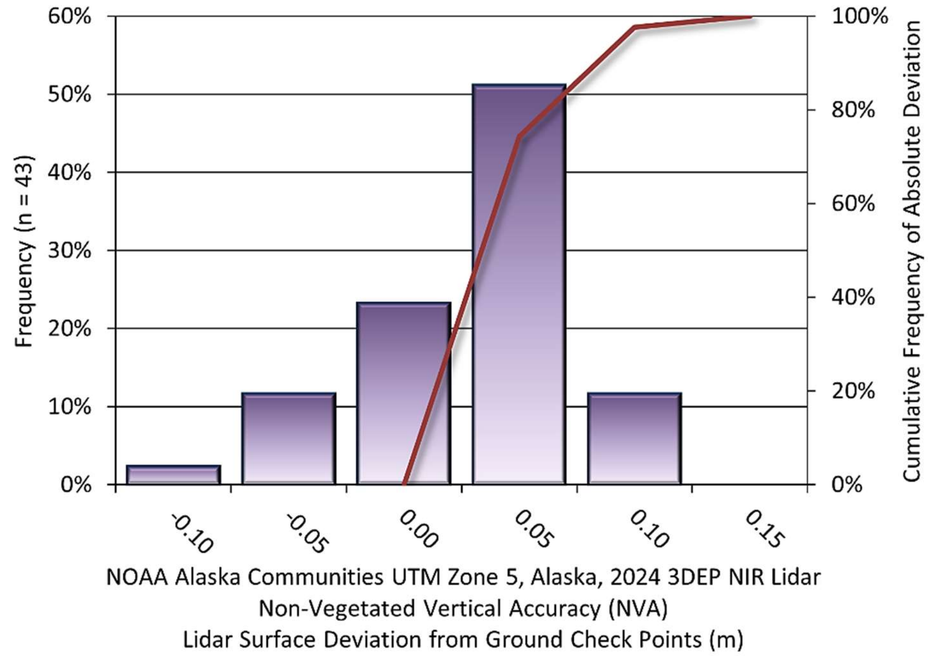


Figure 18: UTM Zone 5 histogram for lidar classified LAS deviation from NVA check points

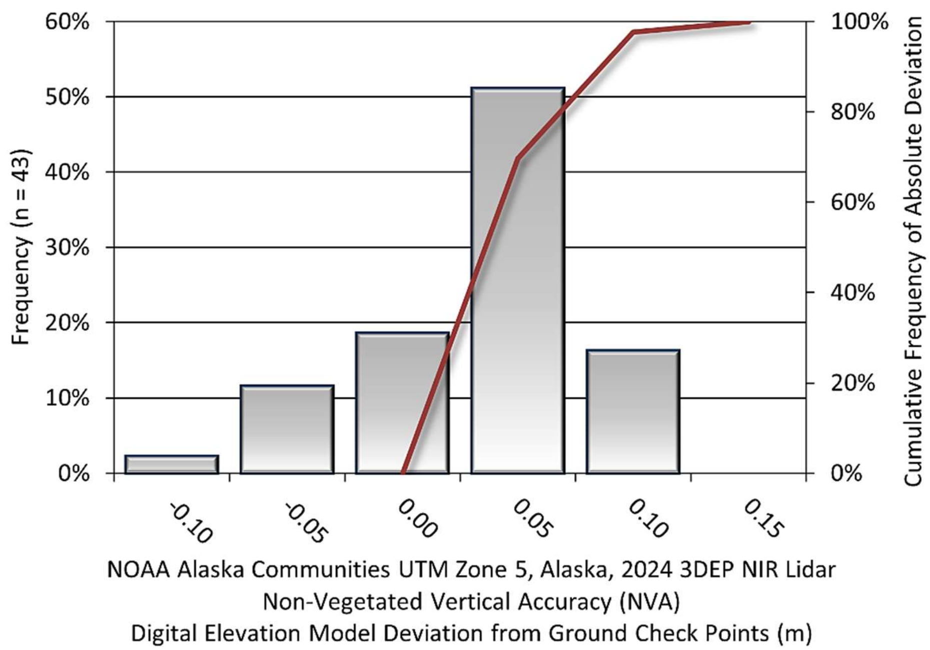


Figure 19: UTM Zone 5 histogram for the lidar bare earth DEM surface deviation from ground check points

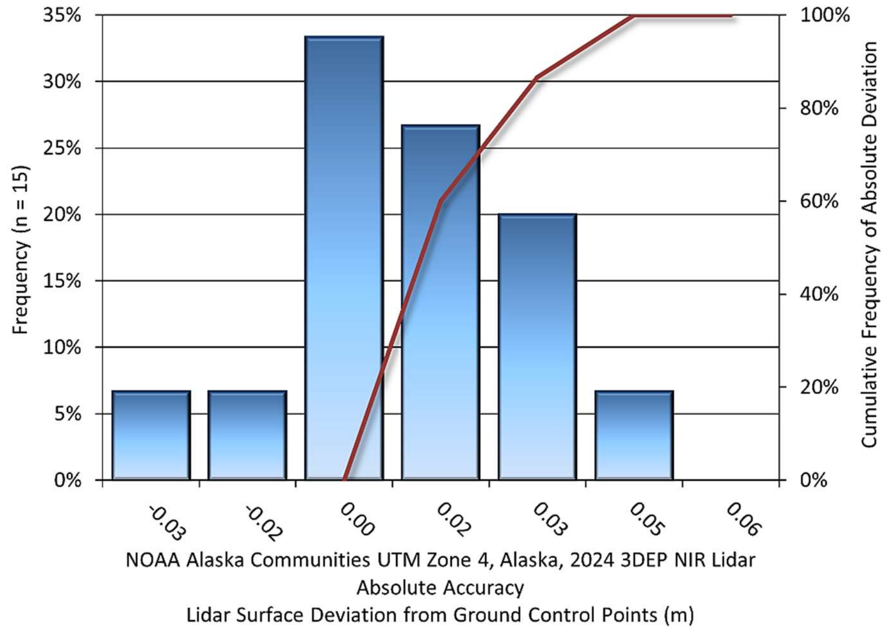


Figure 20: UTM Zone 4 histogram for the lidar surface deviation from ground control points

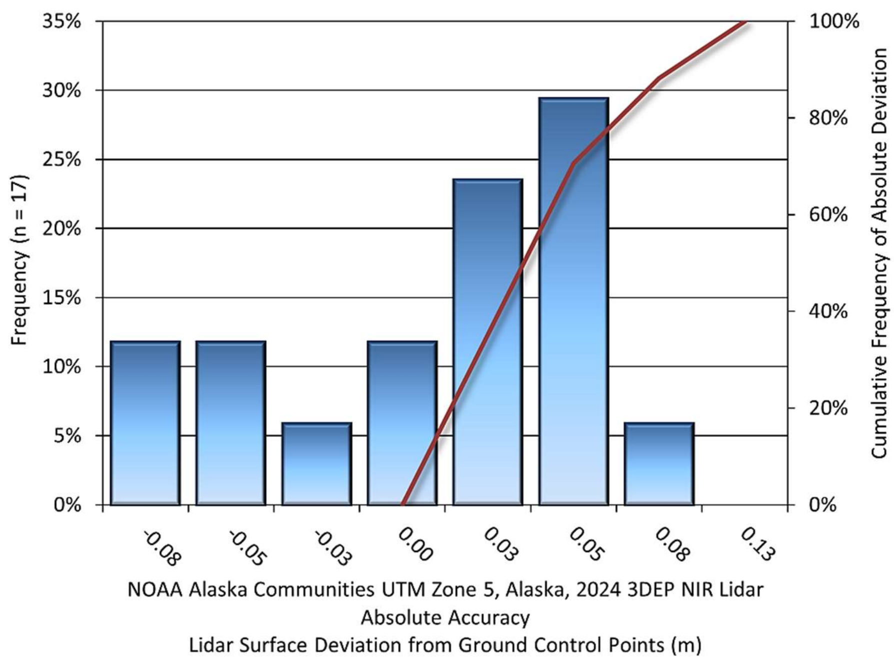


Figure 21: UTM Zone 5 histogram for the lidar surface deviation from ground control points

Lidar Vegetated Vertical Accuracies

NV5 also assessed vertical accuracy using Vegetated Vertical Accuracy (VVA) reporting. VVA compares known ground check point data collected over vegetated surfaces using land class descriptions to the triangulated ground surface generated by the ground classified lidar points. Unlike in non-vegetated areas, the errors associated with data collected in vegetated areas cannot be assumed to approximate a normal distribution. Therefore, accuracy in vegetated areas is evaluated using the 95th percentile (the value for which 95% of absolute values of errors will be less than or equal to) rather than the 95% confidence level.

For the Coastal Communities survey for UTM Zone 4, 26 vegetated checkpoints were collected, with resulting vegetated vertical accuracy of 0.257 meters as compared to the classified LAS, and 0.254 meters as compared to the bare earth DEM evaluated at the 95th percentile (Table 15, Figure 22, and Figure 23).

For the Coastal Communities survey for UTM Zone 5, 19 vegetated checkpoints were collected, with resulting vegetated vertical accuracy of 0.229 meters as compared to the classified LAS, and 0.258 meters as compared to the bare earth DEM evaluated at the 95th percentile (Table 16, Figure 24, and Figure 25).

Table 15: Vegetated vertical accuracy results for UTM Zone 4

Parameter	VVA, as compared to classified LAS	VVA, as compared to bare earth DEM
Sample	26 points	26 points
95th Percentile	0.257 m	0.254 m
Average	0.086 m	0.090 m
Median	0.058 m	0.060 m
RMSE	0.122 m	0.126 m
Standard Deviation (1σ)	0.088 m	0.090 m

Table 16: Vegetated vertical accuracy results for UTM Zone 5

Parameter	VVA, as compared to classified LAS	VVA, as compared to bare earth DEM
Sample	19 points	19 points
95th Percentile	0.229 m	0.258 m
Average	0.101 m	0.098 m
Median	0.108 m	0.115 m
RMSE	0.123 m	0.129 m
Standard Deviation (1σ)	0.072 m	0.086 m

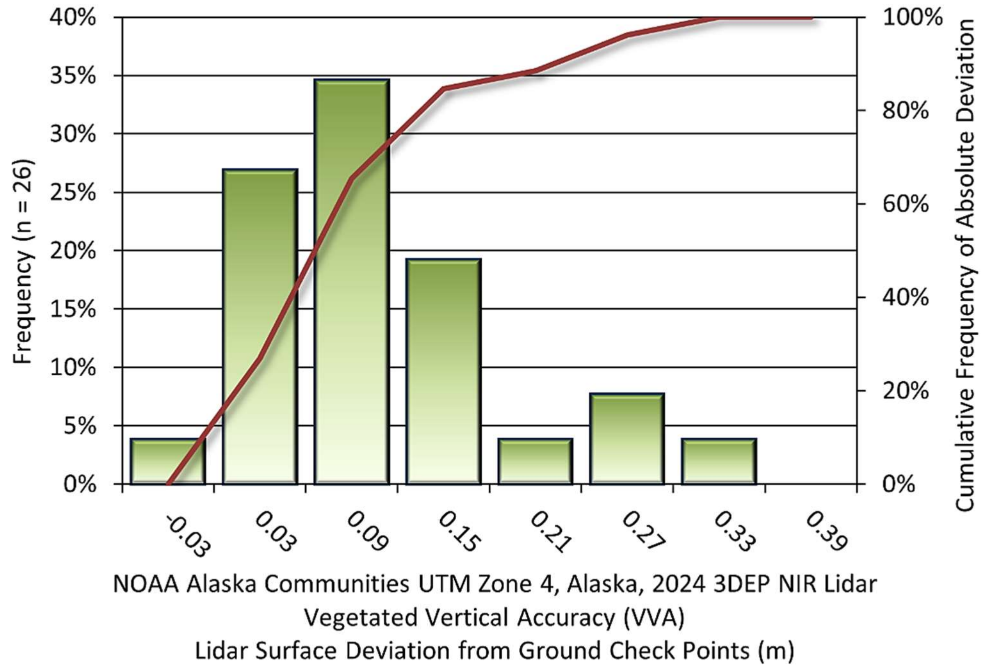


Figure 22: Frequency histogram for the lidar surface deviation from all land cover class point values (VVA) for UTM Zone 4

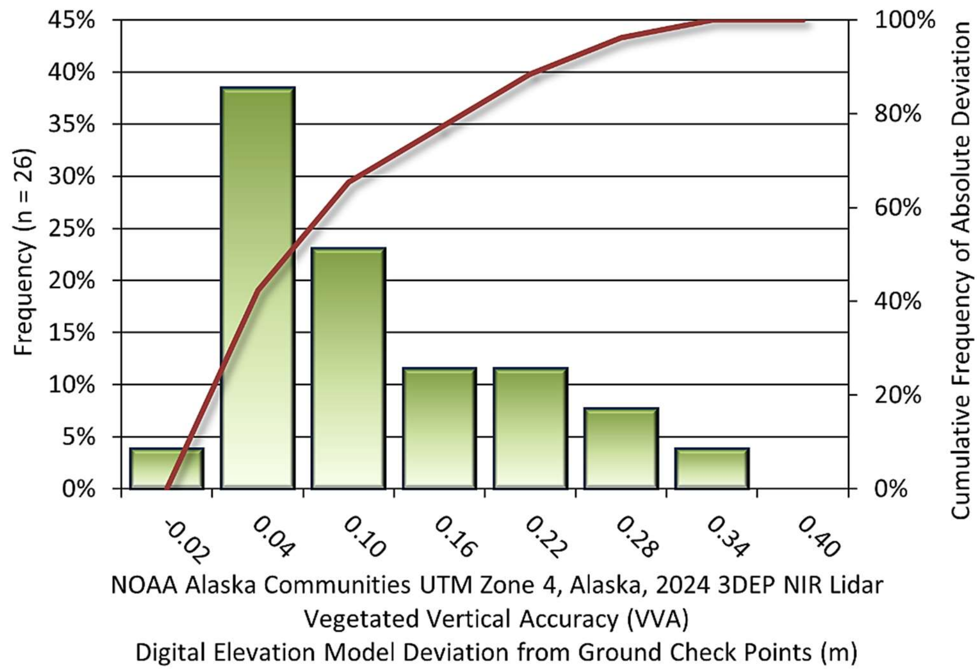


Figure 23: Frequency histogram for the lidar bare earth DEM deviation from vegetated check point values (VVA) for UTM Zone 4

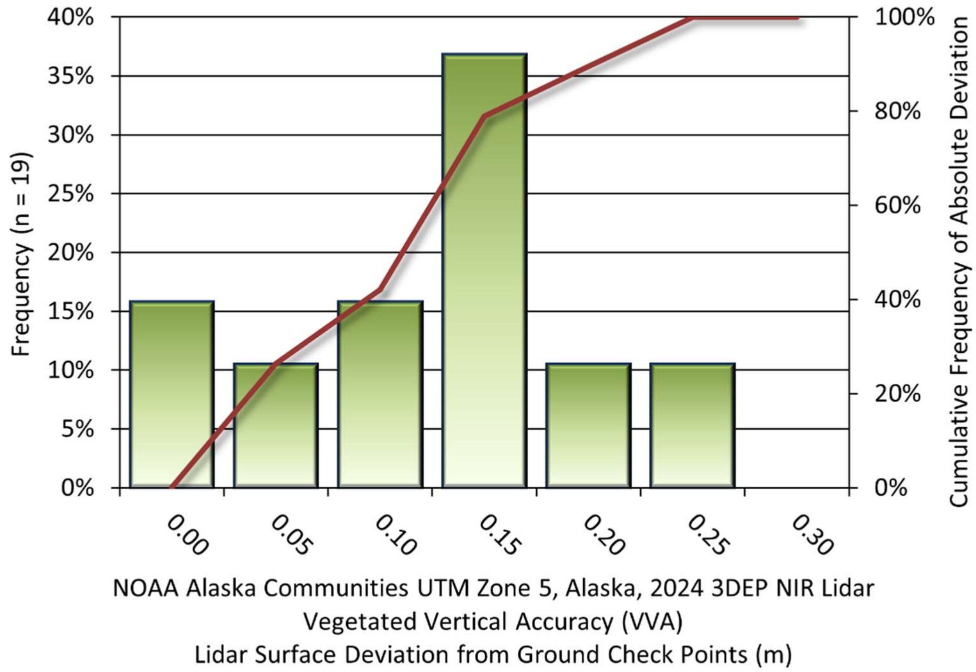


Figure 24: Frequency histogram for the lidar surface deviation from all land cover class point values (VVA) for UTM Zone 5

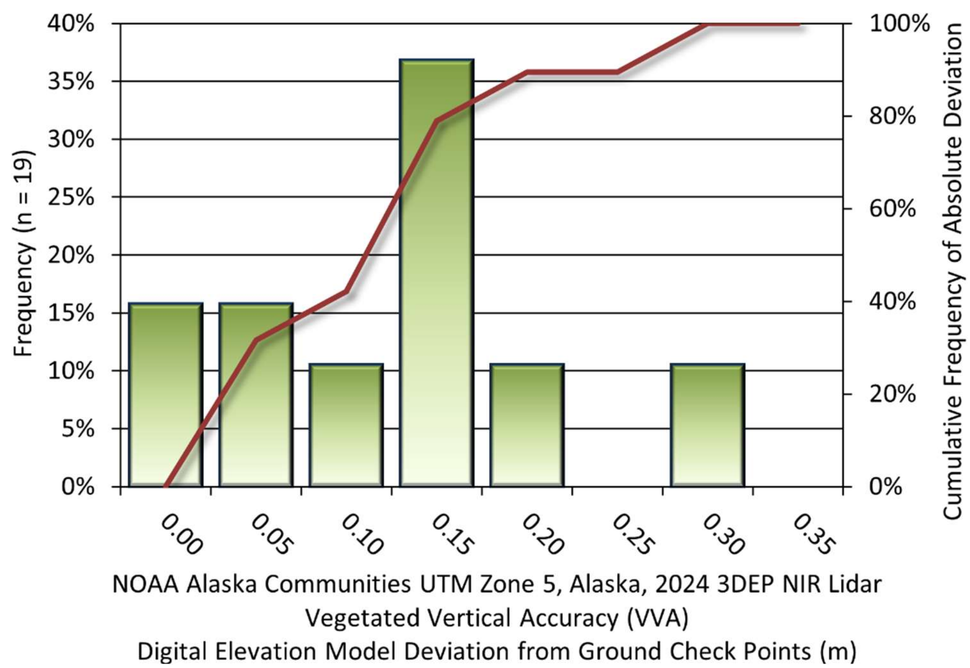


Figure 25: Frequency histogram for the lidar bare earth DEM deviation from vegetated check point values (VVA) for UTM Zone 5

Lidar Relative Vertical Accuracy

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. When the lidar system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for UTM Zone 4 of the Coastal Communities Lidar project was 0.032 meters (Table 17, Figure 26). The average (mean) line to line relative vertical accuracy for UTM Zone 5 of the Coastal Communities Lidar project was 0.036 meters (Table 18, Figure 27).

Table 17: Relative accuracy results for UTM Zone 4

Parameter	Relative Accuracy
Sample	60 flight line surfaces
Average	0.032 m
Median	0.027 m
RMSE	0.030 m
Standard Deviation (1σ)	0.007 m
1.96σ	0.014 m

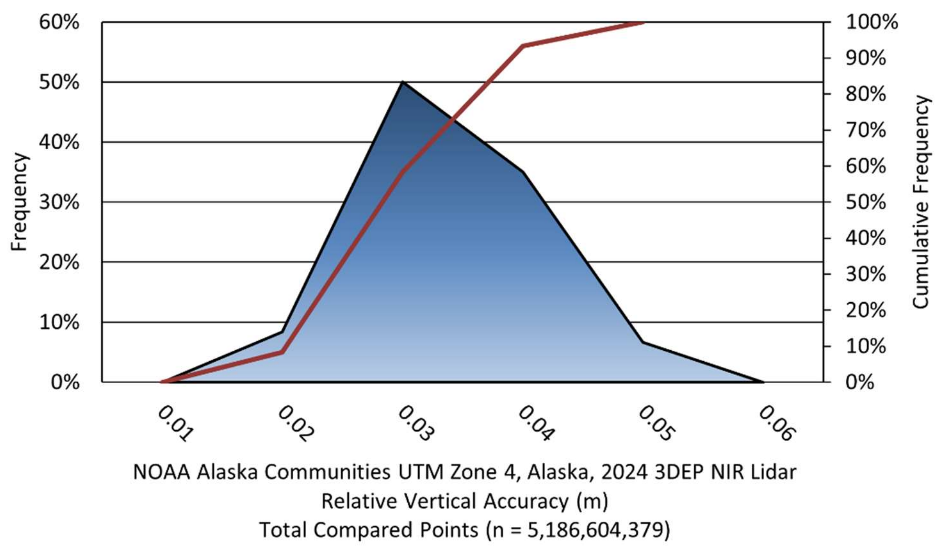


Figure 26: Frequency plot for relative vertical accuracy between flight lines for UTM Zone 4

Table 18: Relative accuracy results for UTM Zone 5

Parameter	Relative Accuracy
Sample	86 flight line surfaces
Average	0.036 m
Median	0.041 m
RMSE	0.044 m
Standard Deviation (1σ)	0.014 m
1.96σ	0.028 m

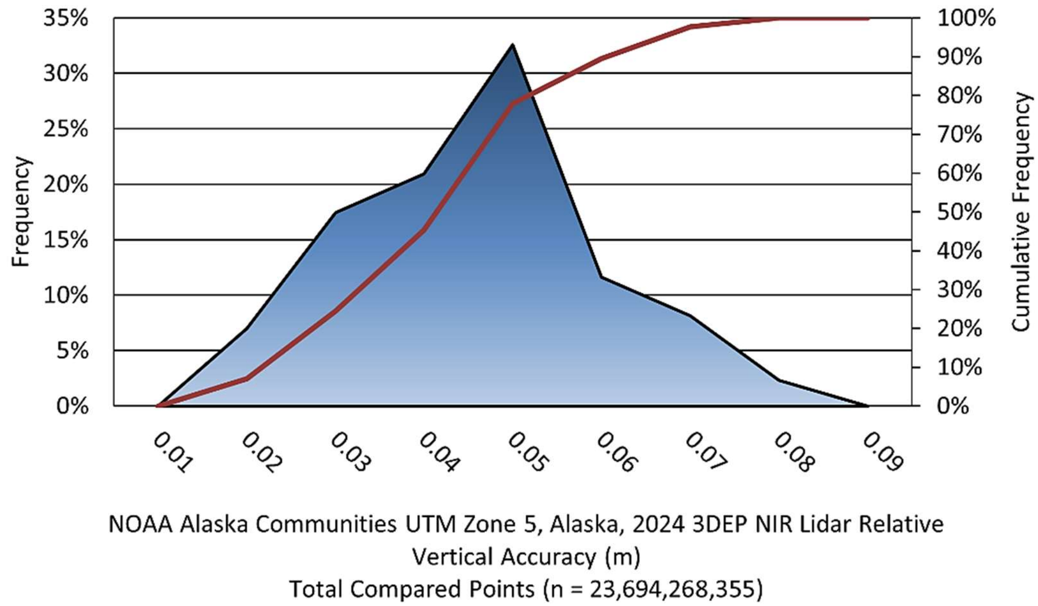


Figure 27: Frequency plot for relative vertical accuracy between flight lines for UTM Zone 5

Lidar Horizontal Accuracy

Lidar horizontal accuracy is a function of Global Navigation Satellite System (GNSS) derived positional error, flying altitude, and INS derived attitude error. The obtained $RMSE_r$ value is multiplied by a conversion factor of 1.7308 to yield the horizontal component of the National Standards for Spatial Data Accuracy (NSSDA) reporting standard where a theoretical point will fall within the obtained radius 95 percent of the time. Based on a flying altitude of 2478 meters for UTM Zone 4, an IMU error of 0.013 decimal degrees, and a GNSS positional error of 0.027 meters, this project was produced to meet 1.742 meters horizontal accuracy at the 95% confidence level (Table 19). Based on a flying altitude of 2478 meters for UTM Zone 5, an IMU error of 0.003 decimal degrees, and a GNSS positional error of 0.023 meters, this project was produced to meet 0.200 m horizontal accuracy at the 95% confidence level (Table 19).

Table 19: Horizontal Accuracy

Parameter	Horizontal Accuracy for UTM Zone 4	Horizontal Accuracy for UTM Zone 5
$RMSE_r$	1.006 m	0.233 m
ACC_r	1.742 m	0.404 m

CERTIFICATIONS

NV5 provided lidar services for the Coastal Communities project as described in this report.

I, Andrew Herbst, have reviewed the attached report for completeness and hereby state that it is a complete and accurate report of this project.

Andrew Herbst
Andrew Herbst (Mar 21, 2025 10:22 AKDT)

Mar 21, 2025

Andrew Herbst
Project Manager
NV5

I, Evon P. Silvia, PLS, being duly registered as a Professional Land Surveyor in and by the state of Alaska, hereby certify that the methodologies, static GNSS occupations used during airborne flights, and ground survey point collection were performed using commonly accepted Standard Practices. Field work for the airborne survey was performed August 1-2,2023; October 2, 2023; June 15-17, 2024; July 31, 2024; and September 21-22, 2024. Fieldwork for the ground survey to support this work was conducted by DOWL and under the supervision of their survey staff.

Accuracy statistics shown in the Accuracy Section of this Report have been reviewed by me and found to meet the "National Standard for Spatial Data Accuracy".

Evon P. Silvia

Mar 21, 2025

Evon P. Silvia, PLS
NV5
Corvallis, OR 97330

Signed: Mar 21, 2025
COA: 125659

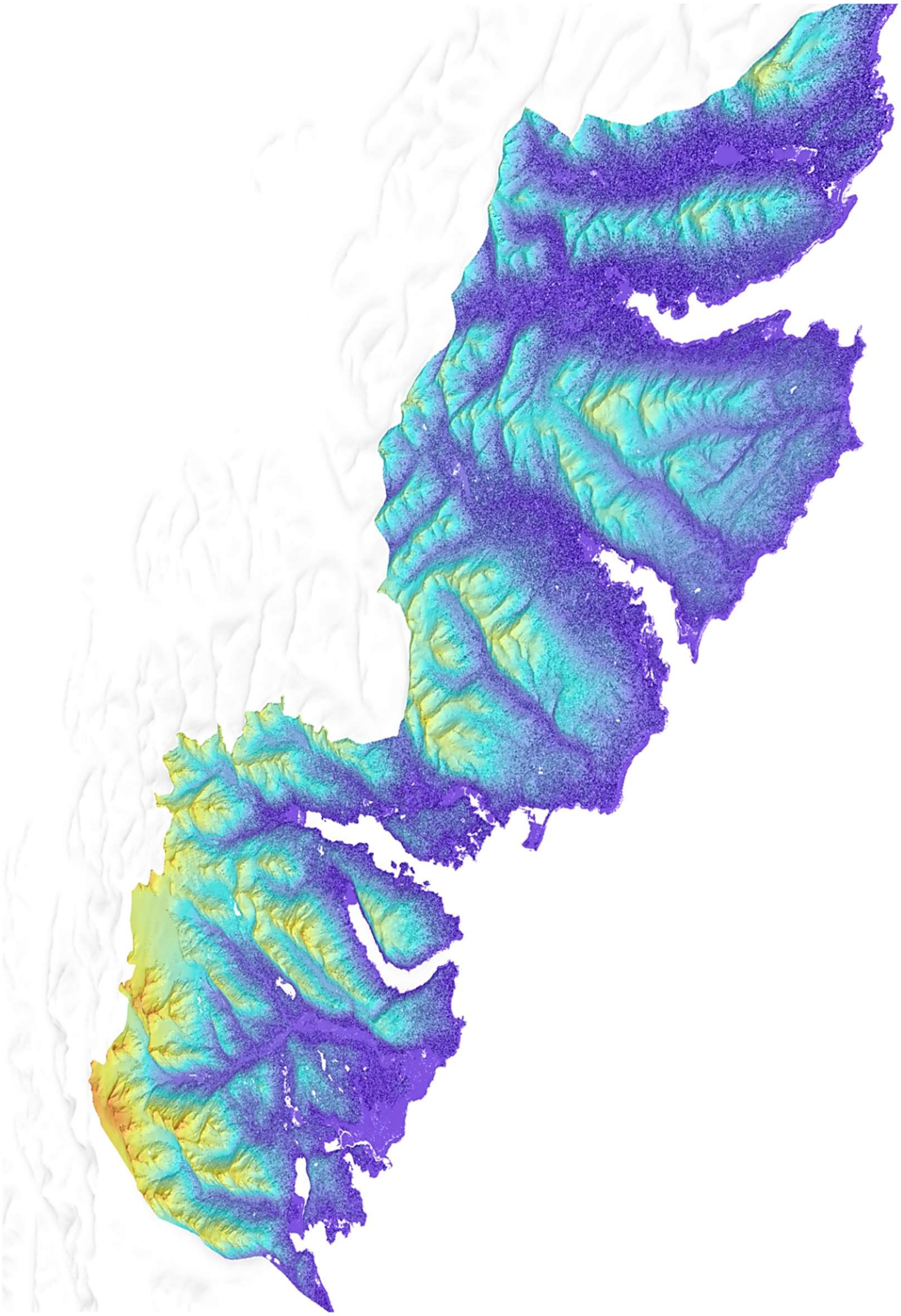


Figure 28: View looking southeast over Kachemak AOI created by the Maximum Surface Height Raster

GLOSSARY

1-sigma (σ) Absolute Deviation: Value for which the data are within one standard deviation (approximately 68th percentile) of a normally distributed data set.

1.96 * RMSE Absolute Deviation: Value for which the data are within two standard deviations (approximately 95th percentile) of a normally distributed data set, based on the FGDC standards for Non-vegetated Vertical Accuracy (NVA) reporting.

Accuracy: The statistical comparison between known (surveyed) points and laser points. Typically measured as the standard deviation (sigma σ) and root mean square error (RMSE).

> **Absolute Accuracy:** The vertical accuracy of lidar data is described as the mean and standard deviation (sigma σ) of divergence of lidar point coordinates from ground survey point coordinates. To provide a sense of the model predictive power of the dataset, the root mean square error (RMSE) for vertical accuracy is also provided. These statistics assume the error distributions for x, y and z are normally distributed, and thus we also consider the skew and kurtosis of distributions when evaluating error statistics. When the distribution of the positional error is normal, the skewness of the distribution is zero and positive errors are equal in magnitude and likelihood to negative errors. The excess kurtosis of a distribution approximating the normal distribution will be near zero, indicating a lack of weight in the tails of the distribution. Here, this means a low frequency of outliers that have high positional error.

> **Relative Accuracy:** Relative accuracy refers to the internal consistency of the data set; i.e., the ability to place a laser point in the same location over multiple flight lines, GPS conditions and aircraft attitudes. Affected by system attitude offsets, scale and GPS/IMU drift, internal consistency is measured as the divergence between points from different flight lines within an overlapping area. Divergence is most apparent when flight lines are opposing. When the lidar system is well calibrated, the line-to-line divergence is low (<10 cm).

> **Root Mean Square Error (RMSE):** A statistic used to approximate the difference between real-world points and the lidar points. It is calculated by squaring each error (the distance between an observed and known value), taking the average of these squared errors, and finally taking the square root of this average.

Data Density: A common measure of lidar resolution, measured as points per square meter.

Digital Elevation Model (DEM): File or database made from surveyed points, containing elevation points over a contiguous area. Digital terrain models (DTM) and digital surface models (DSM) are types of DEMs. DTMs consist solely of the bare earth surface (ground points), while DSMs include information about all surfaces, including vegetation and man-made structures.

Intensity Values: The peak power ratio of the laser return to the emitted laser, calculated as a function of surface reflectivity.

Nadir: A single point or locus of points on the surface of the earth directly below a sensor as it progresses along its flight line.

Overlap: The area shared between flight lines, typically measured in percent. 100% overlap is essential to ensure complete coverage and reduce laser shadows.

Pulse Rate (PR): The rate at which laser pulses are emitted from the sensor; typically measured in thousands of pulses per second (kHz).

Pulse Returns: For every laser pulse emitted, the number of wave forms (i.e., echoes) reflected back to the sensor. Portions of the wave form that return first are the highest element in multi-tiered surfaces such as vegetation. Portions of the wave form that return last are the lowest element in multi-tiered surfaces.

Real-Time Kinematic (RTK) Survey: A type of surveying conducted with a GPS base station deployed over a known monument with a radio connection to a GPS rover. Both the base station and rover receive differential GPS data and the baseline correction is solved between the two. This type of ground survey is accurate to 1.5 cm or less.

Post-Processed Kinematic (PPK) Survey: GPS surveying is conducted with a GPS rover collecting concurrently with a GPS base station set up over a known monument. Differential corrections and precisions for the GNSS baselines are computed and applied after the fact during processing. This type of ground survey is accurate to 1.5 cm or less.

Scan Angle: The angle from nadir to the edge of the scan, measured in degrees. Laser point accuracy typically decreases as scan angles increase.

Native Lidar Density: The number of pulses emitted by the lidar system, commonly expressed as pulses per square meter.

Relative Accuracy Calibration Methodology:

Manual System Calibration: Calibration procedures for each mission require solving geometric relationships that relate measured swath-to-swath deviations to misalignments of system attitude parameters. Corrected scale, pitch, roll and heading offsets were calculated and applied to resolve misalignments. The raw divergence between lines was computed after the manual calibration was completed and reported for each survey area.

Automated Attitude Calibration: All data were tested and calibrated using TerraMatch automated sampling routines. Ground points were classified for each individual flight line and used for line-to-line testing. System misalignment offsets (pitch, roll and heading) and scale were solved for each individual mission and applied to respective mission datasets. The data from each mission were then blended when imported together to form the entire area of interest.

Automated Z Calibration: Ground points per line were used to calculate the vertical divergence between lines caused by vertical GPS drift. Automated Z calibration was the final step employed for relative accuracy calibration.

Lidar accuracy error sources and solutions:

Source	Type	Post Processing Solution
Long Base Lines	GPS	None
Poor Satellite Constellation	GPS	None
Poor Antenna Visibility	GPS	Reduce Visibility Mask
Poor System Calibration	System	Recalibrate IMU and sensor offsets/settings
Inaccurate System	System	None
Poor Laser Timing	Laser Noise	None
Poor Laser Reception	Laser Noise	None
Poor Laser Power	Laser Noise	None
Irregular Laser Shape	Laser Noise	None

Operational measures taken to improve relative accuracy:

Low Flight Altitude: Terrain following was employed to maintain a constant above ground level (AGL). Laser horizontal errors are a function of flight altitude above ground (about 1/3000th AGL flight altitude).

Focus Laser Power at narrow beam footprint: A laser return must be received by the system above a power threshold to accurately record a measurement. The strength of the laser return (i.e., intensity) is a function of laser emission power, laser footprint, flight altitude and the reflectivity of the target. While surface reflectivity cannot be controlled, laser power can be increased and low flight altitudes can be maintained.

Reduced Scan Angle: Edge-of-scan data can become inaccurate. The scan angle was reduced to a maximum of ±29.25° from nadir, creating a narrow swath width and greatly reducing laser shadows from trees and buildings.

Quality GPS: Flights took place during optimal GPS conditions (e.g., 6 or more satellites and PDOP [Position Dilution of Precision] less than 3.0). Before each flight, the PDOP was determined for the survey day.

Ground Survey: Ground survey point accuracy (<1.5 cm RMSE) occurs during optimal PDOP ranges and targets a minimal baseline distance of 4 miles between GPS rover and base. Robust statistics are, in part, a function of sample size (n) and distribution. Ground survey points are distributed to the extent possible throughout multiple flight lines and across the survey area.

50% Side-Lap (100% Overlap): Overlapping areas are optimized for relative accuracy testing. Laser shadowing is minimized to help increase target acquisition from multiple scan angles. Ideally, with a 50% side-lap, the nadir portion of one flight line coincides with the swath edge portion of overlapping flight lines. A minimum of 50% side-lap with terrain-followed acquisition prevents data gaps.

Opposing Flight Lines: All overlapping flight lines have opposing directions. Pitch, roll and heading errors are amplified by a factor of two relative to the adjacent flight line(s), making misalignments easier to detect and resolve.

APPENDIX B – GROUND SURVEY REPORT

See the Attached Ground Survey Report

NOAA COMMUNITIES MAPPING
EEK, ALASKA

SURVEYING AND MAPPING REPORT

Prepared for:

NV5
2014 Merrill Field Drive
Anchorage, Alaska 99501

Prepared by:

DOWL
5015 Business Park Boulevard
Anchorage, Alaska 99503
(907) 562-2000

DOWL Project Number: 1182.63789.01

Field Project dates: August 30, 2024

REPORT DATA SEPTEMBER 09, 2024

NOAA COMMUNITIES MAPPING SUPPORT

TABLE OF CONTENTS

LIST OF ACRONYMS

AOI .... Area of Interest
CA .... Calibration
GNSS .... Global Navigation Satellite System
NGS .... National Geodetic Survey
NVA .... Non-vegetated Vertical Accuracy
OPUS .... Online Positioning User Service
QC .... Quality Control
TBC .... Trimble Business Center
VVA .... Vegetated Vertical Accuracy

HORIZONTAL & VERTICAL CONTROL SUMMARY

1.0 INTRODUCTION

This project consists of surveying selected locations within the Areas of Interest (AOI) to support aerial LiDAR mapping. Three different classifications of data were collected, Calibration (CA) Points, Non-vegetated Vertical Accuracy (NVA) Points and Vegetated Vertical Accuracy (VVA) Points. Incidental to the collection of CA and Quality Control (QC) points, Survey control was both established and recovered for use during this project. DOWL was hired by NV5 as the independent subconsultant to perform these services. NV5 provided DOWL with a general area of the requested data collection, and efforts were made to collect data in those areas. Limited changes were made to their plan.

2.0 HORIZONTAL CONTROL SUMMARY

A field survey was performed by DOWL August 30, 2024, under the field supervision of A. William Stoll, PLS #12041. Before mobilizing to the field, Willie performed a robust search of the NGS record and OPUS Shared record. No existing on site control was utilized as a secondary check to the local OPUS solutions performed while on site.

3.0 HORIZONTAL CONTROL STATEMENT

COORDINATE SYSTEM:
Coordinates are UTM Zone 3 North expressed in US Survey Feet. Coordinates are based on the OPUS derived solution for on-site control.

4.0 VERTICAL CONTROL SUMMARY

Elevations are Geoid12B derived orthometric heights expressed in US Survey Feet. Elevations are based on the OPUS derived solution for on-site control.

5.0 QUALITY ASSURANCE

Quality Assurance (QA) methods and procedures outlined in the statement of services were reviewed with our staff and adhered to. Some examples of QA methods include the following:

- All equipment utilized during this project was checked for accuracy, and adjusted when necessary, prior to commencing any work.
- Redundant distance measurements were made in feet and meters.
- Tripods with optical plummet tribrachs or laser plummet tribrachs were used to set up over the points while measuring all control.

6.0 SURVEYOR'S CERTIFICATION

I, A. William Stoll, Alaska Land Surveyor #12041, do hereby certify that the information contained herein is the result of work performed by me or by others working under my direct supervision.

A. William Stoll, PLS
Alaska Professional Land Surveyor No. 12041

Sept 09, 2024
Date

NOAA COMMUNITIES MAPPING
GOODNEWS, ALASKA

SURVEYING AND MAPPING REPORT

Prepared for:

NV5
2014 Merrill Field Drive
Anchorage, Alaska 99501

Prepared by:

DOWL
5015 Business Park Boulevard
Anchorage, Alaska 99503
(907) 562-2000

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A. William Stoll, PLS
Alaska Professional Land Surveyor No. 12041

Sept 09, 2024
Date

NOAA COMMUNITIES MAPPING

SURVEYING AND MAPPING REPORT

Prepared for:

NV5
2014 Merrill Field Drive
Anchorage, Alaska 99501

Prepared by:

DOWL
5015 Business Park Boulevard
Anchorage, Alaska 99503
(907) 562-2000

DOWL Project Number: 1182.63789.01

Field Project dates: August 28, 2024

REPORT DATA SEPTEMBER 09, 2024

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This project consists of surveying selected locations within the Areas of Interest (AOI) to support aerial LiDAR mapping. Three different classifications of data were collected, Calibration (CA) Points, Non-vegetated Vertical Accuracy (NVA) Points and Vegetated Vertical Accuracy (VVA) Points. Incidental to the collection of CA and Quality Control (QC) points, Survey control was both established and recovered for use during this project. DOWL was hired by NV5 as the independent subconsultant to perform these services. NV5 provided DOWL with a general area of the requested data collection, and efforts were made to collect data in those areas. Limited changes were made to their plan.

2.0 HORIZONTAL CONTROL SUMMARY

A field survey was performed by DOWL on August 28th, 2024, by A. William Stoll, PLS #12041. Before mobilizing to the field, Willie performed a robust search of the NGS record and did not find and NGS Control points or NGS OPUS Shared points as a secondary check to the local OPUS solutions performed while on site.

3.0 HORIZONTAL CONTROL STATEMENT

COORDINATE SYSTEM:
Coordinates are UTM Zone 4 North expressed in US Survey Feet. Coordinates are based on the OPUS derived solution for on-site control.

4.0 VERTICAL CONTROL SUMMARY

Elevations are Geoid12B derived orthometric heights expressed in US Survey Feet. Elevations are based on the OPUS derived solution for on-site control.

5.0 QUALITY ASSURANCE

Quality Assurance (QA) methods and procedures outlined in the statement of services were reviewed with our staff and adhered to. Some examples of QA methods include the following:

- All equipment utilized during this project was checked for accuracy, and adjusted when necessary, prior to commencing any work.
- Redundant distance measurements were made in feet and meters.
- Tripods with optical plummet tribrachs or laser plummet tribrachs were used to set up over the points while measuring all control.

6.0 SURVEYOR'S CERTIFICATION

I, A. William Stoll, Alaska Land Surveyor #12041, do hereby certify that the information contained herein is the result of work performed by me or by others working under my direct supervision.

A. William Stoll, PLS
Alaska Professional Land Surveyor No. 12041

Sept 09, 2024
Date

STATE OF ALASKA
49TH
A. William Stoll
LS-12041
Sept 09, 2024
REGISTERED PROFESSIONAL SURVEYOR

NOAA COMMUNITIES MAPPING
QUINHAGAK, ALASKA

SURVEYING AND MAPPING REPORT

Prepared for:

NV5
2014 Merrill Field Drive
Anchorage, Alaska 99501

Prepared by:

DOWL
5015 Business Park Boulevard
Anchorage, Alaska 99503
(907) 562-2000

DOWL Project Number: 1182.63789.01

Field Project dates: August 30-31, 2024

REPORT DATA SEPTEMBER 09, 2024

NOAA COMMUNITIES MAPPING SUPPORT

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LIST OF ACRONYMS

AOI .... Area of Interest

CA .... Calibration

GNSS .... Global Navigation Satellite System

NGS .... National Geodetic Survey

NVA .... Non-vegetated Vertical Accuracy

OPUS .... Online Positioning User Service

QC .... Quality Control

TBC .... Trimble Business Center

VVA .... Vegetated Vertical Accuracy

HORIZONTAL & VERTICAL CONTROL SUMMARY

1.0 INTRODUCTION

This project consists of surveying selected locations within the Areas of Interest (AOI) to support aerial LiDAR mapping. Three different classifications of data were collected, Calibration (CA) Points, Non-vegetated Vertical Accuracy (NVA) Points and Vegetated Vertical Accuracy (VVA) Points. Incidental to the collection of CA and Quality Control (QC) points, Survey control was both established and recovered for use during this project. DOWL was hired by NV5 as the independent subconsultant to perform these services. NV5 provided DOWL with a general area of the requested data collection, and efforts were made to collect data in those areas. Limited changes were made to their plan.

2.0 HORIZONTAL CONTROL SUMMARY

A field survey was performed by DOWL August 30-31, 2024, under the field supervision of A. William Stoll, PLS #12041. Before mobilizing to the field, Willie performed a robust search of the NGS record and OPUS Shared record. No existing on site control was utilized as a secondary check to the local OPUS solutions performed while on site.

3.0 HORIZONTAL CONTROL STATEMENT

COORDINATE SYSTEM:
Coordinates are UTM Zone 4 North expressed in US Survey Feet. Coordinates are based on the OPUS derived solution for on-site control.

4.0 VERTICAL CONTROL SUMMARY

Elevations are Geoid12B derived orthometric heights expressed in US Survey Feet. Elevations are based on the OPUS derived solution for on-site control.

5.0 QUALITY ASSURANCE

Quality Assurance (QA) methods and procedures outlined in the statement of services were reviewed with our staff and adhered to. Some examples of QA methods include the following:

- All equipment utilized during this project was checked for accuracy, and adjusted when necessary, prior to commencing any work.

- Redundant distance measurements were made in feet and meters.

- Tripods with optical plummet tribrachs or laser plummet tribrachs were used to set up over the points while measuring all control.

6.0 SURVEYOR'S CERTIFICATION

I, A. William Stoll, Alaska Land Surveyor #12041, do hereby certify that the information contained herein is the result of work performed by me or by others working under my direct supervision.

A. William Stoll, PLS
Alaska Professional Land Surveyor No. 12041

Sept 09, 2024
Date

NOAA COMMUNITIES MAPPING
TOGIAK, ALASKA

SURVEYING AND MAPPING REPORT

Prepared for:

NV5
2014 Merrill Field Drive
Anchorage, Alaska 99501

Prepared by:

DOWL
5015 Business Park Boulevard
Anchorage, Alaska 99503
(907) 562-2000

DOWL Project Number: 1182.63789.01

Field Project dates: June 2nd, 2024

REPORT DATA SEPTEMBER 09, 2024

NOAA COMMUNITIES MAPPING SUPPORT

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LIST OF ACRONYMS

AOI .... Area of Interest
CA .... Calibration
GNSS .... Global Navigation Satellite System
NGS .... National Geodetic Survey
NVA .... Non-vegetated Vertical Accuracy
OPUS .... Online Positioning User Service
QC .... Quality Control
TBC .... Trimble Business Center
VVA .... Vegetated Vertical Accuracy

HORIZONTAL & VERTICAL CONTROL SUMMARY

1.0 INTRODUCTION

This project consists of surveying selected locations within the Areas of Interest (AOI) to support aerial LiDAR mapping. Three different classifications of data were collected, Calibration (CA) Points, Non-vegetated Vertical Accuracy (NVA) Points and Vegetated Vertical Accuracy (VVA) Points. Incidental to the collection of CA and Quality Control (QC) points, Survey control was both established and recovered for use during this project. DOWL was hired by NV5 as the independent subconsultant to perform these services. NV5 provided DOWL with a general area of the requested data collection, and efforts were made to collect data in those areas. Limited changes were made to their plan.

2.0 HORIZONTAL CONTROL SUMMARY

A field survey was performed by DOWL June 2nd, 2024, by A. William Stoll, PLS #12041. Before mobilizing to the field, Willie performed a robust search of the NGS record and utilized an NGS Control points as a secondary check to the local OPUS solutions performed while on site.

3.0 HORIZONTAL CONTROL STATEMENT

COORDINATE SYSTEM:
Coordinates are UTM Zone 4 North expressed in US Survey Feet. Coordinates are based on the OPUS derived solution for on-site control.

4.0 VERTICAL CONTROL SUMMARY

Elevations are Geoid12B derived orthometric heights expressed in US Survey Feet. Elevations are based on the OPUS derived solution for on-site control.

5.0 QUALITY ASSURANCE

Quality Assurance (QA) methods and procedures outlined in the statement of services were reviewed with our staff and adhered to. Some examples of QA methods include the following:

- All equipment utilized during this project was checked for accuracy, and adjusted when necessary, prior to commencing any work.
- Redundant distance measurements were made in feet and meters.
- Tripods with optical plummet tribrachs or laser plummet tribrachs were used to set up over the points while measuring all control.

6.0 SURVEYOR'S CERTIFICATION

I, A. William Stoll, Alaska Land Surveyor #12041, do hereby certify that the information contained herein is the result of work performed by me or by others working under my direct supervision.

A. William Stoll, PLS
Alaska Professional Land Surveyor No. 12041

Sept 09, 2024
Date

NOAA COMMUNITIES MAPPING
KACHEMAK BAY, ALASKA

SURVEYING AND MAPPING REPORT

Prepared for:

NV5
2014 Merrill Field Drive
Anchorage, Alaska 99501

Prepared by:

DOWL
5015 Business Park Boulevard
Anchorage, Alaska 99503
(907) 562-2000

DOWL Project Number: 1182.63789.01

Field Project dates: July 17- July 20, 2024

REPORT DATA SEPTEMBER 09, 2024

NOAA COMMUNITIES MAPPING SUPPORT

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LIST OF ACRONYMS

AOI .... Area of Interest

CA .... Calibration

GNSS .... Global Navigation Satellite System

NGS .... National Geodetic Survey

NVA .... Non-vegetated Vertical Accuracy

OPUS .... Online Positioning User Service

QC .... Quality Control

TBC .... Trimble Business Center

VVA .... Vegetated Vertical Accuracy

HORIZONTAL & VERTICAL CONTROL SUMMARY

1.0 INTRODUCTION

This project consists of surveying selected locations within the Areas of Interest (AOI) to support aerial LiDAR mapping. Three different classifications of data were collected, Calibration (CA) Points, Non-vegetated Vertical Accuracy (NVA) Points and Vegetated Vertical Accuracy (VVA) Points. Incidental to the collection of CA and Quality Control (QC) points, Survey control was both established and recovered for use during this project. DOWL was hired by NV5 as the independent subconsultant to perform these services. NV5 provided DOWL with a general area of the requested data collection, and efforts were made to collect data in those areas. Limited changes were made to their plan.

2.0 HORIZONTAL CONTROL SUMMARY

A field survey was performed by DOWL between July 17 and the 20th, 2024, by A. William Stoll, PLS #12041. Before mobilizing to the field, Willie performed a robust search of the NGS record and did not find and NGS Control points but was able to utilize an NGS OPUS Shared points as a secondary check to the local OPUS solutions performed while on site.

3.0 HORIZONTAL CONTROL STATEMENT

COORDINATE SYSTEM:
Coordinates are UTM Zone 5 North expressed in US Survey Feet. Coordinates are based on the OPUS derived solution for on-site control.

4.0 VERTICAL CONTROL SUMMARY

Elevations are Geoid12B derived orthometric heights expressed in US Survey Feet. Elevations are based on the OPUS derived solution for on-site control.

5.0 QUALITY ASSURANCE

Quality Assurance (QA) methods and procedures outlined in the statement of services were reviewed with our staff and adhered to. Some examples of QA methods include the following:

- All equipment utilized during this project was checked for accuracy, and adjusted when necessary, prior to commencing any work.
- Redundant distance measurements were made in feet and meters.
- Tripods with optical plummet tribrachs or laser plummet tribrachs were used to set up over the points while measuring all control.

6.0 SURVEYOR'S CERTIFICATION

I, A. William Stoll, Alaska Land Surveyor #12041, do hereby certify that the information contained herein is the result of work performed by me or by others working under my direct supervision.

A. William Stoll, PLS
Alaska Professional Land Surveyor No. 12041

Sept 09, 2024
Date

STATE OF ALASKA
49TH
A. William Stoll
LS-12041
Sept 09, 2024
REGISTERED PROFESSIONAL SURVEYOR