PHOTOGRAMMETRY-DERIVED ORTHOIMAGERY AND ELEVATION FOR SAINT PAUL, ALASKA, COLLECTED JULY 22–25, 2021

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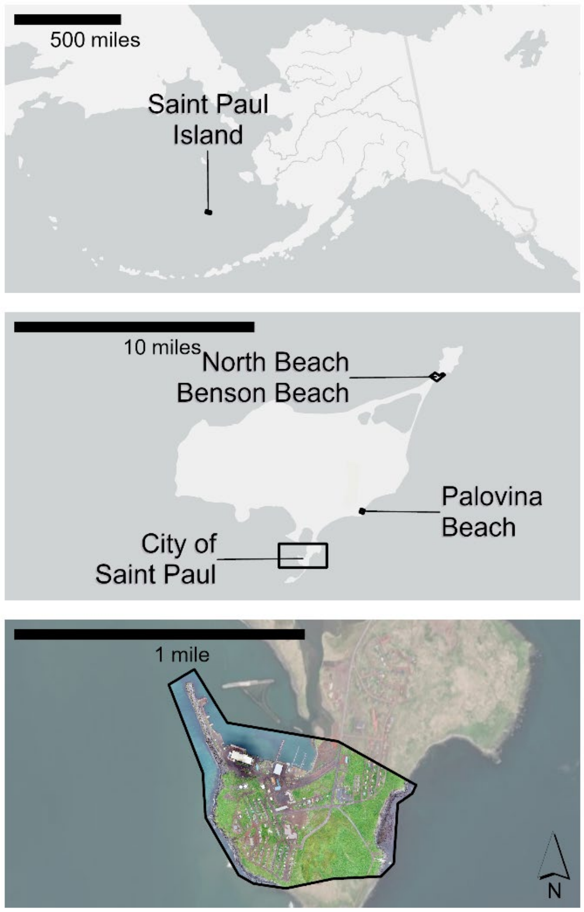
Raw Data File 2022-1



Location map of survey areas with orthoimage of the City of Saint Paul.

This report has not been reviewed for technical content or for conformity to the editorial standards of DGGS.

2022
STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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PHOTOGRAMMETRY-DERIVED ORTHOIMAGERY AND ELEVATION FOR SAINT PAUL, ALASKA, COLLECTED JULY 22–25, 2021

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INTRODUCTION

The State of Alaska Division of Geological & Geophysical Surveys (DGGS) collected low-altitude aerial images from an unmanned aerial vehicle (UAV) from July 22 to 25, 2021 and used Structure-from-Motion (SfM) photogrammetry to produce digital surface models (DSMs) and orthoimagery of for North Beach, Polovina Beach, and the City of Saint Paul (fig. 1). The orthoimagery and elevation data are for assessing coastal hazards and changes. We used Trimble Business Center to process the Global Navigation Satellite System (GNSS) data used for positional control. We used Agisoft Metashape Professional to process the photogrammetry data. These products are released as a Raw Data File with an open end-user license. All files can be downloaded from https://doi.org/10.14509/30836 or https://elevation.alaska.gov.

LIST OF DELIVERABLES

- Orthoimagery
- Digital Surface Models (DSM)
- Metadata

MISSION PLAN

Aerial Photogrammetric Survey Details

DGGS used a DJI Phantom 4 RTK UAV with a FC6310R camera model (8.8 mm lens) to collect 20-megapixel JPEG photographs (5472 x 3648 pixels per image). We flew the aerial surveys with 70 percent sidelap, 80 percent frontlap, and nadir camera orientation stabilized by a 3-axis gimbal. The survey was flown between 100 and 120 m above the ground at 5.5 to 7.9 m/s, respectively. The resulting images cover 1.21 km^2 with ground sampling distance (GSD) of approximately 0.03 m.

Weather and Photo Conditions

DGGS surveyed North and Benson beaches on July 22, 2021, from 4:00 PM to 4:30 PM AKDT. The operator returned the UAV once to change batteries. We flew the Black Bluffs in the east area of the City of Saint Paul on July 23, 2021, from 12:55 PM to 1:05 PM, with the camera oriented 10 degrees off-nadir towards the bluff face. This orientation improved mapping of the vertical bluff face. We flew Polovina Beach on July 23, 2021, from 1:50 PM to 2:00 PM AKDT using one battery. We flew the City of St. Paul on July 25, 2021, from 6:40 PM to 7:40 PM AKDT. The operator returned the UAV twice to change batteries. This survey overlapped with the Black Bluffs survey so we combine the final products. The weather throughout all surveys was overcast with no rain and light to moderate wind. No abnormalities were observed during the flights.

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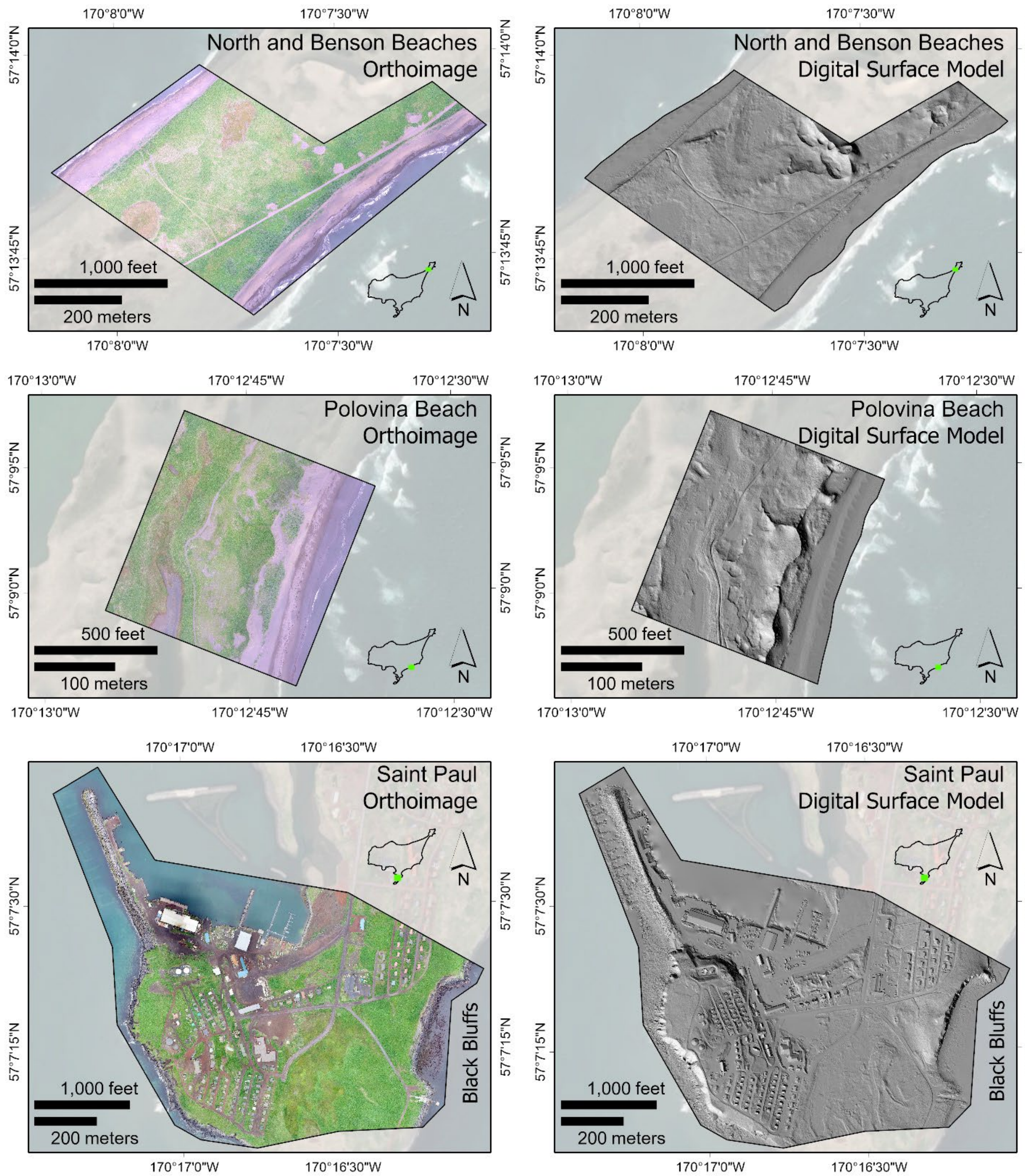

Figure 1. Extent of orthoimagery (left) and DSMs (right) for Saint Paul.

URVEY AND PROCESSING REPORT

Ground Survey Details

DGGS set up a GNSS base station using a Trimble R10 receiver sampling at 5 Hz. The base was installed over a benchmark with a published solution (found at www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBCN02). This provided real-time kinematic (RTK) corrections to the Trimble R8s GNSS receiver. DGGS measured 22 photo-identifiable points with the R8s. DGGS installed temporary benchmarks using the R8s and subsequently occupied these benchmarks with the base station. We derived the corrected base positions using the Online Positioning User Service (found at www.ngs.noaa.gov/OPUS/) and post-processed the R8s positions in Trimble Business Center.

Photogrammetric Dataset Processing

For the surveys at North Beach, Polovina Beach, and the community of Saint Paul the UAV did not maintain RTK connection with the Trimble R10 base station. We apply a post-processing kinematic correction using RTKLIB (an open-source GNSS processing software found at www.rtklib.com). The UAV GNSS receiver samples at 5 Hz, rather than at image acquisition times. We interpolate the corrected positions at image timestamps to derive coordinates. The image timestamp metadata also contains orientation to support the lever arm correction that adjusts coordinates from the GNSS receiver to the camera. We compute the interpolation and lever arm correction using the worksheet found at www.aerotas.com/phantom-4-rtk-ppk-processing-workflow.

For the city survey, the UAV maintained RTK connection. The lever arm correction is automatically applied and camera GNSS coordinates are written to the image metadata in WGS84 ellipsoid. Yaw, pitch, and roll information are not written to the image metadata. The UAV positions are updated using a X, Y, and Z shift from the initial to the corrected base position.

DGGS processed images in Agisoft Metashape Professional software (Version 1.6.3 build 10732). We masked image corners where shadows and image warping were disruptive. Processing steps included aligning images, identifying ground control points (GCPs), manually cleaning the sparse point cloud, optimizing the bundle block adjustment (refining camera positions and lens distortion parameters), constructing the dense point cloud, building the DSM, and creating the orthomosaic image. For the city, we used eight GCPs to create the model, leaving four survey check points. For North and Benson beaches, six GCPs and four check points. For Polovina beach, we could only collect elevation points that were not photo-identifiable. We vertically adjust the elevation model using the average offset of eleven vertical points.

Orthoimagery

The orthoimagery is a three-band (red, green, blue) 8-bit unsigned GeoTIFF file with the “No Data” value set to 0. GSD varies by location (table 1).

Digital Surface Model

The DSM represents surface elevations such as the height of vegetation and buildings. Water bodies can introduce noise. For North, Benson, and Polovina beaches, we manually delineated the ocean boundary to restrict the DSM to the land. For the city DSM, we did not remove water areas because the model includes rocky islets and shallow underwater features of interest (most notably the submerged groins at the northwest breakwater). We filtered the dense cloud to remove low confidence points (most often water surfaces) and prioritize seafloor elevation. However, we do not expect absolute seafloor elevation to be as accurate as above-water features. The DSM is a single-band, 32-bit floating point GeoTIFF file with the "No Data" value set to -3.4028231 x 10^{38}.

Table 1. GSD and area of orthoimage and DSM products.

Location	Orthoimage GSD (m)	DSM GSD (m)	Area (km^2)
North and Benson beaches	0.028	0.057	0.271
Polovina	0.029	0.057	0.067
City	0.030	0.060	0.876

ACCURACY REPORT

Coordinate System and Datum

All data are processed and delivered in NAD83 (2011) UTM Zone 2N and vertical datum NAVD88 (GEOID12B).

Horizontal Accuracy

We quantify the horizontal accuracy of the DSMs and orthoimagery by comparing the known locations of photo-identifiable check points measured with GNSS against their modeled locations in the photogrammetric products (fig. 2). X and Y errors are calculated as the root-mean-square (RMS) error of offsets. The total horizontal error is the root-sum-square error of X and Y RMS errors (table 1).

Horizontal accuracy of the Polovina Beach DSM and orthoimage is not assessed.

Vertical Accuracy

We assess vertical accuracy of the City and North and Benson beaches DSM products using the same check points that are used for horizontal accuracy (fig. 2). For North and Benson beaches, the RMS error of Z offsets is 0.020 m, and the total error of the DSM (X, Y, and Z) is 0.036 m (table 2). For the city survey, the RMS error of Z offsets is 0.028 m, and the total error of the DSM is 0.050 m (table 3). Vertical accuracy is not evaluated for offshore and underwater features.

We assess vertical accuracy of the Polovina Beach DSM using the RMS error of the fit to eleven GCPs at bare-earth locations (fig. 2). The vertical RMS error of the GCPs is 0.017 m. The RMS error of the vertical correction is 0.054 m (n = 11). The total error is 0.056 m (root-sum-square error of the control and fit RMS errors; table 4).

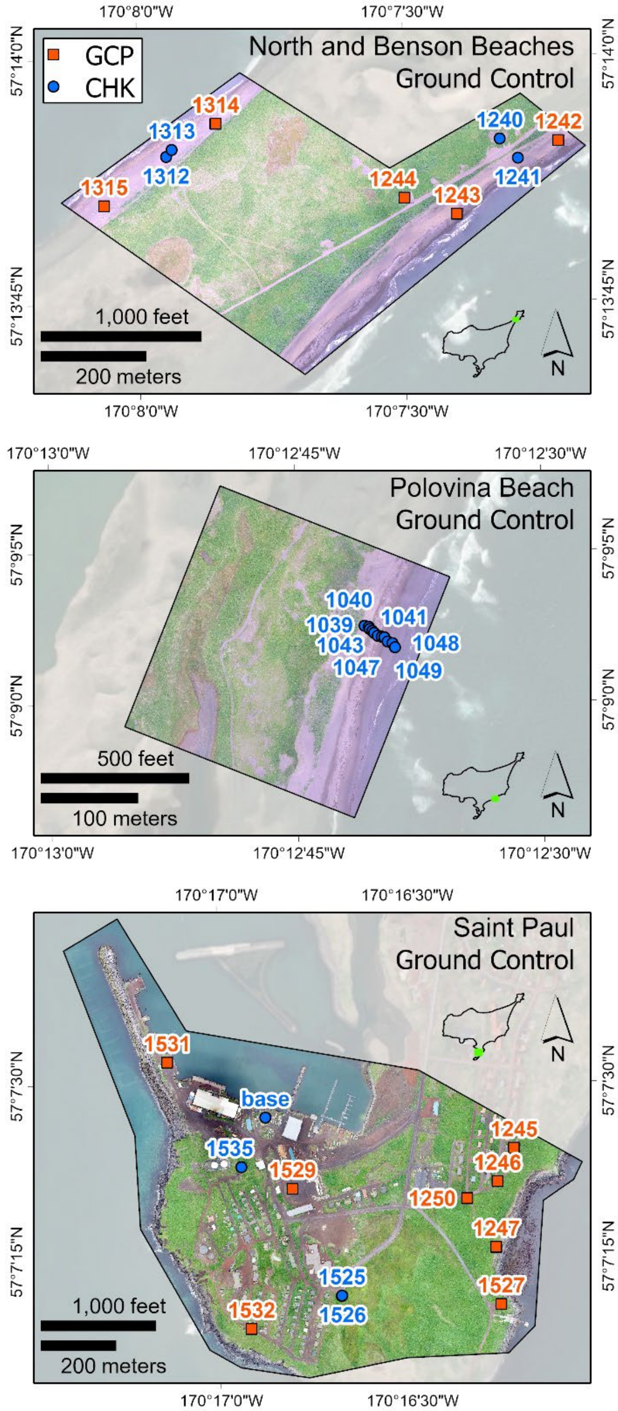

Figure 2. Location of photo-identifiable ground control points (GCPs; red) and check points (CHK; blue).

Table 2. Check point coordinates and offsets from North and Benson beaches orthoimage and DSM.

Check Point	Easting	Northing	Elevation	X Offset (m)	Y Offset (m)	Z Offset (m)
1240	553004.213	6343544.108	4.985	-0.029	0.021	-0.005
1241	553038.612	6343507.741	2.817	-0.040	0.010	0.009
1312	552373.223	6343509.015	2.865	-0.020	-0.002	-0.016
1313	552383.831	6343522.175	2.519	-0.001	-0.015	0.035
			Mean	-0.022	0.003	0.006
			Standard Deviation	0.017	0.015	0.022
			Range	0.040	0.036	0.052
			Root Mean Square Error	0.027	0.014	**0.020**
			Total Error	**0.030 (XY)**		**0.036 (XYZ)**

Table 3. Check point coordinates and offsets from the City of Saint Paul orthoimage and DSM.

Check Point	Easting	Northing	Elevation	X Offset (m)	Y Offset (m)	Z Offset (m)
base	543514.474	6331441.565	4.889	-0.028	-0.066	-0.011
1533	543418.448	6331279.411	29.705	-0.003	-0.018	-0.047
1525	543715.748	6330971.217	4.987	0.006	-0.030	0.030
1526	543717.275	6330971.524	4.971	0.009	-0.022	0.003
			Mean	-0.004	-0.034	-0.006
			Standard Deviation	0.017	0.022	0.032
			Range	0.038	0.048	0.077
			Root Mean Square Error	0.015	0.039	**0.028**
			Total Error	**0.042 (XY)**		**0.050 (XYZ)**

Table 4. Check point coordinates and offsets from Polovina Beach DSM.

Check Point	Easting	Northing	Elevation	GNSS Z Error (m)	Z Offset (m)
1039	547714.953	6334437.859	2.559	0.016	0.020
1040	547719.138	6334436.760	2.041	0.016	0.002
1041	547720.316	6334434.576	1.815	0.016	0.051
1042	547722.616	6334432.581	1.772	0.016	0.015
1043	547724.813	6334430.396	1.769	0.016	0.021
1044	547728.453	6334427.751	1.507	0.017	0.124
1045	547732.745	6334426.506	1.019	0.017	-0.014
1046	547735.322	6334425.843	0.783	0.017	-0.047
1047	547738.343	6334421.674	0.549	0.016	-0.043
1048	547743.539	6334420.119	0.320	0.016	-0.059
1049	547745.907	6334415.744	0.133	0.016	-0.070
			Mean	0.016	0.000
			Standard Deviation	0.000	0.056
			Range	0.001	0.194
			Root Mean Square Error	0.016	0.054
			Total Error	**0.056**	

Data Consistency and Completeness

DGGS visually inspected the orthoimage for data errors such as shifts, seamline mismatches, and water noise overlapping land. There were no significantly erroneous areas that required repair. Visual errors common to these SfM photogrammetry products include discontinuous powerlines, blurriness near high-angle features like buildings, and distortion at water boundaries. Bright objects like metal roofs and white paint can cause overexposure, leading to spurious elevation points.

ACKNOWLEDGMENTS

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