SINGLE-BEAM BATHYMETRIC DATA NEAR CHEFORNAK, ALASKA, COLLECTED AUGUST 17, 2022

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Raw Data File 2023-11

Photo of M2Ocean Hydroball sensor towed behind a boat near Chefornak, Alaska, on August 17, 2022. Photo: Alaska Division of Geological & Geophysical Surveys.

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

2023
STATE OF ALASKA
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DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

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Suggested citation:
Horen, K.C., Christian, J.E., Doiron, Nadine, Poisson, A.C., and Siemsen, Z.J., 2023, Single-beam bathymetric data near Chefornak, Alaska, collected August 17, 2022: Alaska Division of Geological & Geophysical Surveys Raw Data File 2023-11, 8 p.
https://doi.org/10.14509/31009

SINGLE-BEAM BATHYMETRIC DATA NEAR CHEFORNAK, ALASKA, COLLECTED AUGUST 17, 2022

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INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) collected bathymetric data near Chefornak, Alaska, on August 17, 2022 (fig. 1). The purpose of this survey is to provide bathymetric data for the assessment of coastal hazards and riverine erosion studies. These data were collected using an M2Ocean Hydroball integrated bathymetric sensor and processed using CIDCO DepthStar software. Coincident Global Navigation Satellite System (GNSS) base station and water level time series data were collected using Trimble survey equipment and a Solinst Levelogger pressure and temperature sensor, respectively, to correct horizontal and vertical positions. This data product does not meet the International Hydrographic Organization (IHO) bathymetric coverage standard (IHO, 2022), is not intended for use in determining navigability, and is released as a Raw Data File with an open end-user license. All files can be downloaded from https://doi.org/10.14509/31009.

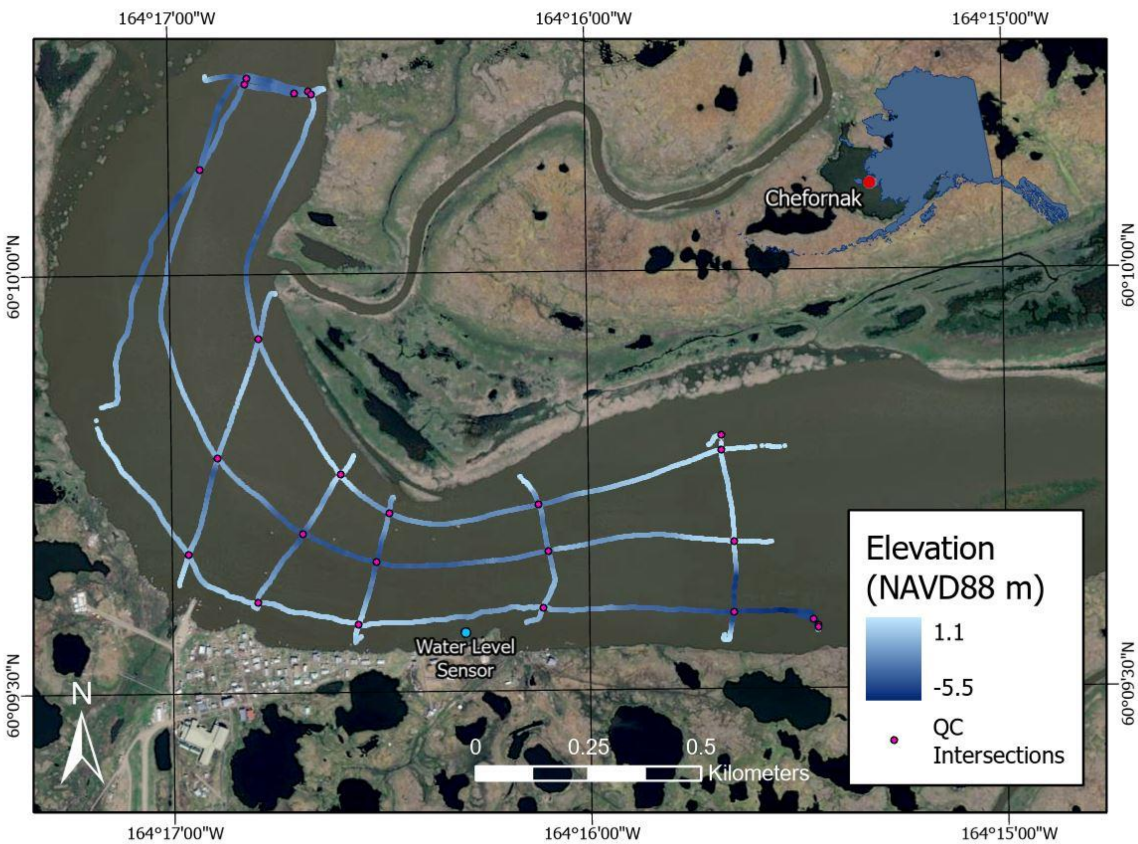

Figure 1. Map of bathymetric soundings near Chefornak, Alaska.

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LIST OF DELIVERABLES

- Bathymetric sounding data
- Data dictionary
- Metadata

METHODS

Field Collection

DGGS used an M2Ocean Hydroball bathymetric sensor, composed of an Imagenex 852 single-beam echosounder (SBES), a Tallysman TW3972 GNSS antenna, and a Honeywell HMR3000 inclinometer to collect field data. On August 17, 2022, DGGS temporarily installed a Trimble R10 receiver sampling at 5 Hz as a GNSS base station over known benchmark 946 6084 D with a published solution available from https://www.ngs.noaa.gov/OPUS/getDatasheet.jsp?PID=BBHK19&ts=21202103238. Base station data were used to correct the HydroBall sensor positions. To provide water level corrections, DGGS collected derived water level time series data from a temporarily installed Solinst model 3001 Levelogger Edge LT M10/F30 pressure and temperature sensor fully submerged approximately 20 m offshore (fig. 2) and at the Kipnuk Airport Automated Surface/Weather Observing System (ASOS/AWOS) station PAKI located approximately 28 km to the southeast.

Figure 2. Solinst Levelogger installation offshore near Chefornak, Alaska.

Survey Details

The bathymetric survey was performed on August 17 from 3:30 PM to 6:30 PM AKDT. The weather throughout the survey was mostly cloudy, with light wind and wave heights under 0.3 m. The Hydroball was attached to a catamaran configuration and towed behind a small boat equipped with an outboard motor at speeds below 4 knots. The Imagenex 852 SBES was configured with a maximum range of 20 m, gain of 5 dB, and pulse length of 120 microseconds. Due to time and vessel constraints, the bathymetric survey was performed using a survey pattern inconsistent with the requirements outlined in the IHO standards (IHO, 2022). Approximately 10.0 km of riverine bathymetry were surveyed.

Data Processing

Base positions were corrected using Online Positioning User Service (OPUS) solutions, which were used to update the Hydroball sensor positions using post-processed kinematic (PPK) adjustments from RTKLIB version 2.4.2 software with the following settings applied: L1+L2 frequencies forward and backward filtered; a 10 degree elevation mask; broadcast ionosphere and Saastamoinen troposphere corrections; a minimum fixed ambiguity ratio of 3; and L1/L2 code/carrier-phase error ratios of 100. During post-processing, DGGS applied International GNSS Service (IGS) precise orbits and final clock solutions retrieved from the Crustal

Dynamics Data Information System (CDDIS) available from https://urs.earthdata.nasa.gov/. Final corrected data were exported as time-stamped position files in WGS84 horizontal coordinate system with ellipsoidal heights.

DGGS collected temperature-compensated pressure–time series data on August 17 from 3:00 PM to 7:00 PM AKDT, at 5-minute intervals on the Levelogger sensor. DGGS retrieved 5-minute interval pressure time series data collected by the Kipnuk Airport ASOS/AWOS station designated PAKI available from https://www.weather.gov/wrh/timeseries?site=PAKI. Using a barometric (millibar) to water column equivalent (meter) conversion of 1.0 mb = 0.0101972 m, DGGS converted both the submerged Levelogger and the weather station data. Subtracting the weather station water column equivalent pressures from the submerged water column equivalent pressures provides the barometrically compensated water level. These data were then adjusted to the vertical datum NAVD88 (GEOID12B) elevation of the submerged sensor location, converted to Coordinated Universal Time (UTC), sampled to the hour to reduce excess noise due to water turbulence, and interpolated to the second using a 4-degree Lagrange interpolating polynomial,

$$z = \sum_{j}^{4} f_j(t), \qquad f_j(t) = z_j \prod_{\substack{k=1 \\ k \neq j}}^{4} \frac{t - t_k}{t_j - t_k}$$

where z_j is the observed water level elevation, t_j is the observation time, t_k represents the other three primary times used in the calculation, and z is the interpolated water level elevation at time t (fig. 3).

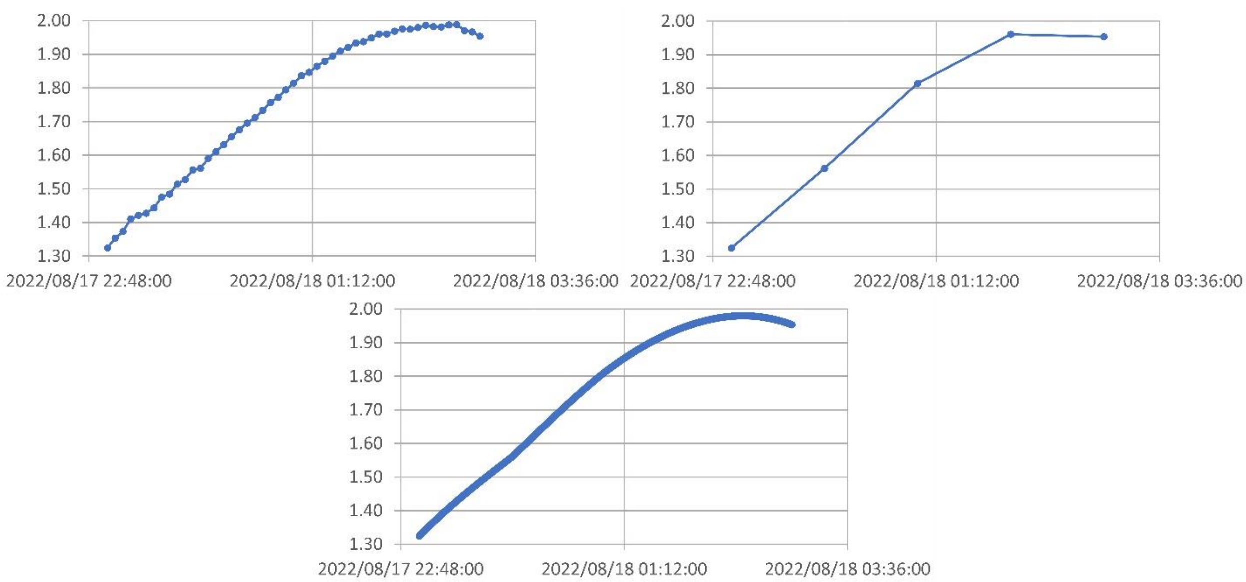

Figure 3. Comparison of 5-minute (top-left), per hour (top-right), and per second (bottom) water level elevation data over a four-hour period of the survey.

Using CIDCO DepthStar software, DGGS imported the Hydroball device file containing raw GNSS position, SBES depth, and inclinometer gyrocompass data. These data were corrected to the 0.115 m catamaran draft and 0.364 m GNSS antenna reference point offset from the SBES acoustic center. These data were then georeferenced to the corrected PPK positions and interpolated water level time series using the water level reference survey (WLRS) sounding reduction method, applying a sound velocity correction of 1500 m/s (saltwater default value) to all data. The final soundings were exported with WGS84 horizontal coordinates and NAVD88 (GEOID12B) elevations. These data were projected to horizontal coordinate system NAD83 (2011) UTM Zone 3 North using Esri ArcGIS Pro version 3.0.2 software.

Data Formatting

All data were delivered in comma-delimited (CSV) format with column headers and accompanied by a data dictionary detailing the header names, definitions, and applicable units.

Coordinate System and Datum

All data were processed in horizontal coordinate system WGS84 and vertical datum NAVD88 (GEOID12B). All data were delivered in horizontal coordinate system NAD83 (2011) UTM Zone 3 North and vertical datum NAVD88 (GEOID12B).

ACCURACY REPORT

The use of the IHO minimum bathymetric standards (IHO, 2022) would be inappropriate for the assessment of these data, which do not meet the IHO prescribed systematic survey pattern criteria. To avoid misinterpretation, DGGS has developed order of accuracy criteria for the qualification of bathymetric survey data separate from but based on the IHO standards. The reported accuracy of these data is intended to express quality only and should not be considered sufficient for safe navigation.

Horizontal Accuracy

We quantified the horizontal accuracy of the GNSS position data using the latitudinal and longitudinal peak-to-peak errors provided by OPUS (table 1). Consistent with OPUS shared solution requirements (NOAA, 2022), DGGS considers high-quality GNSS solutions to have latitudinal and longitudinal errors less than or equal to 0.04 m.

We quantified the horizontal accuracy of individual depth soundings using the maximum manufacturer reported angular accuracy of the Honeywell HMR3000 inclinometer, 0.6 degrees. DGGS applied the following formula to determine the horizontal accuracy for each depth sounding,

$$\pm\Delta(d) = d \tan 0.6°$$

where $\pm\Delta$ is the horizontal uncertainty and d is the sounding depth at a given location.

We categorized the quality of depth sounding data by order of accuracy based on the maximum Total Horizontal Uncertainty (THU) derived from the following formula (IHO, 2022),

$$THU_{max} = \min_{i \in [1,n]} (a + bd_i)$$

where a represents the portion of uncertainty that does not vary with depth, b is a coefficient which represents the portion of uncertainty that varies with depth, d_i is the sounding depth at a given location, and n is the total number of soundings. These data meet DGGS 1st Order standards (table 3) with a 2-dimensional (position) 95 percent confidence level of 0.039 m.

Vertical Accuracy

We quantified the vertical accuracy of the GNSS position data using the combined ellipsoidal height peak-to-peak errors provided by OPUS and ortho height RMS error provided by NOAA's Vertical Datum Transformation software. Consistent with OPUS shared solution requirements (NOAA, 2022), DGGS considers high-quality GNSS solutions to have vertical errors less than or equal to 0.08 m.

We quantified the vertical accuracy of individual depth soundings using the manufacturer reported range resolution, 0.02 m, as a percentage of the maximum range, 50.00m, of the Imagenex 852 single-beam echo-sounder. DGGS applied the following formula to determine the vertical accuracy for each depth sounding,

$$\pm\Delta(d) = \frac{0.02}{50.00}d$$

where $\pm\Delta$ is the vertical uncertainty and d is the sounding depth at a given location.

We categorized the quality of depth sounding data by order of accuracy based on the maximum Total Vertical Uncertainty (TVU) derived from the following formula (IHO, 2022),

$$TVU_{max} = \min_{i \in [1,n]}\left(\sqrt{a^2 + (bd_i)^2}\right)$$

where a represents the portion of uncertainty that does not vary with depth, b is a coefficient that represents the portion of uncertainty that varies with depth, d_i is the sounding depth at a given location, and n is the total number of soundings. These data meet DGGS 1st Order standards (table 3) with a 1-dimensional (depth) 95 percent confidence level of 0.001 m.

Overall Accuracy

We quantified the overall accuracy of the bathymetric data using the vertical separation of overlapping point-to-point 3-dimensional lines within the data. These data intersected 25 times in total, with a separation range between 0.006 m and 0.357 m, average separation of 0.102 m, and median separation of 0.083 m (fig. 4). Overall vertical error is calculated as the root-mean-square (RMS) error of the offsets at these intersection points, with a total vertical error of 0.090 m (table 2). These data meet DGGS 2nd Order standards (table 3) with a 1-dimensional (depth) 95 percent confidence level of 0.179.

Table 1. Base station coordinates and GNSS errors.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Elevation	GNSS X Error (m)	GNSS Y Error (m)	GNSS Z Error (m)
539646.500	6668795.998	12.031	0.015	0.027	0.073

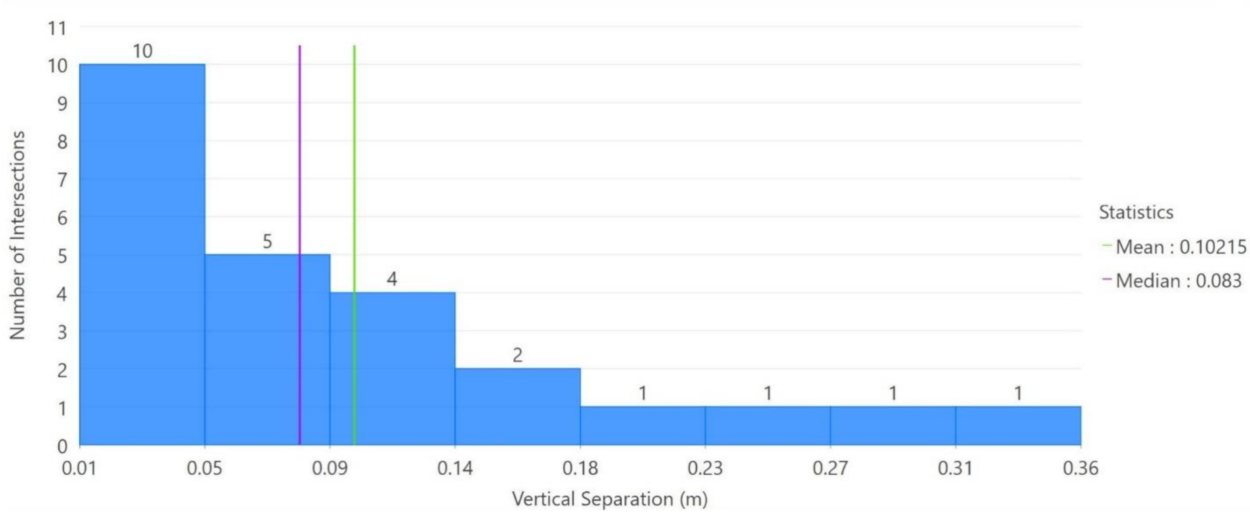

Figure 4. Histogram and summary statistics of vertical separation at data intersections.

Table 2. Survey intersection locations and vertical separations.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Vertical Separation (m)
541025.5397	6669446.6204	0.006
540996.8624	6669838.5494	0.010
540233.0098	6669556.1394	0.013
539971.1648	6670049.0305	0.025
540194.0478	6669418.1656	0.035
541025.5733	6669602.6924	0.036
539880.9258	6669785.7765	0.039
540997.4350	6669804.7465	0.039
540152.8718	6669749.3664	0.041
540050.3939	6670595.6890	0.045
539840.0800	6670424.5190	0.056
540602.3345	6669455.2785	0.077
539940.1761	6670613.8477	0.083
539943.7217	6670627.2036	0.092
539816.2486	6669570.5631	0.093
540070.7504	6669618.8318	0.094
541204.0729	6669430.1659	0.096
540086.3951	6670592.7375	0.131
539969.4384	6669465.0513	0.131
540614.5344	6669581.4128	0.147
540260.8737	6669665.0752	0.160
541213.8387	6669416.8642	0.205

540592.9377	6669683.4529	0.235
540080.1635	6670598.2352	0.306
541214.5668	6669412.7304	0.357
	Mean	**0.102**
	Median	**0.083**
	Standard Deviation	**0.091**
	95% Confidence Level	**0.179**
	Root-Mean-Square Error	**0.090**

Table 3. DGGS order of accuracy criteria.

Criteria	4th Order	3rd Order	2nd Order	1st Order
THU	$a = 20\ m$ $b = 0.10$	$a = 5\ m$ $b = 0.05$	$a = 2\ m$ $b = 0.00$	$a = 1\ m$ $b = 0.00$
TVU	$a = 1.00\ m$ $b = 0.0230$	$a = 0.50\ m$ $b = 0.0130$	$a = 0.25\ m$ $b = 0.0075$	$a = 0.15\ m$ $b = 0.0075$
$\boldsymbol{THU_{max}}$	**20.082 m**	**5.041 m**	**2.000 m**	**1.000 m**
$\boldsymbol{TVU_{max}}$	**1.000 m**	**0.500 m**	**0.250 m**	**0.150 m**

Data Consistency and Completeness

DGGS filtered out low-quality, non-differential (single) GNSS position data using standard categorization (single, float, fixed). All 0.0 m depth soundings, excessive noise, and vertical anomalies were removed through visual inspection. DGGS used time series data for both depth and attitude (pitch and yaw) to manually remove anomalous soundings and any sounding reporting an attitude deviation larger than twenty degrees. No significant erroneous areas requiring repair were identified during this quality control process.

Base station data were processed using the OPUS static processing service, which derives GNSS coordinates from the average of three independent, single-baseline solutions, each computed by double-differenced carrier-phase measurements from three nearby National Continuously Operating Reference Stations (CORS). OPUS provides the range of the three individual single baselines, known as the peak-to-peak error. These ranges include any errors from the CORS used during processing (NOAA, 2022).

OPUS ortho height ranges are estimated using the same calculations applied to horizontal error reporting, typically resulting in a much larger potential error compared to the peak-to-peak error of the ellipsoid height. For more accurate ortho height error reporting, DGGS used NOAA's Vertical Datum Transformation software for final elevation conversions from NAD83 (2011) ellipsoidal heights to NAVD88 (GEOID12B) ortho heights. This software employs accurate, multi-parameter mathematical equations and location specific grid models to perform vertical transformations and report the total root-mean-square error (NOAA, 2016).

ACKNOWLEDGMENTS

We thank the Native Village and City of Chefornak for supporting the creation of these data products, made possible with National Fish and Wildlife Foundation's National Coastal Resilience Funding through our partners at the Alaska Native Tribal Health Consortium. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the Alaska Division of Geological & Geophysical Surveys, the U.S. Government, the National Fish and Wildlife Foundation, or the National Fish and Wildlife Foundation's funding sources. Mention of trade names or commercial products does not constitute endorsement by the Alaska Division of Geological & Geophysical Surveys, the U.S. Government, the National Fish and Wildlife Foundation, or the National Fish and Wildlife Foundation's funding sources.

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