SINGLE-BEAM BATHYMETRIC DATA NEAR KONGIGANAK, ALASKA, COLLECTED JUNE 6, 2023

Keith C. Horen, Nora M. Nieminski, Autumn C. Poisson, and Zachary J. Siemsen

Raw Data File 2024-4

Photo of M2Ocean Hydroball sensor towed behind a boat near Kongiganak, Alaska, on June 6, 2023. Photo: Alaska Division of Geological & Geophysical Surveys.

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SINGLE-BEAM BATHYMETRIC DATA NEAR KONGIGANAK, ALASKA, COLLECTED JUNE 6, 2023

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INTRODUCTION

The Alaska Division of Geological & Geophysical Surveys (DGGS) collected bathymetric data along the Kongnignanohk River near Kongiganak, Alaska, on June 6, 2023 (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 to determine navigability, and is released as a Raw Data File with an open end-user license. All files can be downloaded from https://doi.org/10.14509/31149.

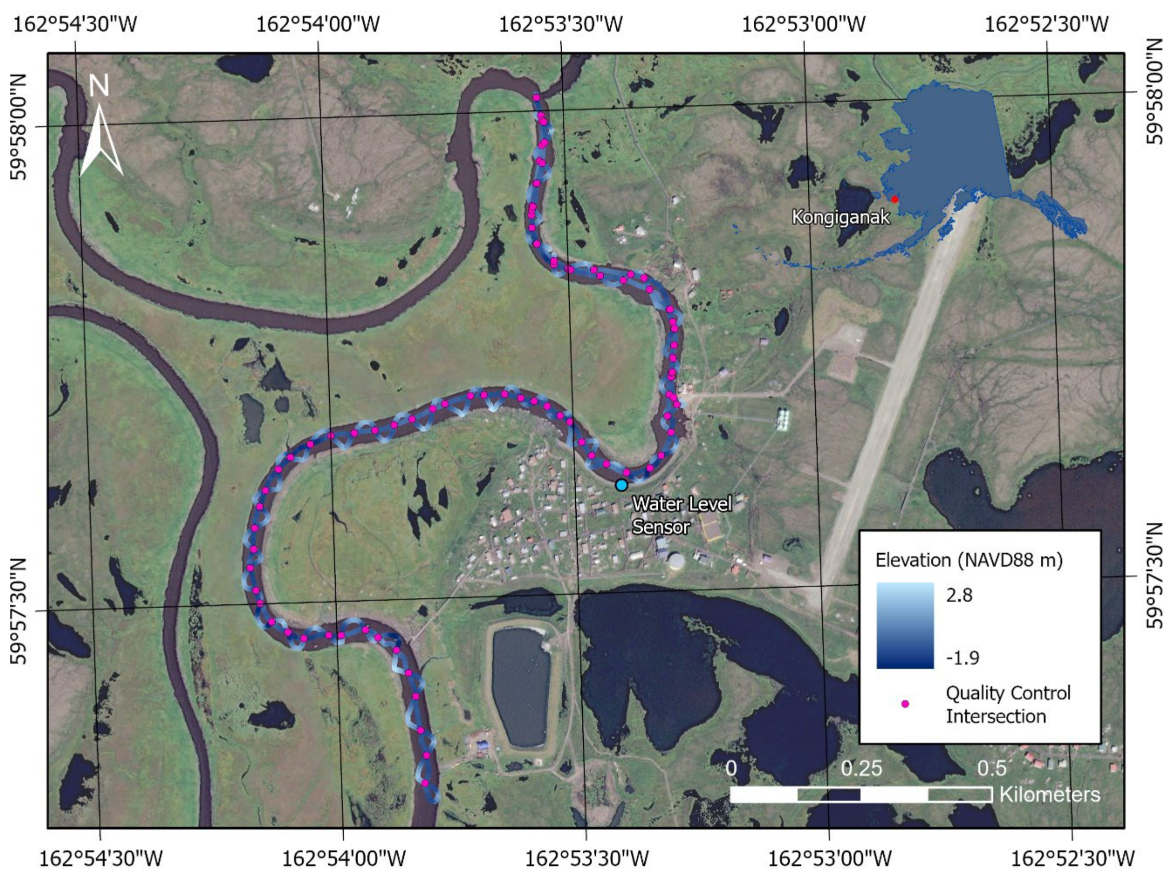

Figure 1. Map of bathymetric soundings along the Kongnignanohk River near Kongiganak, Alaska.

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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 June 6, 2023, DGGS temporarily installed a Trimble R10 receiver sampling at 5 Hz as a GNSS base station over a temporary benchmark. 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 two temporarily installed Solinst model 3001 Levelogger Edge LT M10/F30 pressure and temperature sensors, one fully submerged approximately 1 m off the southern bank of the Kongnignanohk River (fig. 2) and the other placed in a dry, shaded location on land.

Figure 2. Solinst Levelogger installation near Kongiganak, Alaska.

Survey Details

The bathymetric survey was performed on June 6, 2023, from 12:15 PM to 2:15 PM AKDT. The weather throughout the survey was overcast, with light wind and wave heights under 0.1 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 7.0 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 120/100. Final corrected data were exported as time-stamped position files in the WGS84 horizontal coordinate system with ellipsoidal heights.

DGGS collected temperature-compensated pressure-time series data on June 6, 2023, from 9:00 AM to 9:00 PM AKDT, at synchronized five-minute intervals on the two Levelogger sensors. 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 dry air Levelogger data. Subtracting the dry air pressures in 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), and interpolated to the second using a 4-degree Lagrange interpolating polynomial,

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

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

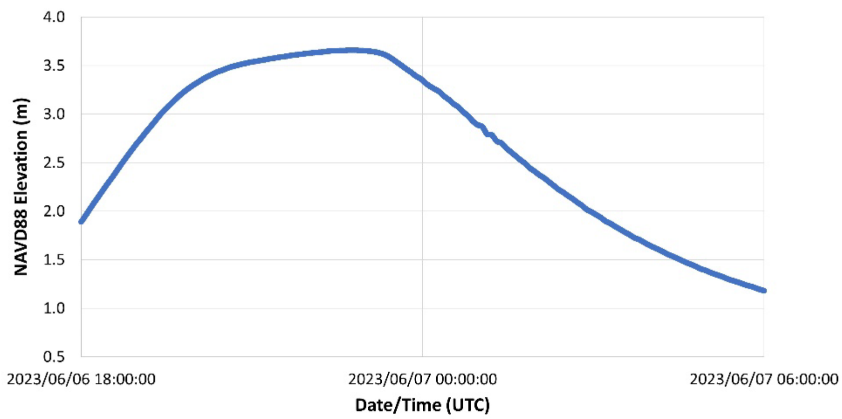

Figure 3. Observed and interpolated water level elevation data during this survey.

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 1450 m/s (fresh-water 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

Using the IHO minimum bathymetric standards (IHO, 2022) would be inappropriate for assessing these data, which do not meet the IHO-prescribed systematic survey pattern criteria. DGGS has developed an order of accuracy criteria for the qualification of bathymetric survey data separate from but based on the IHO standards to avoid misinterpretation (table 1). These accuracy criteria are unique to this survey because they are site-specific and depth-dependent. The reported accuracy of these data is intended to express quality only and should not be considered sufficient for safe navigation.

Table 1. DGGS order of accuracy criteria for this survey.

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	$a = 1.00\ m$ $b = 0.0230$	$a = 0.50\ m$ $b = 0.0130$	$a = 0.25\ m$ $b = 0.0075$	$a = 0.15\ m$ $b = 0.0075$
$\boldsymbol{THU_{max}}$	**20.084 m**	**5.042 m**	**2.000 m**	**1.000 m**
$\boldsymbol{TVU_{max}}$	**1.000 m**	**0.500 m**	**0.250 m**	**0.150 m**

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 2). 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 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 1) with a 2-dimensional (position) 95 percent confidence level of 0.018 m.

Table 2. Base station coordinates and GNSS errors.

NAD83 (2011) Easting	NAD83 (2011) Northing	NAVD88 Elevation (m)	GNSS X Error (m)	GNSS Y Error (m)	GNSS Z Error (m)
618216.692	6648866.311	10.848	0.003	0.003	0.063

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 root-mean-square (RMS) error provided by NOAA's Vertical Datum Transformation software (table 2). 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 of the Imagenex 852 single-beam echosounder, 50.00 m. 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 1) 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 90 times in total (fig. 1 and table 3), with a separation range between 0.001 m and 0.997 m, average separation of 0.260 m, and median separation of 0.222 m (fig. 4). Overall vertical error is calculated as the RMS error of the offsets at these intersection points, with a total vertical error of 0.193 m (table 3). These data meet DGGS 3rd Order standards (table 1) with a 1-dimensional (depth) 95 percent confidence level of 0.377.

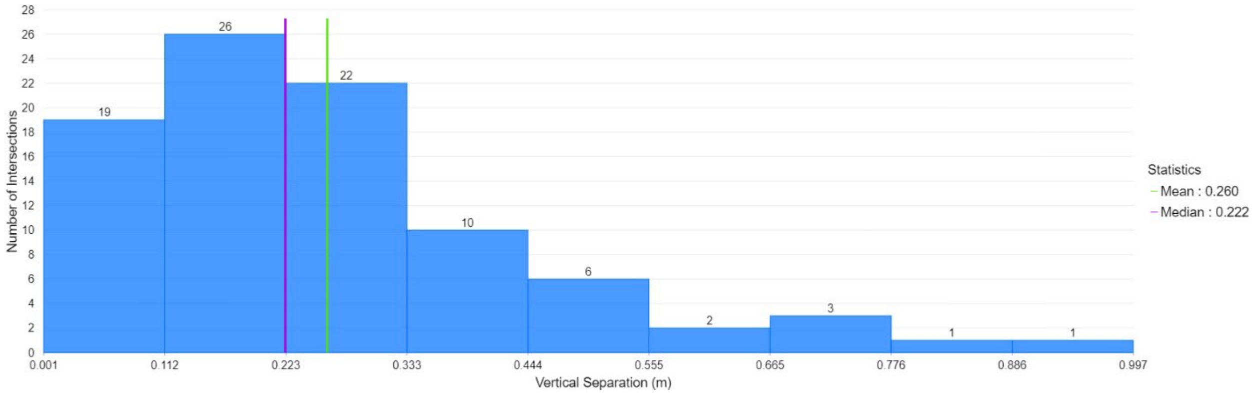

Figure 4. Histogram and summary statistics of vertical separation at data intersections.

Table 3. Survey intersection locations and vertical separations.

NAD83 (2011) Northing	NAD83 (2011) Easting	NAVD88 Vertical Separation (m)
6648696.380	617102.797	0.238
6648732.259	617109.547	0.331
6648772.554	617111.829	0.185
6648652.532	617114.233	0.139
6648813.463	617121.128	0.736
6648627.730	617122.135	0.326
6648844.835	617132.264	0.255
6648592.542	617144.065	0.712
6648884.768	617156.879	0.406
6648573.057	617174.956	0.853
6648908.672	617180.852	0.341
6648560.554	617206.289	0.475
6648933.214	617218.548	0.132
6648566.841	617253.825	0.321
6648950.044	617257.559	0.162
6648566.712	617277.616	0.360
6648954.527	617302.621	0.471
6648577.557	617324.130	0.252
6648960.238	617342.459	0.077
6648562.737	617348.100	0.224
6648970.019	617379.463	0.424
6648538.621	617383.822	0.156
6648494.361	617406.619	0.457
6648981.691	617413.189	0.183

NAD83 (2011) Northing	NAD83 (2011) Easting	NAVD88 Vertical Separation (m)
6648449.880	617420.417	0.236
6648385.080	617430.123	0.227
6648282.899	617438.433	0.407
6648336.228	617440.838	0.029
6649000.925	617452.939	0.165
6649010.329	617476.021	0.416
6649025.863	617524.880	0.331
6649028.026	617550.719	0.001
6649029.561	617591.055	0.368
6649021.838	617621.177	0.093
6649372.521	617642.123	0.367
6649382.909	617642.877	0.079
6649348.512	617643.013	0.136
6649348.930	617643.387	0.147
6649390.685	617643.940	0.068
6649388.924	617645.141	0.012
6649015.532	617647.571	0.300
6649432.651	617650.625	0.212
6649597.776	617651.283	0.572
6649317.994	617651.957	0.130
6649317.932	617652.463	0.310
6649434.049	617652.643	0.368
6649477.110	617658.073	0.067
6649563.371	617660.336	0.129
6649507.212	617661.604	0.175
6649553.773	617661.979	0.997
6649472.561	617662.920	0.201
6649551.929	617665.260	0.422
6649512.365	617667.094	0.204
6649006.520	617671.977	0.319
6649278.412	617685.014	0.221
6649284.779	617685.218	0.644
6648988.456	617696.940	0.183
6649269.393	617711.716	0.024
6649270.350	617713.162	0.048
6648976.045	617716.292	0.099
6649268.181	617717.086	0.063

NAD83 (2011) Northing	NAD83 (2011) Easting	NAVD88 Vertical Separation (m)
6648937.977	617738.708	0.447
6648911.425	617757.217	0.190
6649267.553	617762.155	0.110
6649256.344	617773.519	0.173
6648895.117	617786.020	0.273
6649248.396	617818.208	0.183
6648878.885	617824.349	0.519
6649259.237	617832.424	0.311
6649252.253	617857.820	0.666
6649229.953	617868.410	0.211
6648887.434	617868.988	0.535
6648911.765	617890.514	0.246
6648987.374	617902.584	0.030
6649192.305	617905.820	0.244
6649028.580	617906.091	0.043
6649191.766	617907.684	0.050
6649062.096	617909.955	0.022
6648956.182	617910.002	0.291
6649070.515	617910.520	0.002
6649071.830	617912.272	0.161
6649098.950	617912.766	0.277
6649100.531	617912.943	0.166
6649167.662	617913.154	0.197
6649097.665	617914.049	0.241
6649022.625	617915.043	0.263
6649153.986	617915.545	0.240
6649123.020	617916.108	0.127
6649154.857	617916.165	0.012
6649009.730	617921.270	0.220
	Mean	**0.260**
	Median	**0.222**
	Standard Deviation	**0.194**
	95% Confidence Level	**0.377**
	Root-Mean-Square Error	**0.193**

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 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 orthometric height ranges are estimated using the same calculations applied to horizontal error reporting, typically resulting in a much larger potential error than the ellipsoid height peak-to-peak error. For more accurate orthometric height error reporting, DGGS used NOAA's Vertical Datum Transformation software for final elevation conversions from NAD83 (2011) ellipsoidal heights to NAVD88 (GEOID12B) orthometric 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).

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