Multibeam Bathymetric Survey in Steensby Inlet

Marine Survey Operations Report

2023

Submitted to:

Baffinland
360 Oakville Place Drive
Suite 300
Oakville, Ontario
Canada L6H 6K8

Prepared by:

Seaforth Geosurveys Inc.
300 Prince Albert Road, Suite 200
Dartmouth, NS B2Y 4J2
Phone: 902-468-3579

DOCUMENT CONTROL AND REVISION STATUS

Document Title	Multibeam Bathymetric Survey In Steensby Inlet, Marine Survey Operations Report
Project	Multibeam Survey – Steensby Inlet
Client	Baffinland
Project No.	SGI-907
Document Ref.	SGI907-Baffinland-Steensby Inlet Bathymetric Survey-Ops
Revision No.	1

Document Distribution		
Copy Number	**Distributed to**	**Date**
Master	Seaforth Server	27/11/2023

Revision History		Date	Orig.	Chk.	Appr.	Client
0	Deliver to Client	18 Dec 2023	TF	GC		
1	Client Name Revision	18 Dec 2023	AA	GC	GC	

Signatory Legend:

GC	Garry Casey
DL	David Lombardi
TF	Taylor Fradsham
AA	Arthur Abbott

The following personnel are the designated contacts for any queries regarding this document:

Name	Job Title	Email	Telephone
David Lombardi	President	dlombardi@seafortheng.ca	+902 499 4957
Garry Casey	Manager Geosurveys	gcasey@seafortheng.ca	+902 468 3579 ext 201

TABLE OF CONTENTS

Appendices

Appendix A – Equipment Specs
Appendix B – DPR
Appendix C – MMO Log
Appendix D – Processing Log

Electronic Deliverables sent to CHS

- **External HD – Raw Data Copy**
  - Raw Sensor Data
  - Raw Navigation Data
  - SVP Data
- **External HD (x2) – Processed Data Copies**
  - Processed Multibeam Data
  - Processed Navigation Data
  - Final Surfaces
    - XYZ
    - GeoTiff
    - CSAR
  - Chart (5m contour interval and bathymetric data)
  - AutoCAD Contour Drawing (1m Interval)

1 INTRODUCTION

Seaforth Geosurveys Inc. (Seaforth) was contracted by Baffinland to provide a multibeam bathymetric survey of the selected mandatory area in Steensby Inlet, Nunavut. This project is in response to the Statement of Work (SoW) provided by Baffinland Iron Mines Corporation (Baffinland).

The purpose of this survey is to provide data capable of increasing the accuracy of existing navigational charts and environmental data within the area of interest.

The survey area, as shown in Figure 1-1, was split into three parts. The first section involved a deep-water survey to assess the approach corridor leading into the bay. The second section focused on the near-shore survey and encompassed everything in the bay that is >10m water depth. Area 3 was to be surveyed time permitting.

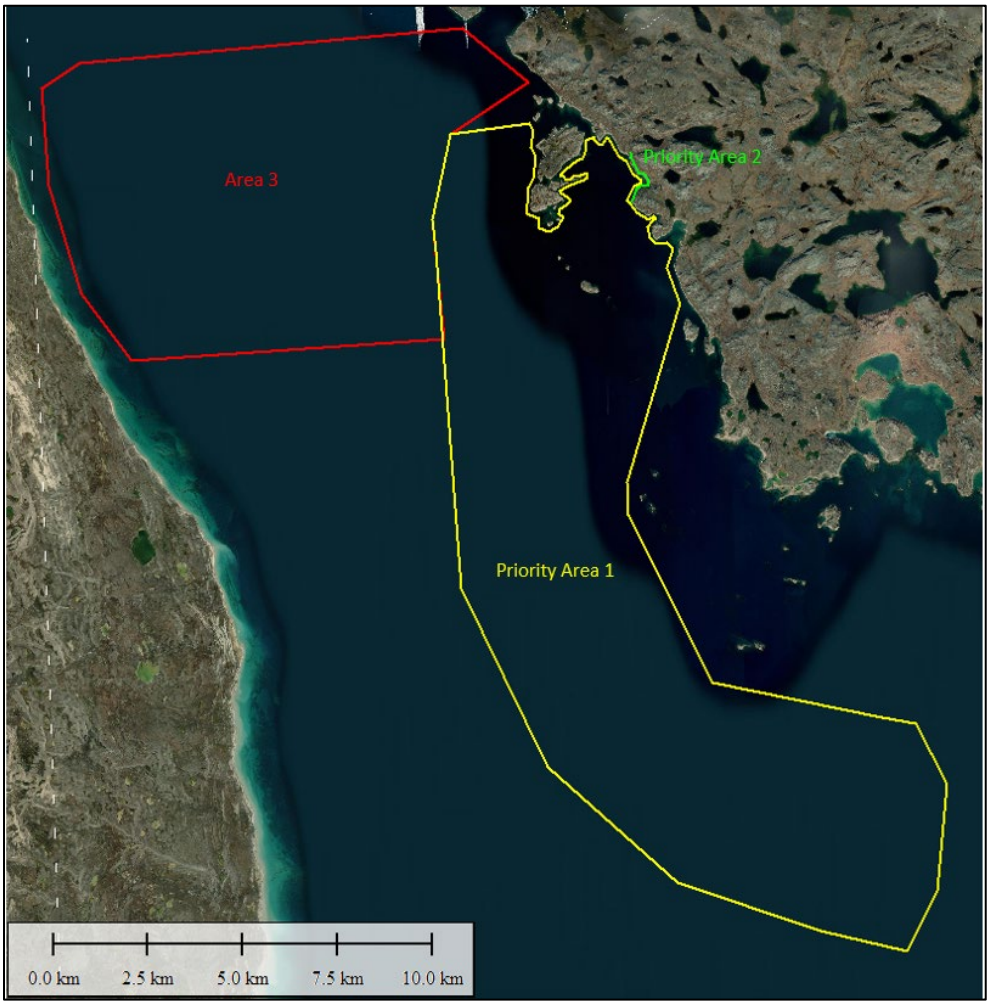

Figure 1-1: Survey Areas for Steensby Inlet, NU

2 SCOPE OF WORK

Table 2.1 outlines the survey area covered along with approximate water depth ranges. Depths have been shifted to chart datum, resulting in some shallow areas showing depths above zero (0) meters.

Survey Area	Approximate Area	Approximate Water Depth Range (+ down)
Mandatory Survey Area 1	127.88 km^2	-4.0m to 146.5m
Mandatory Survey Area 2	1.722 km	-2.5m to 6.0m
Optional Survey Area 3	82.25 km^2	5.0m to 100.0m

Table 2.1: Summary of Baffinland Survey Areas

The following summarizes the project Scope of Work:

- The project scope of work required multibeam data to be collected to International Hydrographic Organization (IHO) S-44 standards. Data is to meet IHO Special Order for all depths <50m, Order 1A for all depths >50 but <100m, and Order 1B for all depths >100m.
- Survey line spacing is to be maintained such that 20% overlapping data with adjacent swaths is achieved.
- A minimum of two sound velocity casts are to be taken each day as well as necessary based on sonar data. All sound velocity casts are to be spatially distributed.

2.1 Changes to Scope of Work

There were no changes to the scope of work.

3 MARINE SURVEY EQUIPMENT

3.1 Survey Vessels

To meet the survey requirements within the set timeframe, two vessels were utilized for conducting the survey operations. The RV Connor Murphy was assigned to survey the deep-water sections within the survey areas, serving as the mothership for a smaller Survey Launch that covered all the shallow water and near shore areas.

3.1.1 RV Connor Murphy

The Connor Murphy is a 28m long steel-hulled vessel, owned and operated by RS Marine, based out of St. Johns, NL (Figure 3-1). The RV Connor Murphy is owned and operated by RS Marine based in St. John's, NL. The Canadian-flagged, Near Coastal - 1 Class - vessel was formerly the

CCGS Harp.

The RV Connor Murphy's LOA is 26m long, with a beam of 7.5m and a draft of 2.5m. The vessel can operate twenty-four hours (24hrs) a day in up to Force five (5) winds (Beaufort Scale), up to three meter (3m) seas, and has an endurance of 45 days.

Survey and vessel crew remained on-board, and the vessel was equipped with enough fuel and provisions to complete the entire trip to and from the survey area.

Figure 3-1: RV Connor Murphy

3.1.2 Survey Launch

This Survey Launch (Figure 3-2) was used in tandem with the deep water vessel to cut down on survey times. It used the RV Connor Murphy as a mothership for transport between areas. The crew for the survey launch were housed onboard the Connor Murphy as a part of the survey crew, and operations were conducted using an 8-hour operational (daylight) day during times of adequate weather.

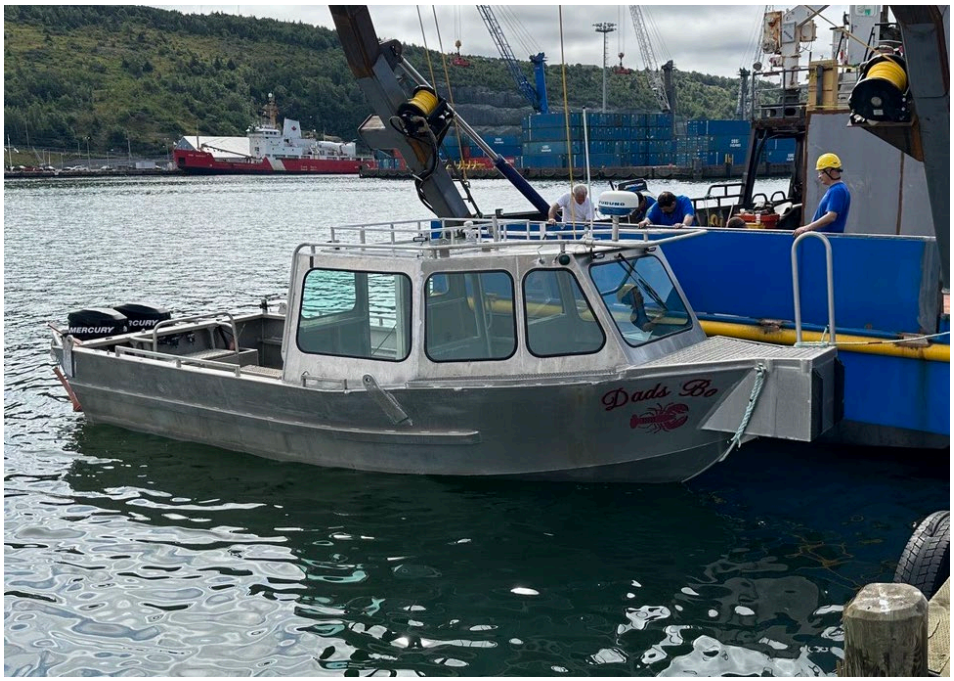

Figure 3-2: Survey Launch

3.2 Survey Equipment

The survey equipment utilized during the bathymetric survey on board the Connor Murphy is listed in Table 3-1, The equipment used for the Survey Launch is listed in Table 3-2.

RV Connor Murphy	
System	**Mobilized Equipment**
Integrated Navigation System:	Kongsberg SIS5
Positioning System:	SBG Apogee Navsight
Differential Corrections:	Fugro GNSS Marinestar Satellite Corrections
Heading System:	SBG Apogee Navsight
Motion Sensor:	SBG Apogee Navsight
Multibeam Echosounder System:	Kongsberg EM712
Velocity Profiler:	AML BaseX SVP

Table 3-1: Mobilized survey equipment – Connor Murphy

Survey Launch	
System	**Mobilized Equipment**
Integrated Navigation System:	BeamworX NavAQ
Positioning System:	PosMV Oceanmaster
Differential Corrections:	Fugro GNSS Marinestar Satellite Corrections
Heading System:	PosMV Oceanmaster
Motion Sensor:	PosMV Oceanmaster
Multibeam Echosounder System:	Norbit Winghead i77h
Velocity Profiler:	AML BaseX SVP

Table 3-2: Mobilized Survey Equipment – Survey Launch

Detailed equipment specifications are included as Appendix A.

3.3 Marine Survey Crew

Seaforth personnel utilized during the project are listed in Table 3-3.

Name	Position	Vessel	Shift
Taylor Fradsham	Party Chief	Connor Murphy	Float
Christian Solomon	Lead Hydrographer / Night Shift	Connor Murphy	0000-1200
Trevor Hoskins	Hydrographer / Day Shift	Connor Murphy	1200-0000
Deven Knowles	Small Vessel Surveyor	Survey Launch	Daylight Hours
Travis Pittman	Captain	Connor Murphy	0600-1200 / 1800-0000
Phill Wilcock	Chief Mate	Connor Murphy	1200-1800 / 0000-0600
Jamie Eddison	Deckhand	Connor Murphy	0600-1200 / 1800-0000
Steve Parsons	Deckhand/Small boat operator	Connor Murphy / Survey Launch	Daylight Hours
Teresa Hanlon Best	MMO	Connor Murphy	0800 - 2000

Table 3-3: Marine survey personnel list

3.4 Project Geodetic Datum

Survey control was referenced to WGS84 with projections in UTM Zone 17N. The geodetic parameters used during survey acquisition are listed in Table 3-4.

Datum Parameters	
Ellipse Name:	WGS84
Datum Name:	WGS84
Semi Major Axis (a):	6378137.0
Semi-minor Axis (b):	6356752.314
Inverse Flattening:	298.257223563

Table 3-4: Project Geodetic Datum Parameters

3.5 Vertical Geodetic Datum

Bathymetry data was reduced to Chart Datum (CD) in post processing utilizing Ellipsoid-referenced surveying techniques. Seaforth utilized Fugro's GNSS Marinestar satellite-based correction service to record high precision ellipsoidal elevations. The Fugro Marinestar high-precision satellite-based corrections is an L-band correction service providing global horizontal positional accuracies of 10cm (95% confidence) and vertical accuracy of 15cm (95% confidence).

The satellite corrections were recorded in real-time using SIS5 navigational software with the SBG Apogee Navsight on the Connor Murphy and through BeamworX NavAQ with the PosMV Applanix Oceanmaster on the Survey Launch.

The separation model to reduce ellipsoidal heights to CD (referenced to WGS84 ITRF08) was supplied by CHS (CANNORTH2016v1HyVSEP_ITRF08_CD_2023SteensbyInlet).

4 SURVEY OPERATIONS

The following is a brief summary of survey operations (Table 4.1):

Date	Event
7th September to 15th September 2023	Mobilization of Connor Murphy and Survey Launch in St. Johns, NL
16th September to 21st September 2023	Transit to Steensby Inlet
21st September 2023	Preform 2nd Patch Test
21st September to 27th September 2023	Arrive on site, start data acquisition
28th September 2023	Preform 3rd Patch Test
28th September to 2nd October 2023	Survey operations in Priority Area 1 and Area 2
2nd October to 8th October 2023	Survey Operations in Area 3 Start transit back to St. Johns NL
18th October 2023	Vessel docked in St. Johns, NL

Table 4.1: Summary of survey operations timeline

4.1 Operational Activity

Table 4.2 details a combined total of survey activities conducted onboard both vessels, the RV Connor Murphy, and the Survey Lauch as reported in the project Daily Progress Reports (DPRs). Figure 4-1 displays the same activity time summary in chart format.

Operation Activity	Hours
Vessel Mobilization (In Port)	192
Equipment Calibration (Mobilization)	37.5
Transit (Mobilization)	225.25
Survey Operations – Connor Murphy	226.75
Survey Operations - Survey Launch	79.5
MMO Pre-Watch	0.5
Weather Downtime	0
Equipment Downtime	0
Vessel Downtime	1.75
Transit (Demobilization)	225.50
In Port Standby (Demobilization)	66.5
Other (Coast Guard Rescue)	2.5
Demobilization (In Port)	4

Table 4.2: Summary of Operational Hours

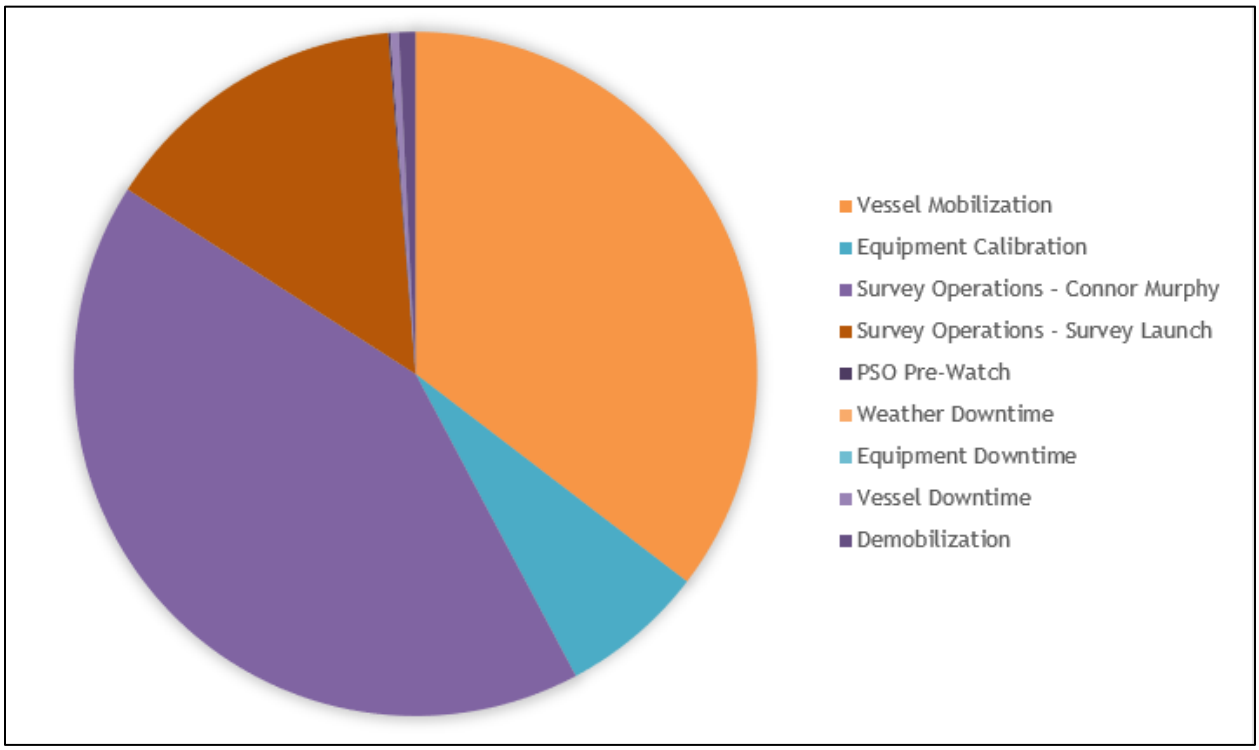

Figure 4-1: Summary of Operational Hours Chart

Refer to Appendix B 'Daily Progress Reports' for detailed daily operations and activities.

4.2 MMO Operations

Due to the Kongsberg EM712 frequency range falling within the hearing range of known marine mammals in the survey area, it was required to have a MMO personnel onboard during daylight operations. The MMO would be on shift from 0800-2000 hours in the wheelhouse keeping a log of any observations made in the field. During nighttime hours, (2000-0800) a Passive Acoustic Monitoring System (PAMS) was deployed off the stern of the vessel and towed while surveying. The nighttime surveyor was responsible for monitoring the PAMS data for any anomalies. For the entire survey operations there were no mammals detected that required mitigation. See Appendix C for full observation logs.

4.3 Mobilization

This section will provide a summary of the mobilization completed for the survey, refer to ***SG1-907_Steensby Inlet MB-Mob Report*** for the full mobilization report.

The Kongsberg multibeam was installed while the Connor Murphy was in dry dock in Glovertown, NL. The vessel then sailed to St. Johns, NL where all the other survey equipment was installed onto the Connor Murphy and the Survey launch.

On board the Connor Murphy, the primary GPS position and heading sensor antennas were installed on the main rail of the vessel's superstructure. The SBG motion unit was placed in the crawl space beneath the wheelhouse and the multibeam Transducer (Tx) and Receiver (Rx) heads were hull mounted inside of a gondola frame.

Figure 4-2: Location of SBG positioning and heading antennas on vessel superstructure.

Figure 4-3: Hull mounted Kongsberg multibeam on the Connor Murphy

The Survey Launch was equipped with a full setup from Norbit which included the portus pole, positioning antennas, and the i77h Winghead multibeam with an integrated PosMV motion unit.

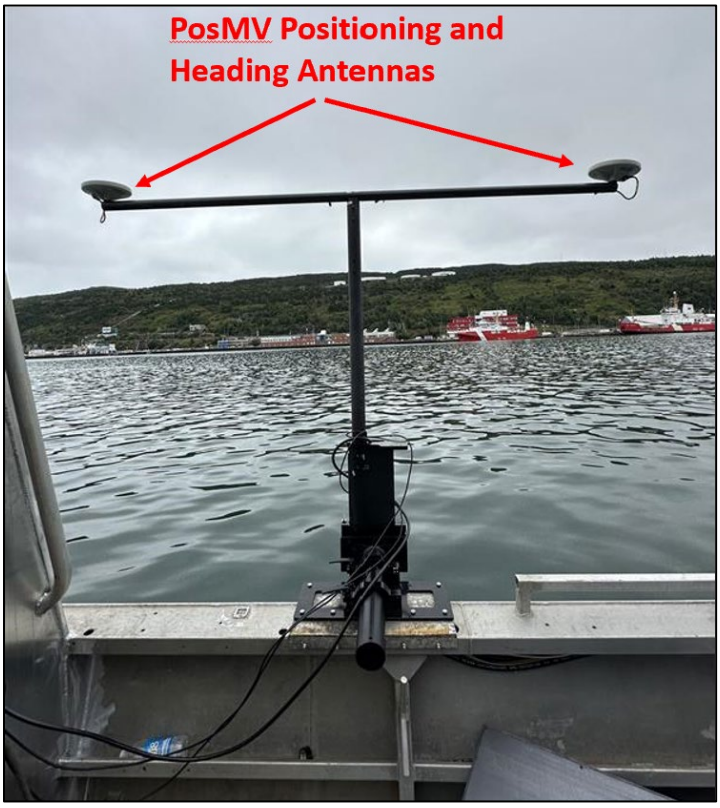

Figure 4-4: PosMV positioning and heading antennas installed on Norbit Portus pole.

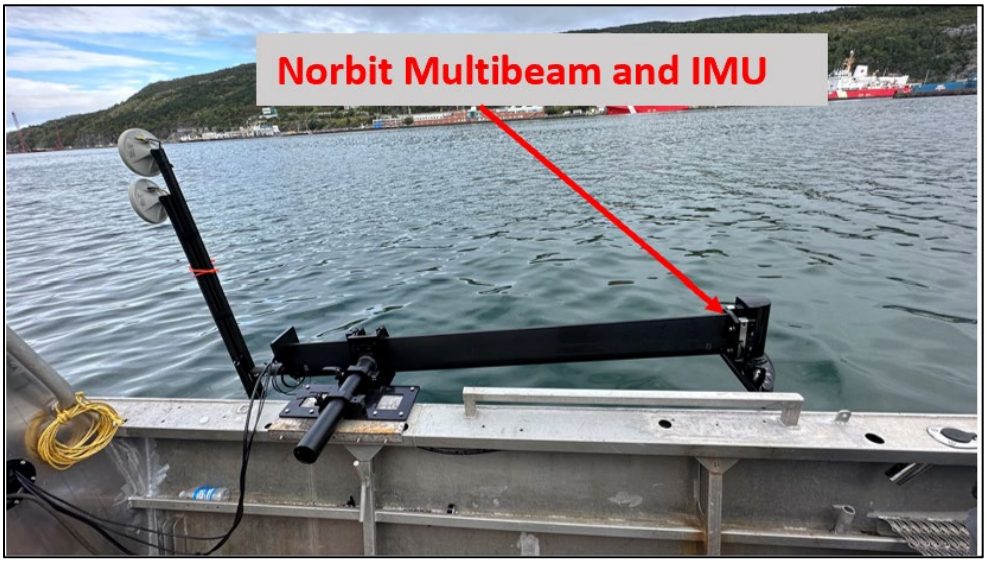

Figure 4-5: Norbit winghead multibeam and integrated IMU installation location

The multibeam calibrations for both vessels were completed in Steensby Inlet, NU. The results of the multibeam calibrations are summarized in Table 4-1 for the Connor Murphy and Table 4-2 for the Survey Launch.

Date	Location	Area	Results (°)		
			Roll Offset	Pitch Offset	Heading Offset
Sept 28th, 2023	Steensby Inlet Lat: 69°57'41.83" N Long: 78°31'38.44" W	Flat seabed with slope and features	+0.505	+0.667	+1.87

Table 4-1: Calibration results for Connor Murphy

Date	Location	Feature	Results		
			Roll Offset	Pitch Offset	Heading Offset
Sept 28th, 2023	Steensby Inlet Lat: 70°15'50.50" N Long: 78°28'29.66" W	Flat area with slope	+0.173	+0.160	+0.410

Table 4-2: Calibration results for Survey Launch

4.4 Survey Methodology

Kongsberg's SIS5 aboard the Connor Murphy and BeamworX's NavAQ on the survey launch formed the central components for positioning and data collection throughout the acquisition process. These systems ensured precise vessel positioning, timing, and recording, enabling the real-time attainment and upkeep of survey specifications.

The EM712 operated using a frequency of 100kHz throughout the survey area. The Norbit Winghead system utilized the 400kHz option for depths ranging from 0-50m and 300 kHz for depths up to 80m.

Raw data files were recorded in Kongsberg's native format (.kmall) in SIS5. Onboard the survey launch, data was recorded in both BeamworX and Norbit. BeamworX produced data in its own format (.bwxraw) and the data was exported as .s7k formatting to bring into Caris. Norbit recorded data in .s7k format as a backup for BeamworX.

Line spacing was variable, determined based on water depth and sonar swath width. Adjacent survey lines were offset on a line-by-line basis depending on the swath width from the adjacent survey line. Lines were spaced such that the data coverage achieved a minimum of 20% overlap on adjacent lines.

5 DATA PROCESSING

5.1 Multibeam Data Processing

The majority of the multibeam processing took place in the office post survey, with a portion completed aboard during the return transit from the survey area. All data processing was done using Caris 11.4 software with surface cleaning being completed in QPS Qimera 2.6. Refer to Appendix D for full processing log and notes.

The data was processed to comply with the CHS scope of work, requiring an accuracy to meet International Hydrographic Organization (IHO) Standards for Hydrographic Surveys (S-44) SPECIAL ORDER (for depths <50m), Order 1A (for depths >50m and <100m), and Order 1b (for depths >100m).

Data processing followed the workflow listed below:

1. Import kmall files and .s7k files
2. Import Auxiliary Files
    a. SBET
    b. RMS
    c. Delayed Heave
3. Georeference Bathymetry
    a. Apply Sound Velocity Correction (SVC)
    b. Source set to GPS or Tide
    c. Apply Separation Model
    d. Compute TPU – Realtime
4. Create CUBE Surfaces
5. Data QC
    a. Attitude Editor - GPS Tide data cleaning
    b. Subset Editor – Area based cleaning using QPS Qimera
    c. Add QC Layer
6. Export Products
    a. CSAR files
    b. XYZ
    c. GeoTiffs

Refer to the Processing Report for a comprehensive breakdown of the post-processing steps undertaken to generate the final surface from the data.

5.2 Data QC

To verify the data has been corrected to CD, comparisons to the CHS NONNA Bathymetry data were conducted. CHS data overlapped the SGI survey at various locations within the surveyed area. Notably, a portion of NONNA data overlapped both shallow and deep water data in Priority Area 1. Furthermore, in Area 3, a single strip of NONNA data coincided with the collected data.

The following pictures show the Difference Surface created (outlined in black) in CARIS by comparing the collected data to the CHS NONNA data. A Difference Surface is used to find changes by comparing two surfaces of the same area that were created at different times. Each point in the surface creates a difference value and the color range is based off of those difference values. The statistic report images highlights the mean difference between the two surfaces.

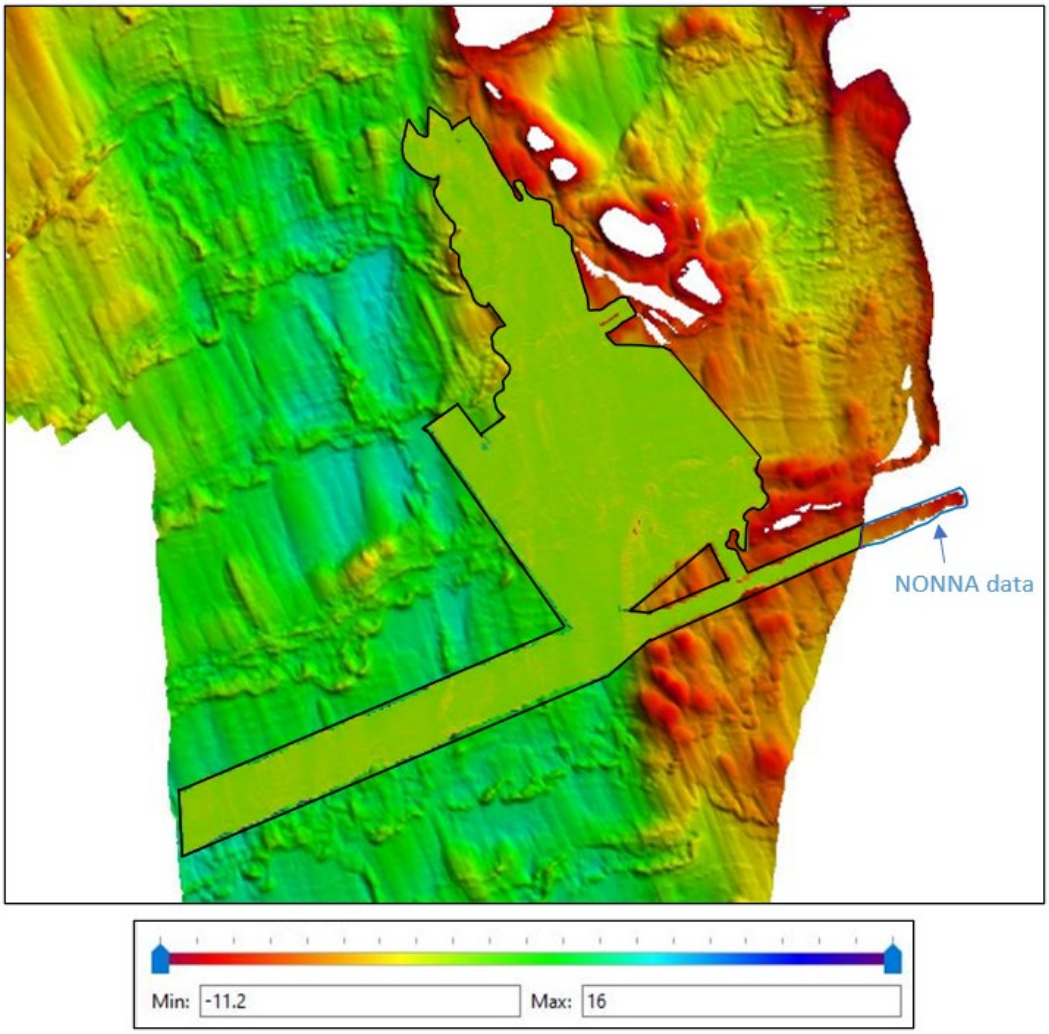

Figure 5-1: Difference Surface (outlined in black) between collected data and CHS NONNA data, min and max range in meters

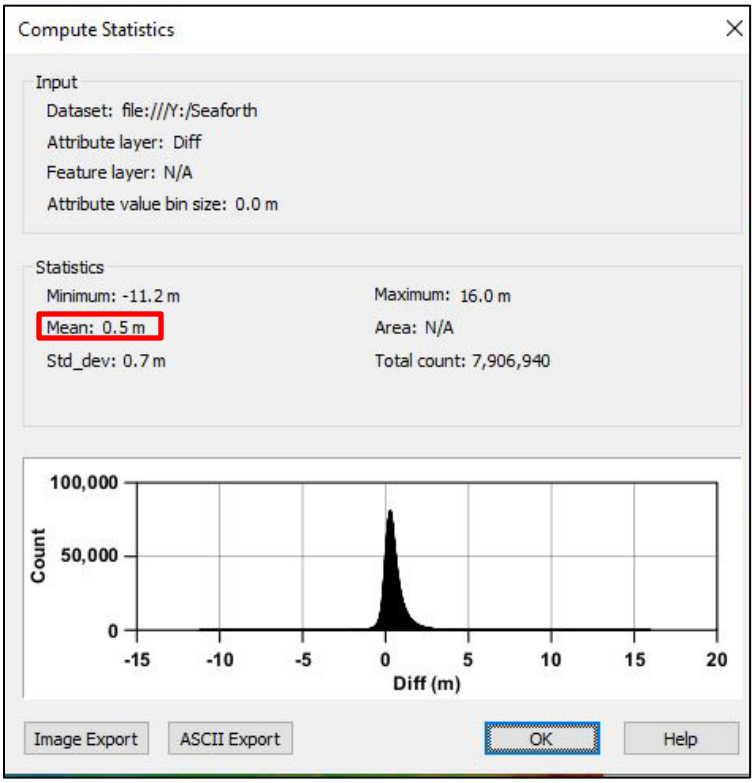

Figure 5-2: Statistics computed for the shallow water Difference Surface between collected data and NONNA data

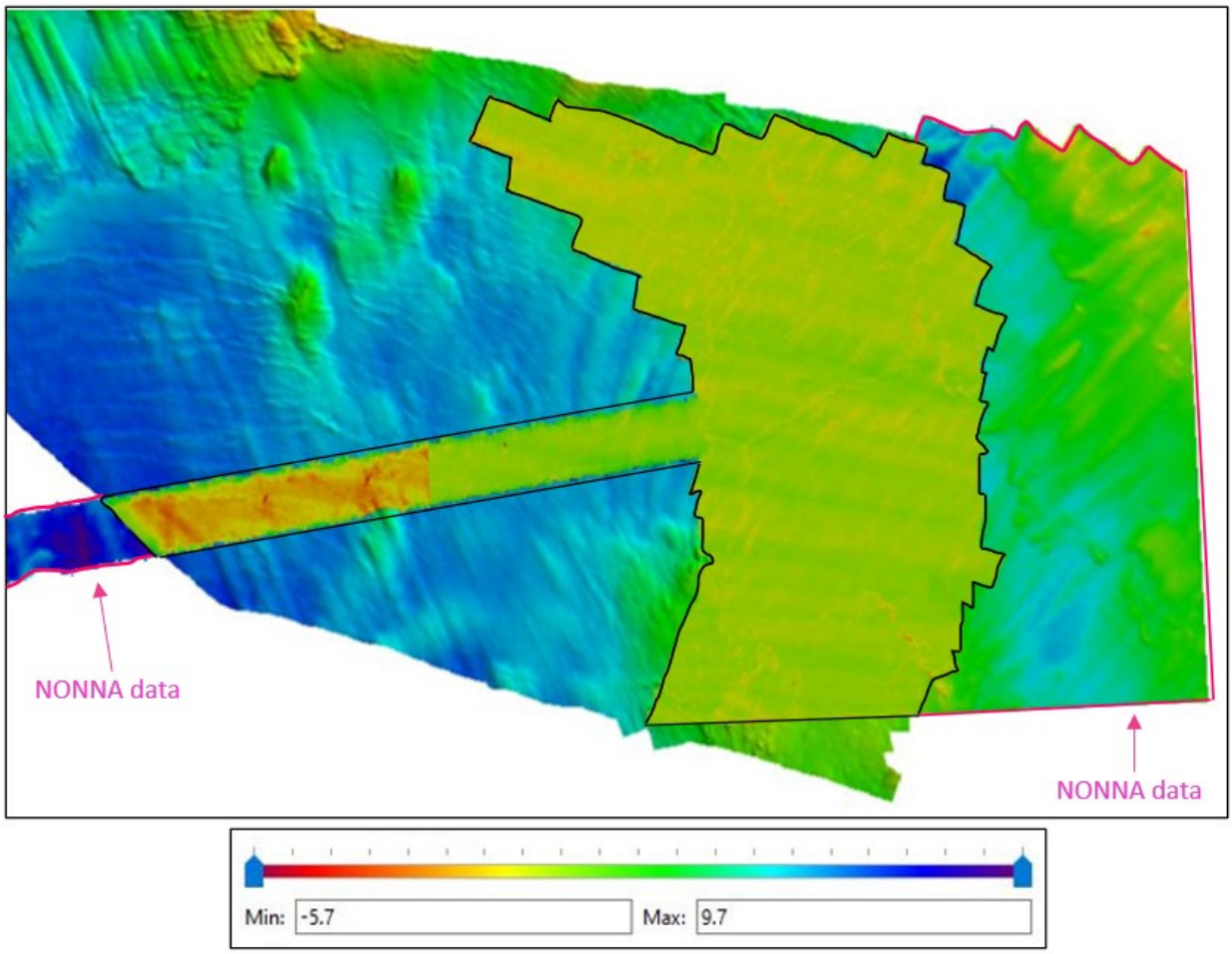

Figure 5-3: Difference Surface (outlined in black) between collected data and CHS NONNA data, min and max range in meters.

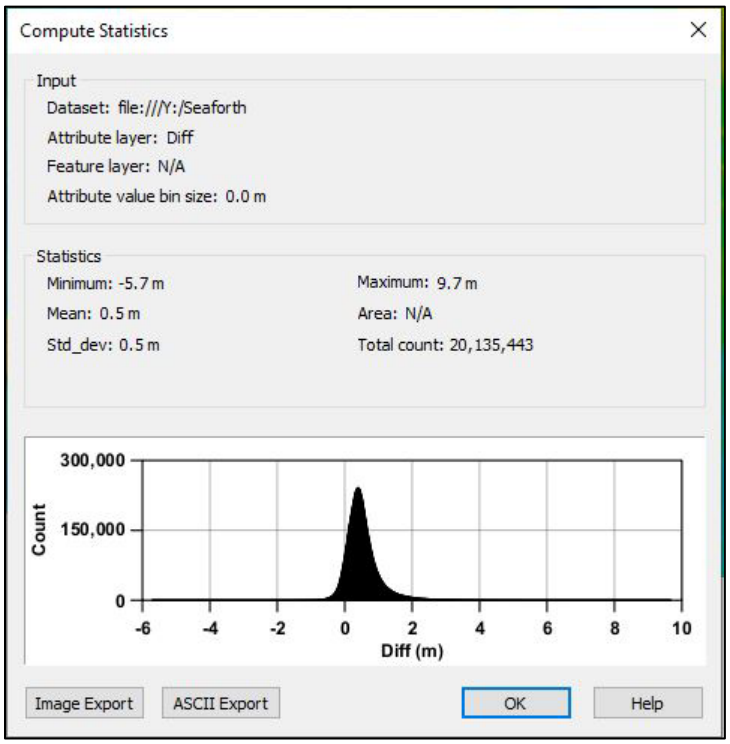

Figure 5-4: Statistics computed for the deep water Difference Surface between collected data and NONNA data.

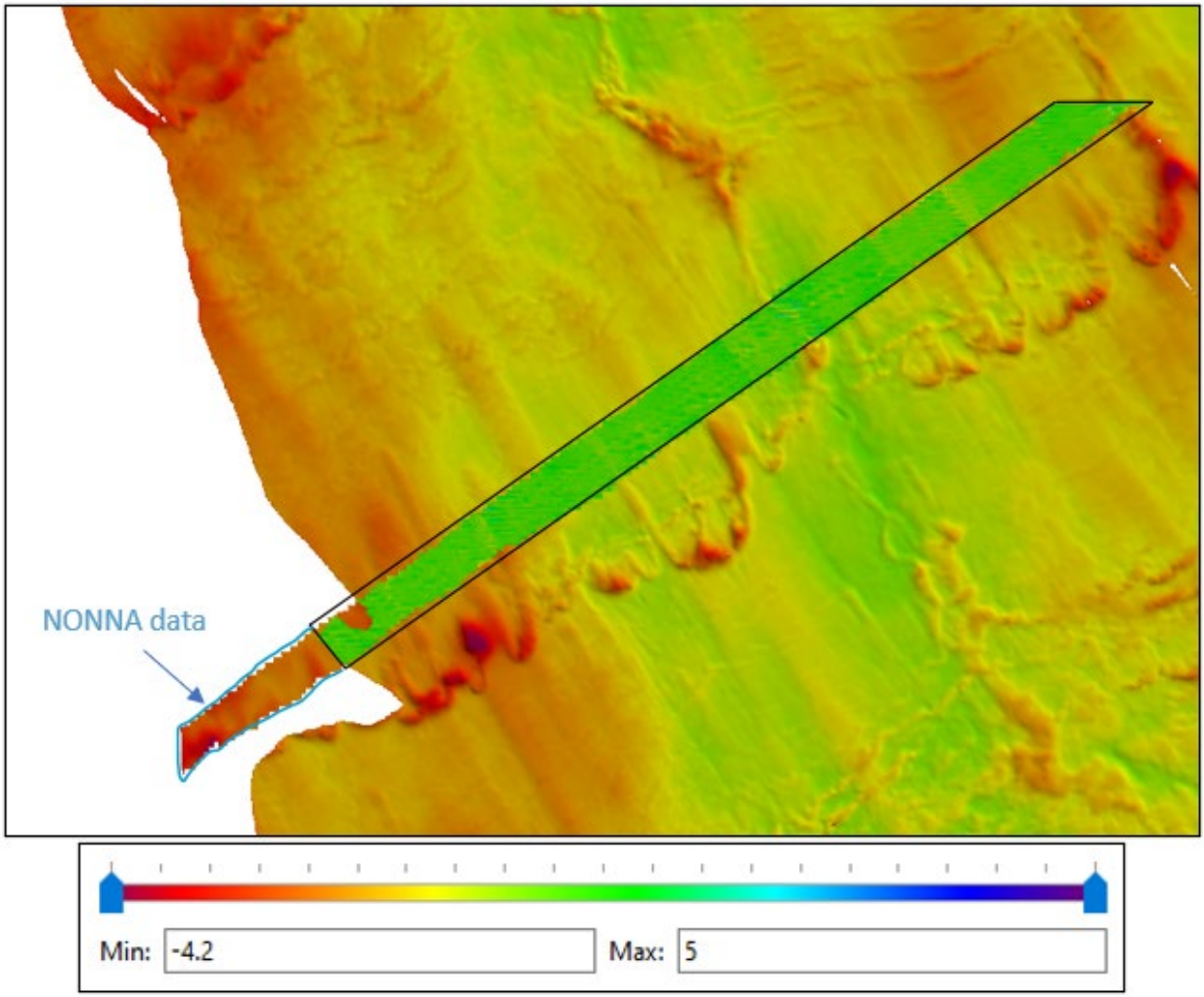

Figure 5-5: Difference Surface (outlined in black) between collected data and CHS NONNA data, min and max range in meters.

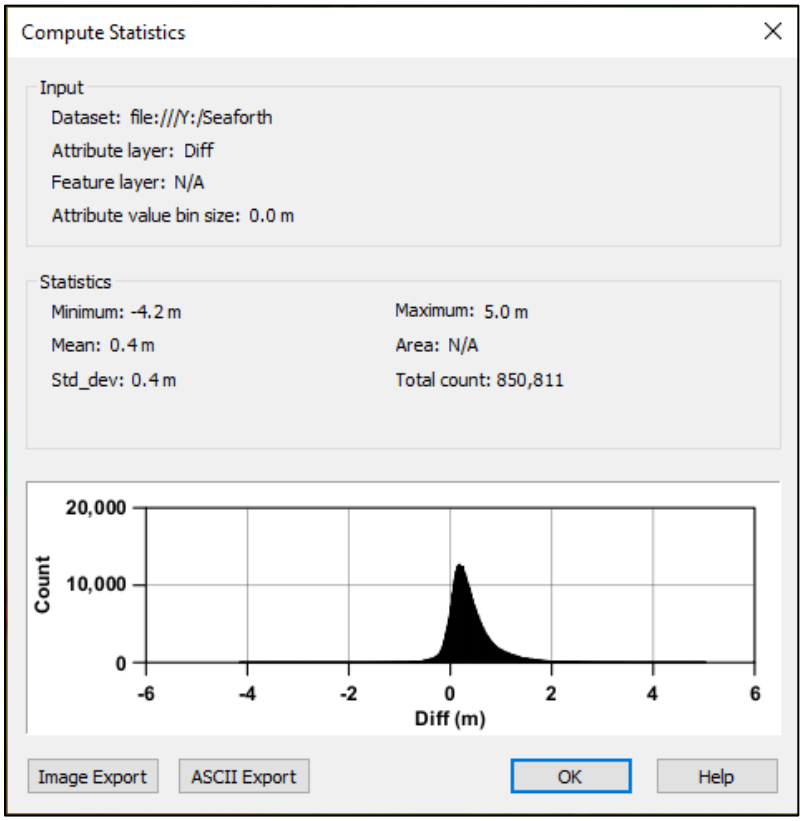

Figure 5-6: Statistics computed for the Area 3 Difference Surface between collected data and NONNA data.

In addition to the above surfaces, a QC report was generated using an expression that takes into account the IHO survey standards and density requirements set by the client for the survey. The results of the expression based on the 1m CUBE surface can be seen in Figure 5-7 and Figure 5-8.

*"IF (Density > 5 AND Depth<=50 AND Uncertainty<=((0.25^2)+((0.0075*Depth)^2))^0.5) then 1 else if (Density > 5 AND Depth>50 AND Uncertainty <=((0.5^2)+((0.013*Depth)^2))^0.5) then 2 else if (Uncertainty >((0.5^2)+((0.013*Depth)^2))^0.5) then 3 else NO_DATA"*

According to the QC report, 99.93% of all the collected data meets the required survey standards and density, while only 0.06% of the data collected does not meet the survey specifications.

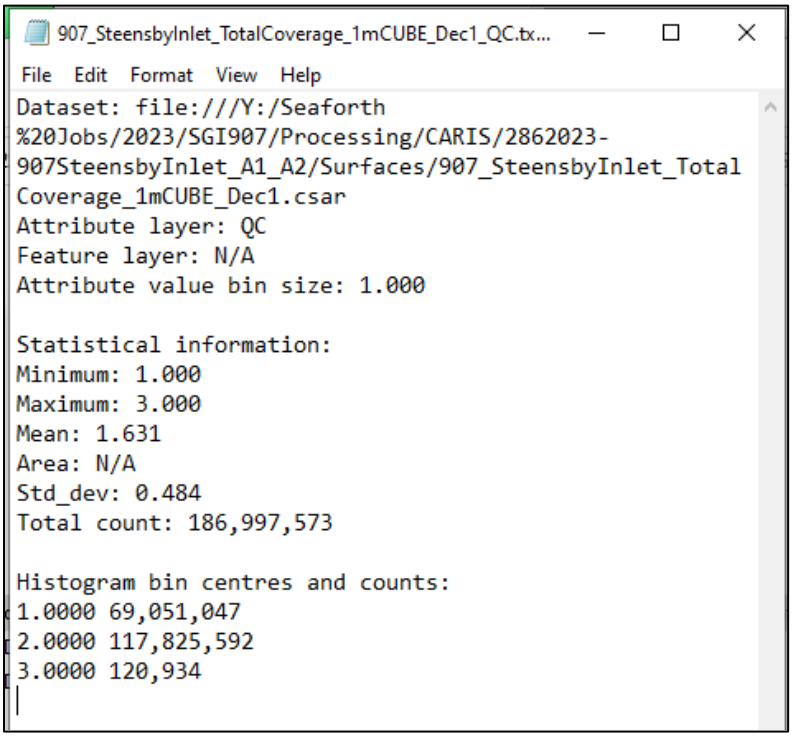

Figure 5-7: QC Report showing the results from the expression assessing data compliance with both the IHO survey Standards and data density requirements.

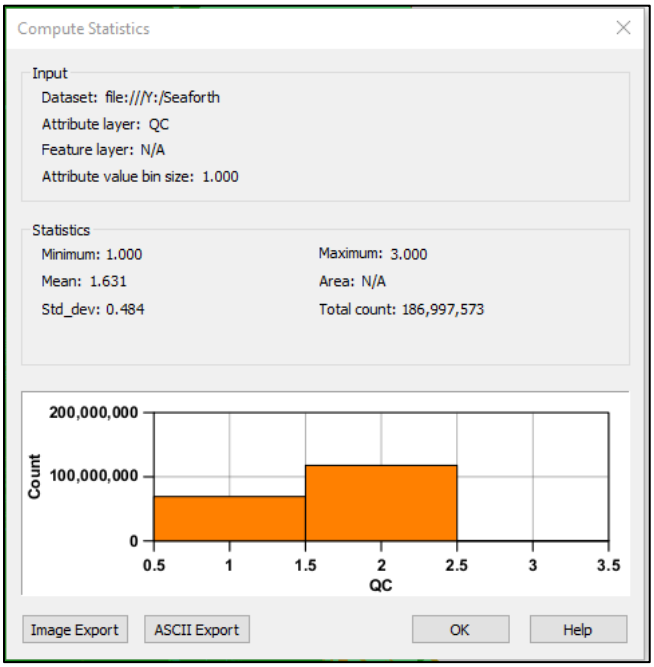

Figure 5-8:Statistical form of showing the results from the expression assessing data compliance with both the IHO survey Standards and data density requirements.

6 SAFETY

Safety introduction and vessel familiarization were conducted by the captain for all survey personnel joining the vessels. HSE procedures were reinforced, focused primarily on deck procedures to ensure proper PPE was being worn; all deck work was conducted using at least two (2) personnel. PFDs were worn during all deck operations including the deployment and recovery of the PAMS towed system and during all SVP casts.

7 RESULTS

Approximately 207 km^2 of bathymetry data was collected across eleven (11) days of survey operations. The weather was extremely favourable during survey operations, with no weather days for the Connor Murphy and only two (2) days for the Survey Launch.

Final, cleaned surfaces were exported using resolutions based on water depth using the following parameters:

Water Depth	Surface Resolution
<50m	1m
50 to 100m	2m
>100m	5m

Table 7-1: Surface resolution based on water depths.

The following figure presents the final processed multibeam data collected within the survey area in Steensby Inlet, NU.

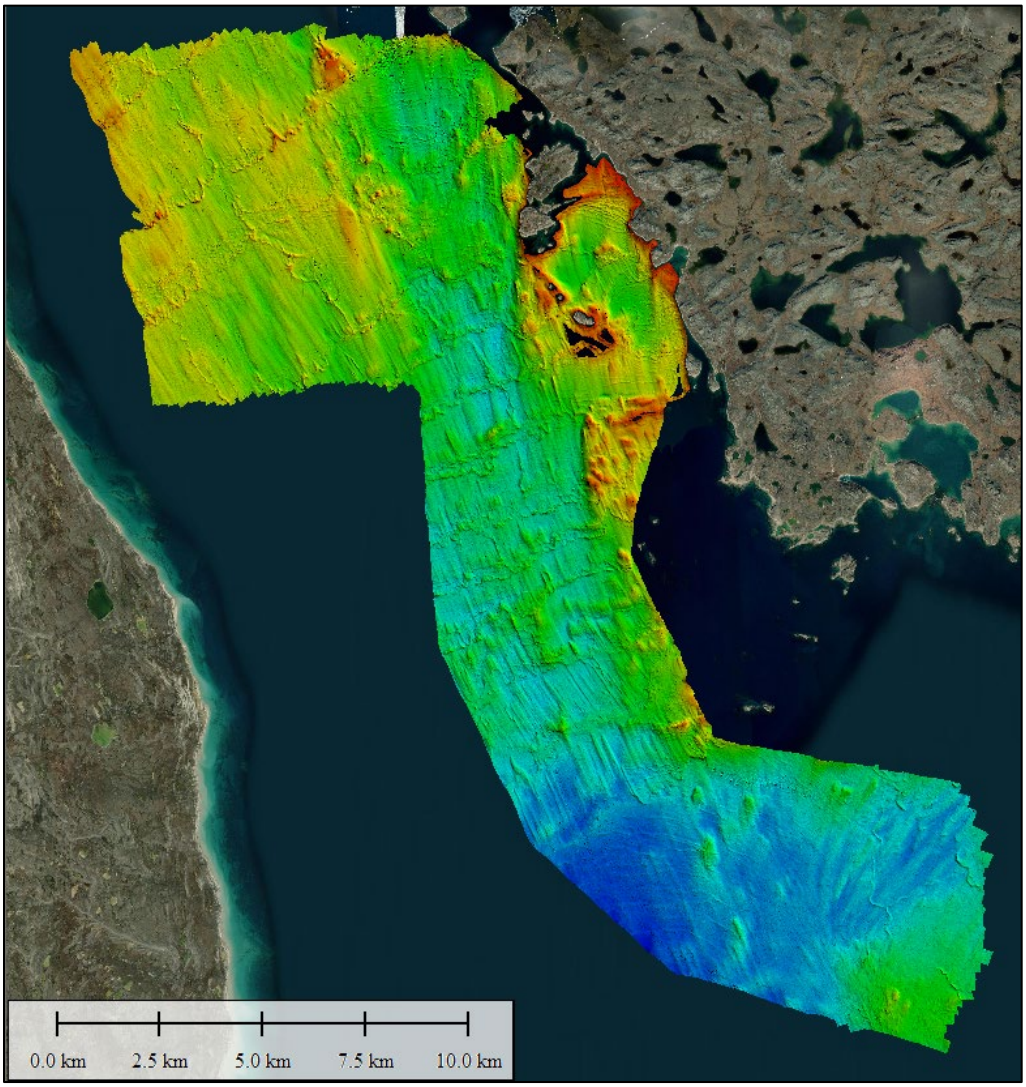

Figure 7-1: Final surface of data for Steensby Inlet, NU

8 DELIVERED DATA

The data delivered to CHS includes both processed and raw data provided on external hard drives.

The provided external hard drive for **Raw Data** contains the following folder structure:

- **Raw Data** (All Raw data organized is sub-folders per Julian Day and then per vessel)
  - **MBES Data**
    - **JDXXX**
      - Connor Murphy
        - .kmall files
      - Survey Launch

        - .bwxraw files
        - .s7k exports from BeamworX
        - Norbit .s7k files
    - **SVP**
        - **JDXXX**
            - Connor Murphy
            - Survey Launch
    - **DGNSS_IMU_Data**
        - **JDXXX**
            - Connor Murphy
            - Survey Launch

The provided external hard drives for **Processed Data** contains the following folder structure:

- **Raw Data** (All Raw data organized is sub-folders per Julian Day and then per vessel)
    - **MBES Data**
        - **JDXXX**
            - Connor Murphy
                - .kmall files
            - Survey Launch
                - .bwxraw files
                - .s7k exports from BeamworX
                - Norbit .s7k files
    - **SVP**
        - **JDXXX**
            - Connor Murphy
            - Survey Launch
    - **DGNSS_IMU_Data**
        - **JDXXX**
            - Connor Murphy
            - Survey Launch
- **Processed Data** (CARIS folder structure & processed nav data)
    - **CARIS Project**
        - Background
        - Contours
        - HDCS_Data
        - Preprocess
        - Project
        - Surfaces
        - SVP
        - Template

- Tide
- Video

- **Processed Position Data**
  - **CM_SBG_Sessions**
    - **JDXXX**
      - Export
        i. Delayed Heave
        ii. SBET
        iii. RMS
  - **PosMV_Files**
    - **JDXXX**
      - Export
        i. Delayed Heave
        ii. SBET
        iii. RMS
- **Qimera Cleaning**
  - Qimera project with updated hips file
    - Area 3 cleaning edits were done in: 3142023_907SteensbyInlet_A3
    - Area 1 and 2 cleaning edits were done in: A1_A2_PointCleaned

- **Final Products**
  - **XYZ**
    - 1m CUBE Surface
  - **CSAR**
    - 1m, 2m, 5m CUBE surfaces
  - **GeoTiff**
    - 1m, 2m, 5m CUBE surfaces
  - **Charts**
    - 5m contour interval chart with bathymetric data
    - AutoCAD Drawing with 1m contour interval