Survey Report

Sequim Bay
Multibeam Bathymetric Survey
December, 2015

SUBMITTED BY

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# APPENDICES

Appendix A  Equipment Specifications
1.0 INTRODUCTION

C&C Technologies, Inc., an Oceaneering International Company, (hereinafter referred to as either ‘Contractor’ or C&C) provides the following report to PNNL’s Marine Science Laboratory, Sequim, WA (hereinafter referred to as the ‘Client’) for a bathymetric survey of Sequim Bay, the channel around Travis Spit, and a small area to the North Side of Travis Spit as shown in Figure 1.

Figure 1 Survey Area overlain with Bathy Hillshade
The purpose of the survey was to provide a full digital terrain data set generated from the multibeam (MBES) survey with 100% coverage. Specific deliverables include:

- Full coverage tide-corrected digital MBES bathymetry DTM
- Coincident MBES Backscatter data

A Kongsberg EM3002 dual head multibeam sonar was used for its ability to provide high resolution and accurate (IHO Order 1 or better) bathymetry, water column, and calibrated backscatter data. Backscatter information can be used to aid bottom type/classification.

### 1.1 Survey Methodology

As shown in Figure 1, the survey area covers a large portion of Sequim Bay, the channel around Travis Spit, and a small area to the North Side of Travis Spit. The survey was carried out in a manner that ensured 100 percent coverage to within the shallow limits of the sonar system or safe navigation of the vessel. Figure 2 is our survey post plot showing the lines run to cover the survey area. Due to unknown bathymetry and the variable shape of the survey area, several areas were collected via a “coverage” approach that filled in gaps where necessary (Figure 2).
2.0 SURVEY OPERATIONS

2.1 Summary

The survey was conducted using C&C’s Almar survey vessel, chosen for its capability of working safely in shallow waters. Survey equipment mobilized aboard the vessel included a single beam echosounder (SBES), multibeam echosounder (MBES), sound velocity profiler (SVP), and a DGNSS positioning and attitude system. Survey operations were conducted during daylight hours only. Survey personnel consisted solely of C&C surveyors.

Initial vessel mobilization and testing occurred on Monday, December 7th to determine acceptable operation of the equipment prior to transit to the survey area. Vessel and personnel transited to the survey area from our offices in Bothell, WA on Tuesday, December 8th. The vessel was launched that day at nearby John Wayne Marina and calibrations performed. Survey operations began the next day after a brief induction and Safety meeting by the Client and lasted through the evening of the 14th. Small pockets of inclement weather prevented survey for portions of the day on both the 10th and the 13th.

During the survey, the crew arrived at the vessel at first light and initialized all the equipment. The vessel transited to the survey area and performed a sound velocity cast. Survey would then begin with sound velocity casts taken as needed. Real-time DTM creation was used for QC purposes and to ensure full seafloor coverage was attained.

Upon completion of survey activities to the approval of the Client, the vessel was demobilized to the extent needed for safe transport and the crew and vessel returned to the C&C offices in Bothell, WA the morning of December 15th.

Survey personnel consisted of one Senior Hydrographer to manage MBES operations and one vessel operator (Table 1). An onsite data processor was provided to perform data QC.

<table>
<thead>
<tr>
<th>Table 1 Survey Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey Personnel</td>
</tr>
<tr>
<td>Party Chief/Surveyor</td>
</tr>
<tr>
<td>Surveyor/Boat Operator</td>
</tr>
<tr>
<td>Onsite Data Processor</td>
</tr>
<tr>
<td>Total Personnel</td>
</tr>
</tbody>
</table>
3.0 METHODOLOGY & EQUIPMENT

3.1 Survey Vessel

C&C provided our shallow water capable Almar vessel that was ideally suited to this type of survey. Specific information regarding the dimensions and equipment configuration aboard the Almar can be found below in Table 2 and displayed in Figure 4 and Figure 5.

Figure 3 C&C Almar Sounder survey vessel
Table 2 Almar Vessel Statistics

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOA (Overall)</td>
<td>29ft</td>
</tr>
<tr>
<td>Beam</td>
<td>8ft</td>
</tr>
<tr>
<td>Draft</td>
<td>1.5ft</td>
</tr>
<tr>
<td>Cruising Speed</td>
<td>30kts</td>
</tr>
</tbody>
</table>

Figure 4 Profile view of Almar Configuration.
3.2 Mobilization

All personnel and equipment were staged from our C&C offices in Bothell, Washington. Prior to the start of mobilization all survey systems and components were tested using C&C and/or the manufacturer’s recommended procedures.

Equipment was mobilized on the vessel prior to the survey. Equipment and spares required to conduct the survey were made available to a reasonable extent based on limited storage capabilities aboard the Almar.
3.2.1 Calibrations

Prior to departure, all computer systems were tested to demonstrate connectivity with the various positioning and survey systems. On-site calibration of survey equipment and sensors was completed prior to start of survey activities and found to be within spec. The following offsets were found as a result of the patch test and applied to the data real time within the SIS operating software. The accuracy of the offsets was subsequently confirmed during acquisition, with several locations of high relief (e.g., Figure 6) providing a clear example of the relative accuracy of the acquisition settings.

<table>
<thead>
<tr>
<th>Offset</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch</td>
<td>+2.4</td>
</tr>
<tr>
<td>Roll</td>
<td>+0.4</td>
</tr>
<tr>
<td>Yaw (Heading)</td>
<td>-2.7</td>
</tr>
</tbody>
</table>

Table 3 Calibration Results

Figure 6 Soundings coloured by line, inner channel

3.3 Multibeam Survey

3.3.1 Positioning Systems

C-Nav

A C-Nav 3050 GNSS receiver was used to provide high accuracy position data during the survey. The 3050 is a 66-channel GPS/GLONASS dual frequency receiver utilizing the worldwide C-NavC² Corrections Service to provide real-time precise point positioning (PPP) solutions within <10 cm accuracy. Position data was output to all sensor acquisition systems and raw data logged directly from the receiver. C-Nav ellipsoidal height data was utilized in post-processing for kinematic water level corrections.
**POSMV**

An Applanix POSMV 320v4 provided high accuracy position, motion, and heading data to all bathymetric survey systems. The POSMV is an inertially-aided positioning and orientation system commonly used for high-performance hydrographic surveying. The C-Nav 3050 served as both an auxiliary GNSS and RTCM differential correction source to the POSMV.

**Hypack Survey**

Hypack navigation software provided real-time vessel positioning from DGNSS, motion sensor and heading/gyrocompass inputs. The system provided independent data gathering and logging of echosounder bathymetric data, trackline data and navigation from various system inputs. The system collected, displayed and logged various DGNSS quality information and additional online quality assessment information.

**Horizontal / Vertical Control**

All instrument locations were referenced to a common point located near the survey vessel’s center of mass (labelled IMU on Figure 4 and Figure 5). Data from all positioning systems were logged using the local ellipsoidal datum (WGS84), and post-processed as necessary. Survey data was acquired in meters and projected in UTM Zone 10N. It was determined during post-processing that the NOAA tide estimates for Sequim Bay were not accurate enough to remove all tidal artifacts from the data. Therefore the survey was tide-corrected by logging the vertical position of the vessel (with respect to the WGS84 ellipsoid) during the survey period, and filtering the data based on a 6-minute moving window Chebyshev filter to remove heave. This data was then vertically shifted from the WGS84 ellipsoid to MLLW based on an iterative best fit method to the nearest NOAA tidal reference (Sequim Bay Entrance, stationID: 9444555).

3.3.2 Single Beam Sonar (SBES)

A Ross Laboratories 825B survey-grade SBES, operating at a frequency of 200 kHz, was used to collect depth measurements within the survey area. This was used as a secondary method of providing real time validation of observed MBES depths.

**Calibration**

To ensure accurate echosounder installation, a bar check and leadline comparison was performed dockside prior to survey activities and found to be operating within manufacturer specifications. Sound velocity profiles taken during survey operations were applied in real-time and in post-processing.

**Positioning, Attitude, and Sound Velocity**

The SBES was coupled with the Applanix POSMV, described above, for real-time position, heading, and motion compensation in the Hypack software. Sound velocity in the water column was collected using an YSI Castaway CTD.

**Data Acquisition**

SBES data was logged using Hypack Survey software, also used as the primary navigation program. Data from the POSMV 320 provided motion correction to soundings.

3.3.3 Multibeam Sonar System (MBES)
A Kongsberg EM3002 dual head, 300 kHz high-resolution, dynamically-focused MBES was used for bathymetric, backscatter and water column information. The system is hard-mounted using a C&C proprietary over-the-side mount system.

**Calibration**

MBES calibration and testing was conducted using an internal systems check and a patch test standard with IHO standards and common hydrographic practice.

**Positioning, Attitude, and Sound Velocity**

The MBES system was coupled with the Applanix POSMV, described above, for real-time position, heading, and motion compensation. Sound velocity at the sonar head was measured with a Valeport MiniSV, while water column profiles were taken as frequently as necessary using the YSI Castaway CTD.

**Data Acquisition**

The Kongsberg Seafloor Information System (SIS) MBES acquisition system was used to acquire and store all MBES data. Data from all ancillary sensors including position, attitude, and sound velocity, were sent to SIS and integrated within the data packet for each sonar ping. All data was stored in SIS’s binary *.all data format for post-processing, analysis, and archiving. Water column data from the entire survey area was recorded in a separate *.wcd file, to minimize the size of the *.all files. Real-time acquisition displays provide data quality control and sonar coverage assessment during the survey. The MBES status, line log, health and integration with ancillary systems were recorded in the appropriate system logs.
4.0 RESULTS

4.1 Processing Methodology

The MBES data was processed in Caris HIPS and SIPS 9.0.21, an industry-leading bathymetric processing software suite. Data processing followed the standard workflow outlined in Figure 7.

![Caris HIPS and SIPS workflow](image)

**Figure 7 Caris HIPS and SIPS workflow**

4.2 Processing Notes

During data processing it was determined that the port EM3002 head had several slightly offset beams, which over the project produced tracklines in the data. These were partially corrected by adjusting the beam file with a 0.5% correction, but the tracklines are still visible in the data. These were deemed to be cosmetic blemishes, and the sonar head in question has been removed from active service. We do not believe that this artifact impacts the quality of the data for this survey area.

During processing it was also found that several lines were acquired with old or spatially inconsistent sound velocity profiles. This was especially prevalent in the channel area, as this region represents a turbulent mixing of multiple water bodies. Data with incorrect sound velocity profiles were updated, and all sounding re-ray traced to provide the highest possible sounding accuracy within the channel region. Other than these instances the data collected is of high quality, and required very little manual processing.
The MBES backscatter data was processed in both Caris HIPS and SIPS and in Fledermaus FM Geocoder 7.4.2. A side-by-side comparison of the two backscatter mosaics showed that the Fledermaus mosaic provided a more visually consistent image, and at a higher resolution (0.38 m pixel size).

### 4.3 Deliverables

MBES deliverables:
- 1.5 m grid of survey area in Fledermaus .sd format, ASCII grid, and GeoTIFF
- 5 m grid of survey area in Fledermaus .sd format, ASCII grid, and GeoTIFF
- Backscatter imagery in GeoTIFF and ASCII grid
- Fledermaus .SCENE with all elements integrated
- Copy of Iview4D to display Fledermaus files

Ancillary deliverables:
- Raw MBES data including water column
- Raw SBES data
- Raw navigational data

### 4.4 Imagery Examples

Below are three imagery examples, also included in the deliverables folder. Figure 8 is of an area of special interest defined by the Client, and shows detail of the channel region with clear sand ripples and other high-current structures. In Figure 9 the backscatter mosaic revealed the location of the municipal outflow pipe (backscatter mosaic is overlain on the bathymetry for perspective). Finally, Figure 10 shows the inner bay with sediment flow features and a possible gas expulsion region (delineated by a ‘cat’s paw’ like set of expulsion craters).

![](image.png)

**Figure 8 Channel region detail perspective**
Figure 9 Outflow pipe imaged in backscatter mosaic

Figure 10 Inner bay backscatter mosaic with sediment flow features