MARITIME CONSTRUCTIONS

Report of Survey

Project Name : Healthy Coorong, Healthy Basin – Bathymetric survey
Project Location : Central Coorong between The Needles and Hack Point
Client : Department for Environment and Water
Contract No : DEW-D0012038
Contract ID : 1875
Internal No : SV.E.0001 HCHB Coorong Bathymetric Surv

Document No.		**SV.E.0001**			
Document Title		**Report of Survey –** HCHB Coorong Bathymetric Survey			
Rev.	**Date**	**Issue type**	**Originator**	**Review by**	**Approval by**
A	14/04/21	Final	H. Thomas	A.Bolton	A. Bolton

CONTENTS

TABLES IN THE MAIN TEXT

FIGURES IN THE MAIN TEXT

ABBREVIATIONS

CORS	Constantly Operating Reference Stations
DEW	Department for Environment and Water
DEM	Digital Elevation Model
GDA94	Geocentric Datum Australia 1994
GNSS	Global Navigation Satellite System
GRS80	Geodetic Reference System (1980)
IMS	Integrated Management System
MGA54	Map Grid Australia Zone 54
PSM	Permanent Survey Mark
QC	Quality Control
RTK	Real Time Kinematic
SBES	Single Beam Echosounder
SV	Sound Velocity
SVP	Sound Velocity Profile
THU	Total Horizontal Uncertainty
TVU	Total Vertical Uncertainty

1. Introduction

1.1 Projection Description

Maritime Constructions was contracted by DEW to collect bathymetric elevation data to update the Coorong's DEM and enable more up-to-date modelling if dredging is to be assessed in the region. The bathymetric elevation data was collected spatially, where possible, with previously collected data to enable appropriate 'training' of the Coorong's DEM.

The primary objectives of this project were:

- Collect bathymetric elevation data along 235 transects, totaling 135.6 km (Blue Lines)
    - Transects referred to in terms of 'Northern' and 'Southern' areas, clearly separated by the wide lagoon north west of Parnka Point
- Collect approximately 18.6 km of bathymetric data along the length of the deepest part of the main channel between The Needles and Hack Point (Red Line)

The Coorong survey objectives and extents area delineated in Figure 1.1 below.

Figure 1.1: Coorong survey area and objectives

1.2 Document Scope

This document describes the equipment and personnel, geodetic parameters, operations and data processing methodologies adopted during the survey. All survey related works were carried out in accordance with Maritime Constructions IMS ensuring on-site crew conducted works adopting best safety practices, environmental protection procedures and quality control. The safety of the public, fauna, flora and crew was paramount during the execution of the survey.

1.3 Survey Summary

1.3.1 General

Project Number MC Internal		**Project Locality**	
SV.E.0001		Central Coorong between The Needles and Hack Point.	
Survey Authority/Client		**Client Contact**	
Department for Environment and Water		David Hudson	Stephen Madigan
Hydrographic Surveyor-In-Charge		**Certification or Qualification**	
Huw Thomas		Certified Professional Hydrographic Surveyor - 2	
Start date of Survey	17/03/2021	**End Date of Survey**	01/04/2021
Number of field days	12	**Class of Survey**	N/A
Survey Platform/Vessel Name		**Survey Platform/Vessel Name**	
Survey Kayak (SBES)			
Survey Report Completed By		Huw Thomas	
Date of Survey Report Completion		14/04/21	

1.3.2 Details of Survey Execution

The following positioning systems were used:		
Positioning System 1	Trimble SPS986 GNSS Antenna using VRSnow (SBES)	
Positioning System 2	Trimble R10 RTK GNSS Base Station (LBS)	
Positioning System 2	Trimble R10 Smart Antenna (LBS)	
Positioning System 2	Trimble R8 Smart Antenna (LBS)	
The following sounding systems were used:		
	Model/System Details	**Frequency (kHz)**
Echosounder 1	Cee-Echo	200
Echosounder 2		
Motion Reference Unit (Heave compensation)	RTK GNSS	
Logging and processing systems used, and Versions:		
Logging	Hypack 2020	
Processing	Hypack 2020	
Survey Plan line spacing	N/A	
Has data been thinned from that collected	No	
Data - thinning	0.75m Shoal bias	

Sounding Plot - thinning method and bin size	Shoalest Sounding – 20m

1.3.3 Horizontal Control

Soundings are on the following Datum:	
Datum	GDA94
Spheroid	GRS80
Projection and Zone	MGA94, Zone 53
THU – Total Horizontal Uncertainty. Estimated Accuracy of Soundings at 1.96 sigma (95%) confidence level	**0.99m (SBES – at maximum depth of 4.5m)** **0.05 (LBS)**

1.3.4 Vertical Control

Tides Applied	N/A
Sounding Datum	Australian Height Datum
Geoid details if using GPS tides	AUS Geoid 09
AHD / Chart Datum separation value	N/A
Tide Board/Gauge 1	N/A
Tide Board/Gauge 2	N/A
Survey Mark used for datum connection	67261171
Survey Mark used for RTK Verification	CS01 / CS02
Method for Sound Velocity correction	Sound Velocity Profile
Temperature and Salinity values used	N/A
Tide Model comments (if applicable)	
TVU – Total Vertical Uncertainty. Estimated Accuracy of Soundings at 1.96 sigma (95%) confidence level	**0.16m (SBES)** **0.07m (LBS)**
Comments	

1.4 Deliverables

A list of deliverables and their format are highlighted in

Table 1-1 below.

Table 1-1: Deliverables

Deliverable	File Name	Format
XYZ Dataset	HCHB_CL_MGA94_AHD_0.75m HCHB_SBES_MGA94_AHD_0.75m HCHB_LBS_MGA94_AHD	X, Y, Z
Report of Survey	HCHB_Report_of_Survey_RevA	PDF
Sounding Plots	HCHB_A3_Sounding_Plot_MGA94_AHD_1_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_2_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_3_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_4_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_5_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_6_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_7_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_8_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_9_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_10_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_11_of_12 HCHB_A3_Sounding_Plot_MGA94_AHD_12_of_12	PDF

2. Personnel and Equipment

2.1 Personnel

Personnel involved with data collection and processing operations are as follows:

Table 2-1: Project Personnel

Name	Position
Adam Bolton	Project Manager
Huw Thomas	Surveyor in Charge | CPHS Level 2 | SBES operations| Data Processing / QC / Product Generation / Reporting
Curren Goodwin	Director Calculated Surveys | LBS Data Collection
Sam Barrera	Surveyor Calculated Surveys | LBS Data Collection
Hamish Grant	Surveyor Calculated Surveys | LBS Data Collection
Jack Good	Surveyor Calculated Surveys | LBS Data Collection
Scott Bromell	Support Vessel Coxswain

2.2 Survey Kayak

SBES equipment was mobilised onto a 14ft Hobie Pro Angler Kayak. The small size and shallow draft of the Kayak allowed easy maneuverability and therefore the ability to survey into very shallow water to maximize SBES coverage while maintaining safe operation. A summary of the survey Kayak is presented in Table 2-2.

Table 2-2: Vessel Details

Description	
MAIN DIMENSIONS	
Length OA	4.2 m
Breadth	0.97 m
Maximum draft	0.2 m
DESIGN PARTICULARS	
Hull materials	Rotomolded Polyethylene
CAPACITIES and SPEED	
Engine	1.5HP
Cruising speed	3 knots
FUEL CONSUMPTION	
Fuel	0.5 litres per hour
Class	N/A
	

2.3 Support Vessel – WAJ Workboat

The support vessel was used to ensure the safety of the field crew, shuttle the LBS team to different areas and sides of the Coorong as well as conducting towing duties for the Survey Kayak to minimize fuel and engine use when operating at the far extents of the survey area. A summary of the support vessel is presented in Table 2-3.

Table 2-3: Vessel Details

Description		
MAIN DIMENSIONS		
Length OA	5 m	
Breadth	2.21 m	
Maximum draft	0.22 m	
DESIGN PARTICULARS		
Hull materials	Aluminium	
CAPACITIES and SPEED		
Engine	30HP	
Cruising speed	8 knots	
FUEL CONSUMPTION		
Fuel	Approx. 10 litres per hour	
Class	AMSA 2D	

2.4 Survey Equipment

Survey equipment used during data collection operations is summarised in

Table **2-4** and Table 2-5.

Table 2-4: Summary of SBES Survey Equipment

Number	System	Manufacturer
1 x	CeeEcho 24/200kHz SBES	Cee Hydrosystems
1 x	Hypack 2020 Acquisition / Processing software	Hypack
1 x	Panasonic Toughbook laptop (acquisition computer)	Panasonic
1 x	Digibar Pro Sound Velocity Profiler	Telydyne
1 x	SPS986 Smart Antenna using VRSnow RTK service	Trimble
1 x	TSC3 GNSS field controller	Trimble

Table 2-5: Summary of LBS Survey Equipment

Number	System	Manufacturer
1 x	R10 RTK GNSS Base Station	Trimble
2x	R8 RTK Smart Antenna	Trimble
1 x	TDL450 UHF Radio (RTK connection broadcast)	Trimble
1 x	TSC3 field controller	Trimble
1 x	TSC7 field controller	Trimble

Number	System	Manufacturer
2x	Flat base adaptor for survey pole	

Figure 2.1: Typical LBS equipment setup with flat base plate adaptor to mitigate lagoon bed penetration (orange)

2.5 Software

The software presented in Table 2-6 was used for data acquisition, processing and product generation.

Table 2-6: Summary of Software

Product	Purpose	Version	Vendor
Hypack 2020	SBES acquisition and processing	20.0.5.0	Hypack
Global Mapper	Field coverage assessment	V21.0	Blue Marble
Civil 3D	Chart generation	2021	Autodesk

3. Survey Geodesy

3.1 Geodetic and Projection Parameters

All control coordinates and collected survey data are referenced to the Geocentric Datum of Australia 1994 (GDA94) projected onto the Map Grid of Australia 1994 (MGA94) Zone 54 South. All elevations have been referenced to the Australia Height Datum (AHD).

Table 3.1: Project Geodetic and Projection Parameters – GDA94 (MGA94)

Real Time Global Navigation Satellite System (GNSS) Geodetic Parameters		
Datum:	Geocentric Datum of Australia 1994	
Ellipsoid:	Geodetic Reference System 1980 (GRS80)	
Semi-major Axis:	a = 6 378 137.000 m	
Inverse Flattening:	$^1/_f$ = 298.257 222 101	
Project Projection Parameters		
Map Projection:	Transverse Mercator	
Grid System:	Map Grid of Australia 1994 Zone 54	
Central Meridian:	141° East	
Latitude of Origin:	0° (Equator)	
False Easting:	500 000 m	
False Northing:	10 000 000 m	
Scale Factor on Central	0.9996	
Units:	Metres	
Project Height System		
Orthometric	Australia Height Datum	

3.2 Positioning Methodology

Horizontal and vertical positioning for LBS and SBES data collection operations was performed using RTK GNSS survey equipment. The methodology used for the delivery of the high accuracy RTK corrections to the roving GNSS antennas was slightly different for LBS and SBES operations.

3.2.1 SBES Positioning Methodology

Horizontal and vertical positioning for SBES data collection used Trimble's VRSNow network. The technology selects permanent CORS network stations close to the area of operation and provides high accuracy RTK corrections to the roving GNSS antenna, mounted on the Kayak, over an Internet or 4G connection. This service provides standard RTK accuracies without the need to setup a local base station daily.

3.2.2 LBS Positioning Methodology

Except for the first day of data collection when a VRSnow RTK solution was used, horizontal and vertical positioning for LBS operations adopted a more traditional RTK GNSS setup. A base station was setup daily over an established survey control point adjacent to the Parnka Point boat ramp, transmitting corrections to both roving GNSS antennas conducting LBS pickup.

3.3 Horizontal Control

An extensive reconnaissance was conducted prior to data collection on South Australian PSM's in the vicinity of the survey area. In general, survey marks in the area were noted to be of low 'Order' being derived through handheld GPS and scaling techniques. PSM 67261171 was identified to be of suitable order and in close enough proximity to the Parnka Point boat ramp to be used as the 'Primary' control point for further control derivation.

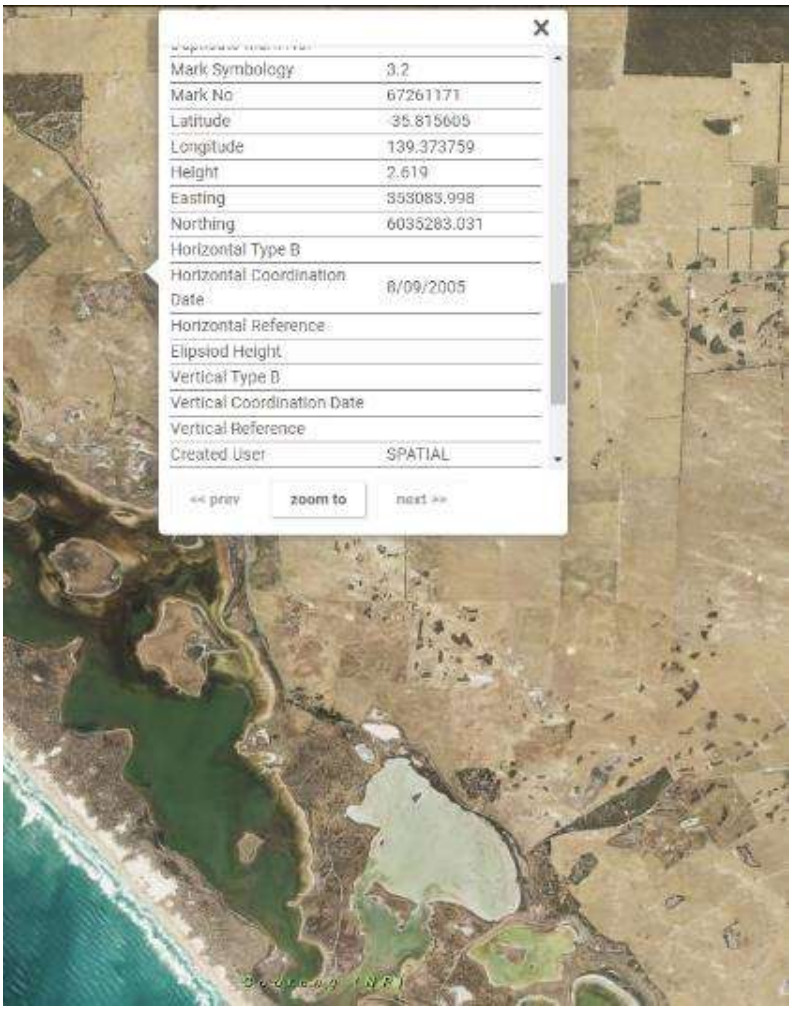

Figure 3.1: PSM 67261171

Two 'Secondary' control points, CS01 and CS02, were established at the Parnka Point boat ramp using Rapid Static RTK techniques. The RTK base was set over PSM 67261171 to tie the 'Secondary' control points into existing state geodetic infrastructure. The derived control points were subsequently used daily for RTK and SBES equipment checks and use by the RTK Base Station for LBS data collection.

Figure 3.2: 'Secondary' control points CS01 and CS02

Table 3-2: Secondary Control Coordinates

Survey Mark	Easting	Northing	Height
CS01	355286.419	6025778.021	1.663
CS02	355274.187	6025805.619	3.334

3.4 Vertical Control

All elevation data was referenced to the Australia Height Datum (AHD) through the application of RTK GNSS data.

As both RTK systems were aligned to the project geodetic and projection parameters, there was no requirement for the vertical transformation of survey data.

4. Survey Equipment and Data QC

This section outlines the QC checks carried out by Maritime Constructions and its sub-contractor to confirm the validity of all survey equipment and resultant data.

4.1 LBS RTK GNSS Checks

Checks on the LBS RTK GNSS equipment were carried out daily during data collection operations. Observations were taken on primary and secondary control points, as described in section 3.3, at the beginning and end of the day to ensure all equipment was operating correctly and within theoretical accuracies.

Daily LBS Checks

CS01	355286.419	6025778.021	1.663
CS02	355274.187	6025805.619	3.334
PSM 67261171	353083.39	6035281.553	2.619

				Morning							Afternoon					
Date	Instrument	Surveyor	Survey Style	Check Point	Easting	Northing	Elevation	East Diff	North Diff	Elv Diff	Easting	Northing	Elevation	East Diff	North Diff	Elv Diff
17.03.21	Trimble R10	Curren	Network	PSM 67261171	353083.392	6035281.562	2.608	0.002	0.009	-0.011	353083.402	6035281.572	2.606	0.012	0.019	-0.013
18.03.21	Trimble R10	Curren	Network	PSM 67261171	353083.381	6035281.553	2.603	-0.009	0.000	-0.016	353083.399	6035281.541	2.611	0.009	-0.012	-0.008
18.03.21	Trimble SPS986	Sam	Network	PSM 67261171	353083.399	6035281.541	2.612	0.009	-0.012	-0.007	353083.392	6035281.529	2.599	0.002	-0.024	-0.020
19.03.21	Trimble R10	Curren	Network	CS01	355286.419	6025778.021	1.646	0.000	0.000	-0.017	355286.432	6025778.015	1.644	0.013	-0.006	-0.019
19.03.21	Trimble SPS985	Sam	Network	CS01	355286.435	6025778.042	1.658	0.016	0.021	-0.005	355286.429	6025778.040	1.652	0.010	0.019	-0.011
22.03.21	Trimble R10	Curren	Base and Rover	PSM 67261171	353083.406	6035281.543	2.612	0.016	-0.010	-0.007	353083.400	6035281.540	2.621	0.010	-0.013	0.002
22.03.21	Trimble R10	Jack	Base and Rover	PSM 67261171	353083.401	6035281.540	2.609	0.011	-0.013	-0.010	353083.416	6035281.533	2.622	0.026	-0.020	0.003
23.03.21	Trimble R10	Curren	Base and Rover	CS02	355274.181	6025805.613	3.331	-0.006	-0.006	-0.003	355274.186	6025805.621	3.329	-0.001	0.002	-0.005
23.03.21	Trimble R10	Jack	Base and Rover	CS02	355274.189	6025805.618	3.336	0.002	-0.001	0.002	355274.194	6025805.619	3.335	0.007	0.000	0.001
24.03.21	Trimble R10	Curren	Base and Rover	CS02	355274.176	6025805.619	3.332	-0.011	0.000	-0.002	355274.178	6025805.621	3.334	-0.009	0.002	0.000
24.03.21	Trimble R10	Jack	Base and Rover	CS02	355274.196	6025805.625	3.334	0.009	0.006	0.000	355274.187	6025805.619	3.340	0.000	0.000	0.006
25.03.21	Trimble R10	Curren	Base and Rover	CS02	355274.186	6025805.622	3.328	-0.001	0.003	-0.006	355274.196	6025805.615	3.336	0.009	-0.004	0.002
25.03.21	Trimble R10	Jack	Base and Rover	CS02	355274.190	6025805.624	3.335	0.003	0.005	0.001	355274.192	6025805.622	3.336	0.005	0.003	0.002
26.03.21	Trimble R10	Curren	Base and Rover	CS02	355274.186	6025805.628	3.330	-0.001	0.009	-0.004	355274.184	6025805.622	3.328	-0.003	0.003	-0.006
26.03.21	Trimble R10	Jack	Base and Rover	CS02	355274.200	6025805.622	3.342	0.013	0.003	0.008	355274.189	6025805.623	3.332	0.002	0.004	-0.002
29.03.21	Trimble R10	Curren	Base and Rover	CS02	355274.186	6025805.628	3.338	-0.001	0.009	0.004	355274.192	6025805.622	3.335	0.005	0.003	0.001
29.03.21	Trimble R8	Hamish	Base and Rover	CS02	355274.181	6025805.624	3.330	-0.006	0.005	-0.004	355274.193	6025805.627	3.333	0.006	0.008	-0.001
30.03.21	Trimble R10	Curren	Base and Rover	CS02	355274.184	6025805.630	3.333	-0.003	0.011	-0.001	355274.187	6025805.628	3.329	0.000	0.009	-0.005
30.30.21	Trimble R8	Hamish	Base and Rover	CS02	355274.190	6025805.626	3.330	0.003	0.007	-0.004	355274.186	6025805.622	3.336	-0.001	0.003	0.002
							Min	**-0.011**	**-0.013**	**-0.017**			**Min**	**-0.009**	**-0.024**	**-0.020**
							Max	**0.016**	**0.021**	**0.008**			**Max**	**0.026**	**0.019**	**0.006**
							Mean	**0.002**	**0.002**	**-0.004**			**Mean**	**0.006**	**0.000**	**-0.004**
							SdDev	**0.008**	**0.008**	**0.006**			**SdDev**	**0.008**	**0.011**	**0.007**

Figure 4.1: LBS RTK GNSS Checks

As can be seen in Figure 4.1, the statistical analysis of the results shows excellent agreement between the absolute coordinates of the control points and the daily check observations. It is noted that one 'East Diff' and three 'North Diff' observations fall outside of the theoretical equipment accuracy however the maximum magnitude by which any of the outlying residuals exceed the expected accuracy is 0.006m.

The results of the LBS RTK GNSS checks confirm the correct operation of the LBS RTK GNSS equipment throughout data collection and as a result no transformation of the raw data was deemed necessary.

4.2 SBES RTK GNSS Checks

Checks on the SBES RTK GNSS equipment were carried out daily during data collection operations prior to setup on the Survey Kayak. Observations were taken on secondary control point CS02, as described in section 3.3, at the beginning and end of the day to ensure all equipment was operating correctly and within theoretical accuracies of the Trimble VRSnow service

Survey Check Parnka Point

Known	CS01	355286.419	6025778.021	1.663
Known	CS02	355274.187	6025805.619	3.334
Known	PSM 67261171	353083.39	6035281.553	2.619

				Morning							Afternoon					
Date	Instrument	Surveyor	Survey Style	Check Point	Easting	Northing	Elevation	East Diff	North Diff	Elv Diff	Easting	Northing	Elevation	East Diff	North Diff	Elv Diff
17.03.21	Trimble SPS986	Huw	VRSnow	CS01	355286.436	6025778.068	1.656	0.017	0.047	-0.007	355286.404	6025778.048	1.655	-0.015	0.027	-0.008
19.03.21	Trimble SPS986	Huw	VRSnow	CS01	355286.430	6025778.061	1.670	0.011	0.040	0.007	355286.432	6025778.051	1.663	0.013	0.030	0.000
22.03.21	Trimble SPS986	Huw	VRSnow	CS01	355286.432	6025778.024	1.649	0.013	0.003	-0.014	355286.427	6025778.019	1.652	0.008	-0.002	-0.011
23.03.21	Trimble SPS986	Huw	VRSnow	CS01	355286.440	6025778.051	1.650	0.021	0.030	-0.013	355286.429	6025778.032	1.658	0.010	0.011	-0.005
26.03.21	Trimble SPS986	Huw	VRSnow	CS01	355286.419	6025778.047	1.680	0.000	0.026	0.017	355286.427	6025778.059	1.647	0.008	0.038	-0.016
29.03.21	Trimble SPS986	Huw	VRSnow	CS01	355286.420	6025778.043	1.655	0.001	0.022	-0.008	355286.467	6025778.024	1.645	0.048	0.003	-0.018
30.03.21	Trimble SPS986	Huw	VRSnow	CS01	355286.441	6025778.058	1.662	0.022	0.037	-0.001	355286.406	6025778.059	1.649	-0.013	0.038	-0.014
31.03.21	Trimble SPS986	Huw	VRSnow	CS01	355286.427	6025778.055	1.657	0.008	0.034	-0.006	355286.430	6025778.015	1.652	0.011	-0.006	-0.011
01.04.21	Trimble SPS986	Huw	VRSnow	CS01	355286.435	6025778.034	1.644	0.016	0.013	-0.019	355286.430	6025778.034	1.652	0.011	0.013	-0.011
							Min	**0.000**	**0.003**	**-0.019**			**Min**	**-0.015**	**-0.006**	**-0.018**
							Max	**0.022**	**0.047**	**0.017**			**Max**	**0.048**	**0.038**	**0.000**
							Mean	**0.012**	**0.028**	**-0.005**			**Mean**	**0.010**	**0.017**	**-0.010**
							SdDev	**0.008**	**0.014**	**0.011**			**SdDev**	**0.018**	**0.017**	**0.006**

Figure 4.2: SBES RTK GNSS Checks

Once again, the statistical analysis of the results shows excellent agreement between the absolute coordinates of the control points and the daily check observations. It is noted that 'East Diff' and 'North Diff' residuals regularly exceed the expected theoretical accuracies however the maximum magnitude by which any of the outlying residuals exceed the expected horizontal accuracy is only 0.030m. Vertical residuals all fall within expected theoretical accuracies.

The results of the LBS RTK GNSS checks confirm the correct operation of the LBS RTK GNSS equipment throughout data collection and as a result no transformation of the raw data was deemed necessary.

4.3 SBES BAR Checks

SBES Bar Checks were conducted throughout data collection to confirm the SBES transducer was accurately measuring depth as well as quantifying the measured vertical offset between the GNSS antenna and the face of the SBES transducer. The verification of the vertical offset is critical as it is the primary measurement used in reducing SBES data to the project vertical datum.

The Bar Check was completed by lowering a metal plate to a known depth below the transducer face. The acquisition software was then checked to ensure the measured depth aligned with the known depth. As the distance of the plate beneath the GNSS antenna was also known, an AHD value of the plate was derived and checked against the measured AHD value in the acquisition software. This confirmed the vertical offset value and that the acquisition software was correctly reducing SBES data to AHD.

Table 4-1: Bar Check – SBES Transducer

SBES Bar Checks - Transducer			
Date	**Bar Depth (Fixed)**	**Observed SBES Depth**	**Diff**
17.03.21	0.40	0.39	0.01
21.03.21	0.40	0.40	0.00
01.04.21	0.40	0.40	0.00
	Mean		**0.00**
	StDev		**0.01**

Table 4-2: Bar Check – Vertical Offset

SBES Bar Checks – Vertical Offset			
Date	**Bar Depth (AHD)**	**Observed SBES Depth (AHD)**	**Diff**
17.03.21	0.68	0.67	0.01
21.03.21	0.72	0.71	0.01
01.04.21	0.56	0.56	0.00
	Mean		**0.00**
	StDev		**0.00**

4.4 SBES vs LBS Comparison

A comparison between SBES and LBS data was conducted to assess the vertical agreement between the two methodologies and positioning systems. Only points from the two datasets that fell within 0.75m of each other were used for this assessment. A visual representation of the spread of these comparison points and results can be seen below.

Figure 4.3: SBES vs LBS Comparison Checks

Table 4-3: SBES vs LBS

	SBES			LBS			Difference		
Point #	Easting	Northing	Elevation	Easting	Northing	Elevation	East Diff	North Diff	Elv Diff
1	350703.99	6032102.93	-0.50	350704.33	6032102.78	-0.48	-0.34	0.15	-0.02
2	350492.60	6031574.47	-0.28	350492.68	6031574.56	-0.28	-0.08	-0.09	0.00
3	351027.61	6031841.97	-0.13	351027.62	6031842.04	-0.13	-0.01	-0.07	0.00
4	351136.76	6031821.85	-0.29	351136.94	6031822.06	-0.28	-0.18	-0.21	-0.01
5	351383.16	6031642.28	-0.29	351383.41	6031642.14	-0.30	-0.25	0.14	0.01
6	352133.98	6030758.60	-0.07	352133.96	6030758.27	-0.09	0.02	0.33	0.02
7	352203.50	6030599.23	-0.15	352203.85	6030599.24	-0.14	-0.35	-0.01	-0.01
8	354412.17	6027541.72	-0.49	354412.19	6027542.22	-0.53	-0.02	-0.50	0.04
9	354670.63	6027465.88	-0.31	354670.60	6027465.59	-0.29	0.03	0.29	-0.02
10	355252.36	6027312.87	-0.40	355252.44	6027312.49	-0.39	-0.08	0.38	-0.01
11	356840.70	6024991.72	-0.59	356840.47	6024991.78	-0.56	0.23	-0.06	-0.03
12	358593.32	6024026.19	-0.72	358592.63	6024026.18	-0.75	0.69	0.01	0.03
13	359010.72	6023262.80	-0.48	359010.57	6023263.18	-0.50	0.15	-0.38	0.02
14	359332.45	6023246.01	-0.66	359332.67	6023246.03	-0.67	-0.22	-0.02	0.01
15	359624.53	6022861.88	-0.59	359624.60	6022861.62	-0.56	-0.07	0.26	-0.02
16	360692.42	6022000.35	-0.49	360692.46	6022000.46	-0.49	-0.04	-0.11	0.00
								Min	**-0.03**
								Max	**0.04**
								Mean	**0.00**
								SdDev	**0.02**

`

The results of the SBES vs LBS Comparison showed good vertical agreement between the two survey methodologies.

4.5 SBES Cross Line Comparison

Data collected along the Needles to Hack Point centreline that intersected with each of the transects was compared and a statistical analysis conducted to provide an assessment of the relative accuracy and repeatability of the SBES system. The analysis was split into three regions (North, Mid and South) with a 0.75m circle of influence filter applied to comparison soundings. A summary of the results is highlighted in the table below, statistical and graphical outputs for each of the comparison can be found in the following sections.

Table 4-4: Cross Line Comparison results

Centreline Region	Average Difference	Standard Deviation
North	-0.01	0.06
Mid	-0.07	0.07
South	0.00	0.07
Mean	**-0.07**	**0.07**
StDev	**0.04**	**0.01**

The statistical analysis of the SBES cross line comparison shows excellent relative agreement of SBES data throughout the extents of the survey area.

4.5.1 North

Key	Value
ARITHMETIC MEAN	-0.01
STANDARD DEVIATION	0.06
PERCENTAGE BETWEEN +S	71.49%
-10s	0
-9s	0
-8s	0
-7s	0
-6s	0
-5s	3
-4s	13
-3s	27
-2s	207
-1s	573
+1s	666
+2s	215
+3s	17
+4s	6
+5s	6
+6s	0
+7s	0
+8s	0
+9s	0
+10s	0

Figure 4.4: North SBES Comparison Statistics

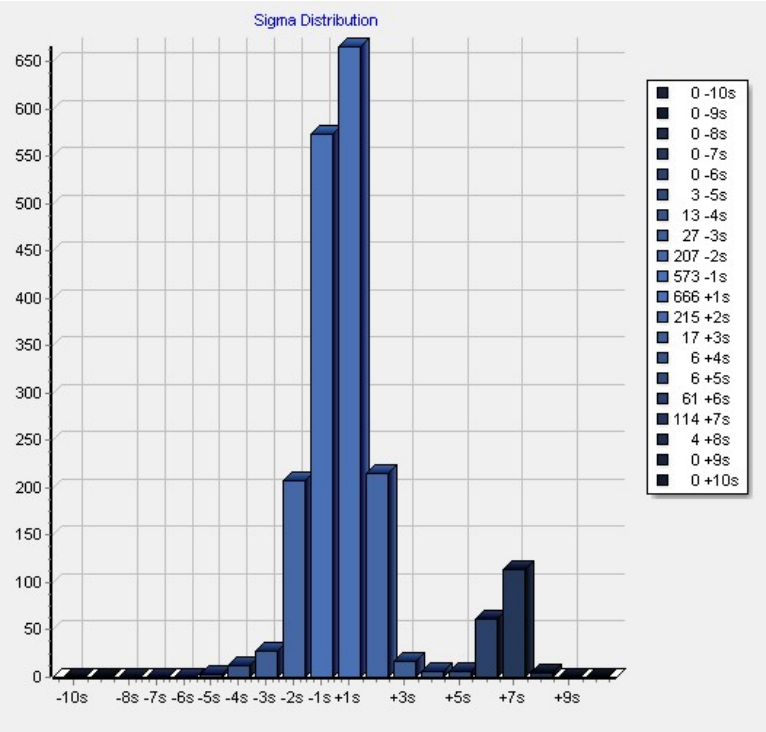

Figure 4.5: North SBES Sigma Distribution Graph

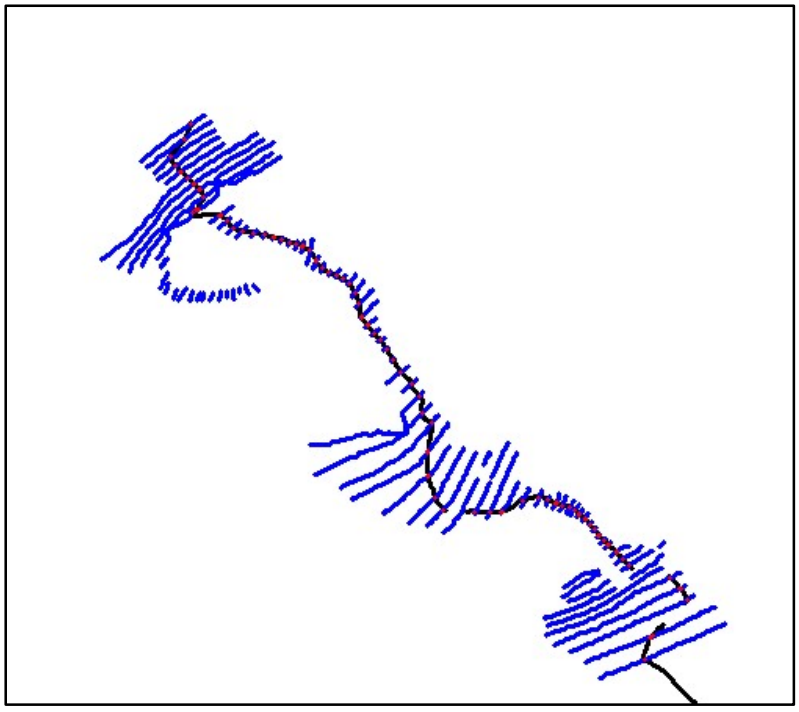

Figure 4.6: North SBES Crossline Comparison Intersections

4.5.2 Mid

Key	Value
ARITHMETIC MEAN	-0.07
STANDARD DEVIATION	0.07
PERCENTAGE BETWEEN +S	70.11%
-10s	0
-9s	0
-8s	0
-7s	0
-6s	0
-5s	0
-4s	7
-3s	45
-2s	194
-1s	424
+1s	662
+2s	200
+3s	14
+4s	3
+5s	0
+6s	0
+7s	0
+8s	0
+9s	0
+10s	0

Figure 4.7: Mid SBES Comparison Statistics

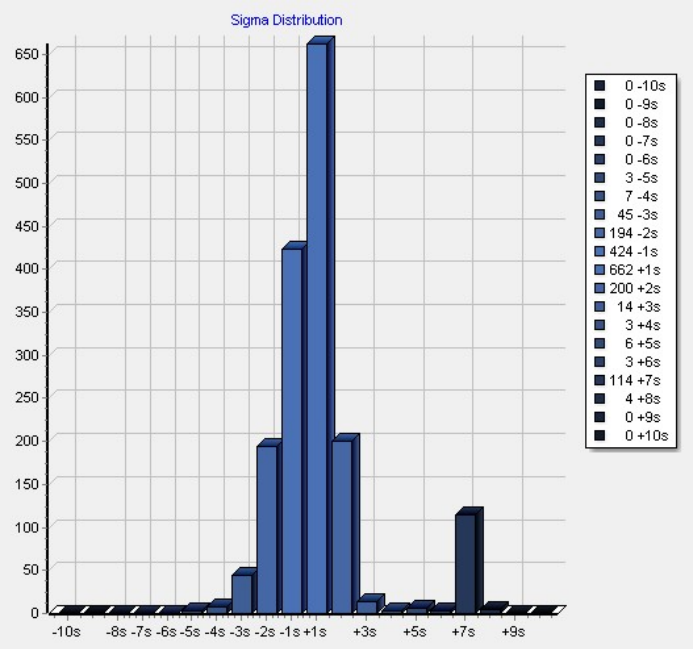

Figure 4.8: Mid SBES Sigma Distribution Graph

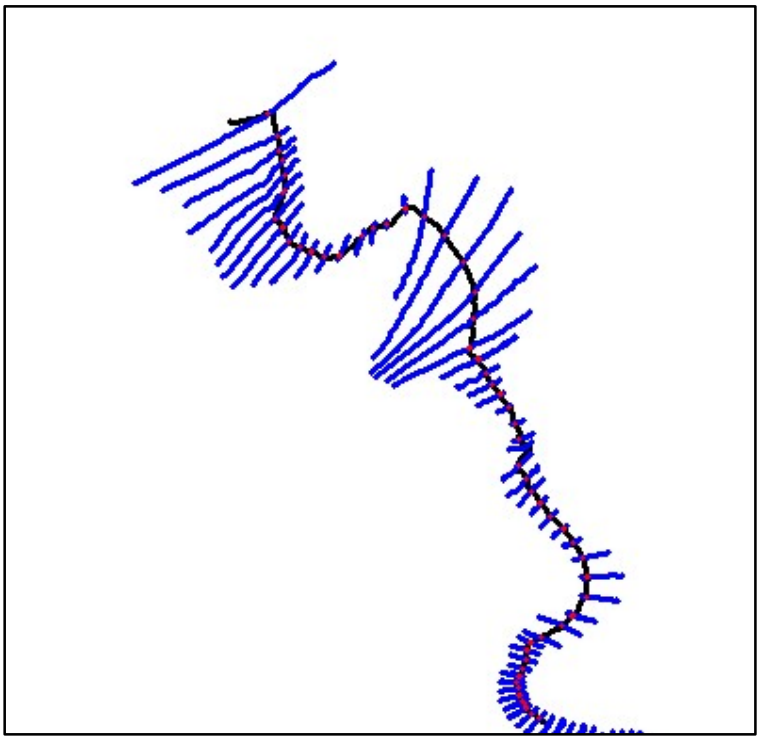

Figure 4.9: North SBES Crossline Comparison Intersections

4.5.3 South

Key	Value
ARITHMETIC MEAN	0.00
STANDARD DEVIATION	0.07
PERCENTAGE BETWEEN +S	69.98%
-10s	0
-9s	0
-8s	0
-7s	0
-6s	0
-5s	0
-4s	0
-3s	25
-2s	380
-1s	1002
+1s	847
+2s	331
+3s	12
+4s	21
+5s	24
+6s	0
+7s	0
+8s	0
+9s	0
+10s	0

Figure 4.10: South SBES Comparison Statistics

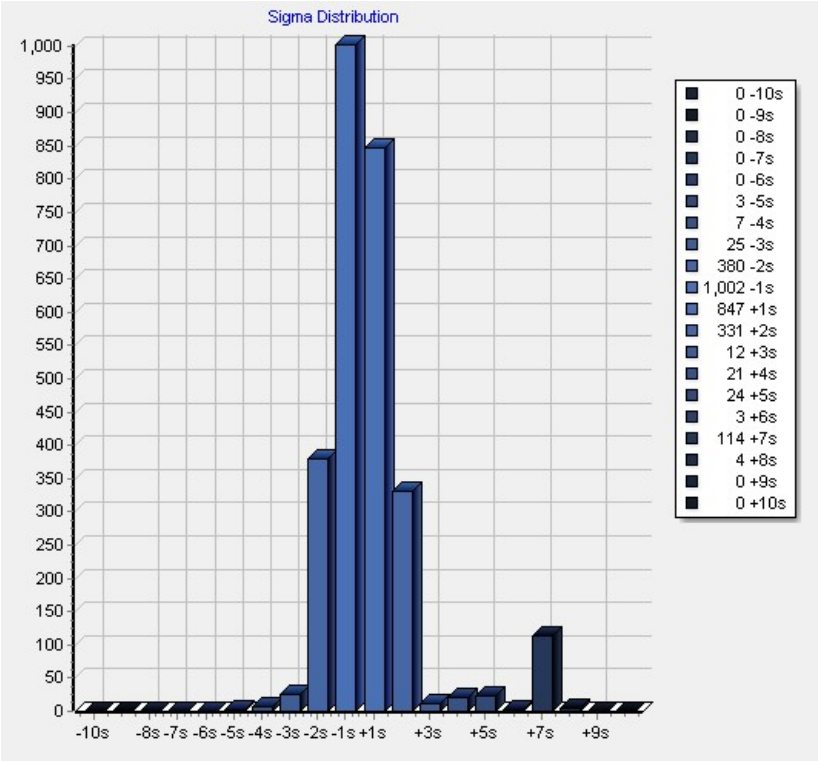

Figure 4.11: South SBES Sigma Distribution Graph

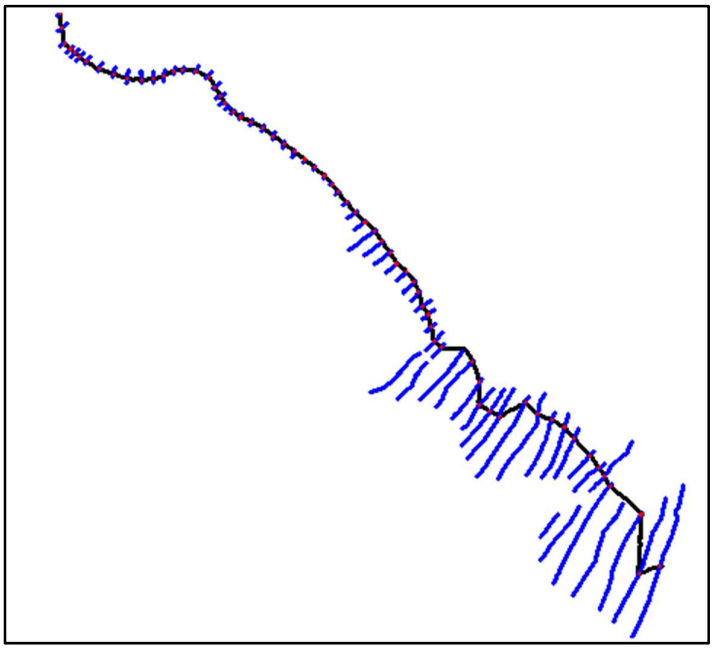

Figure 4.12: Mid SBES Sigma Distribution Graph

4.6 Sound Velocity Profiles

Although not as critical due to the extremely shallow nature of the survey area, sound velocity profiles were collected daily and throughout the survey area to ensure an accurate SV was applied to SBES data during post processing. Where extended SVPs were unable to be collected throughout the water column due to shallow water depth, data was corrected using an averaged SV value. Sound velocity for the centerline between Needles and Hack Point was corrected using averaged SV readings taken throughout the survey area. Daily SV sampling locations and values are highlighted in the following sections.

4.6.1 17 Mar 21

Figure 4.13: 17 Mar 21 Sound Velocity Profile

4.6.2 19 Mar 21

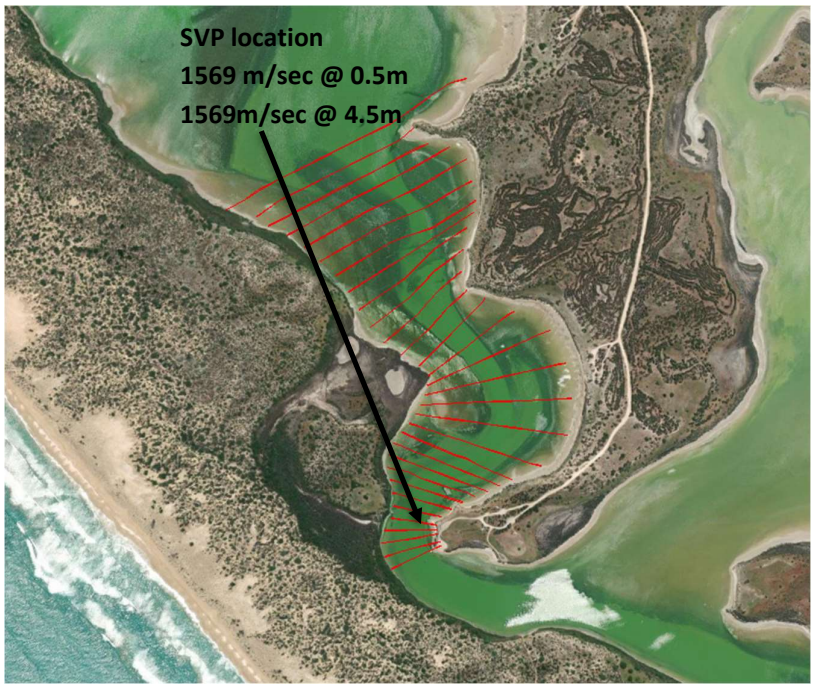

Figure 4.14: 19 Mar 21 Sound Velocity Profile

4.6.3 22 Mar 21

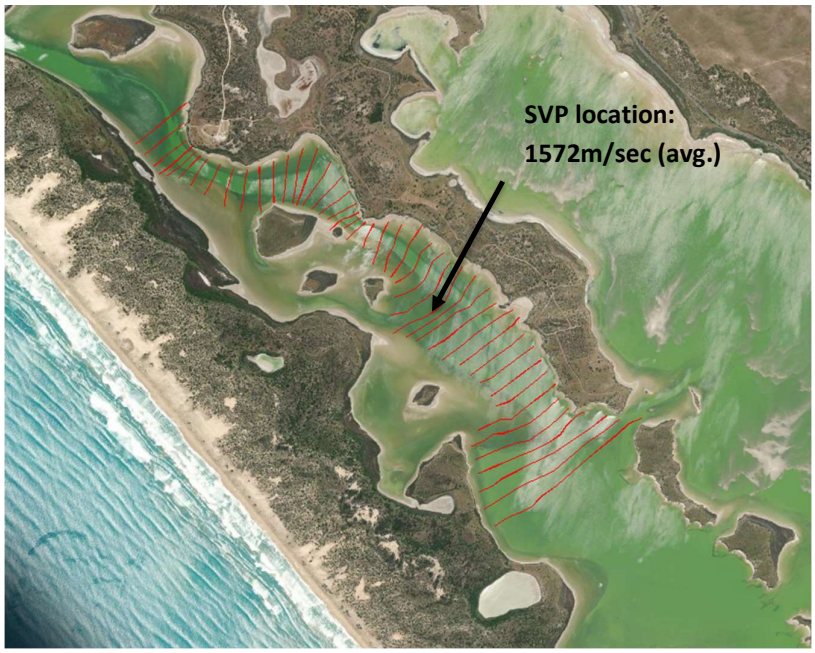

Figure 4.15: 22 Mar 21 Sound Velocity Profile

4.6.4 23 Mar 21

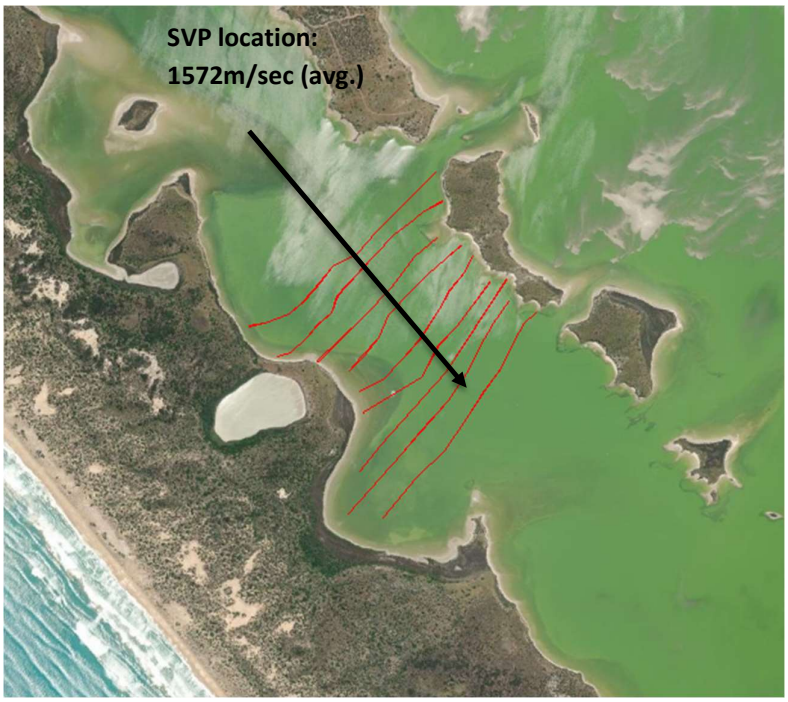

Figure 4.16: 23 Mar 21 Sound Velocity Profile

4.6.5 26 Mar 21

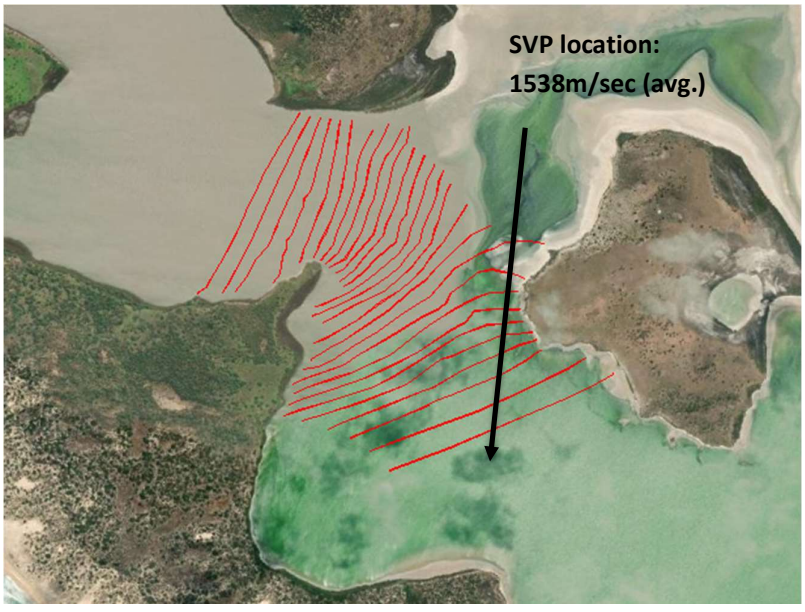

Figure 4.17: 26 Mar 21 Sound Velocity Profile

4.6.6 29 Mar 21

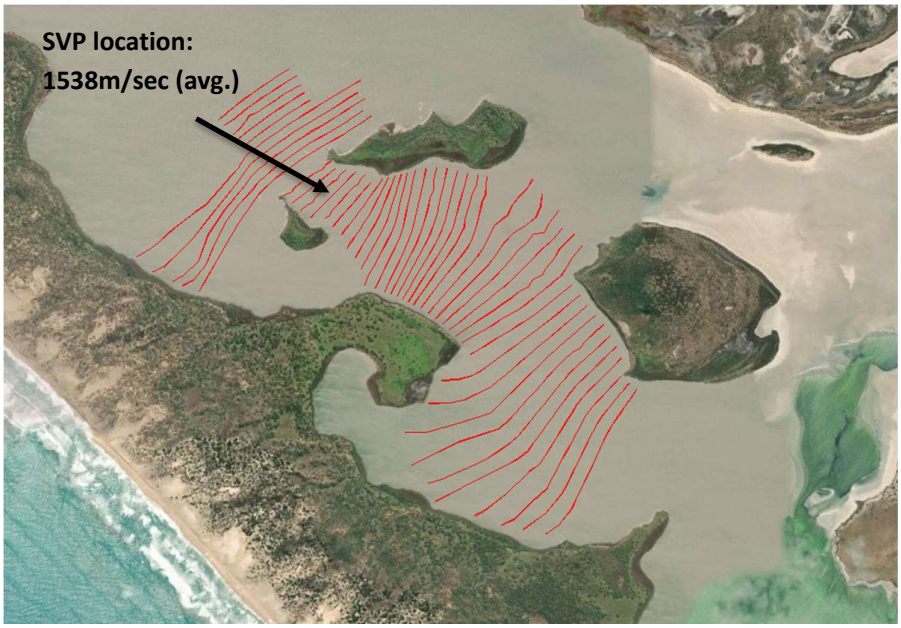

Figure 4.18: 29 Mar 21 Sound Velocity Profile

4.6.7 30 Mar 21

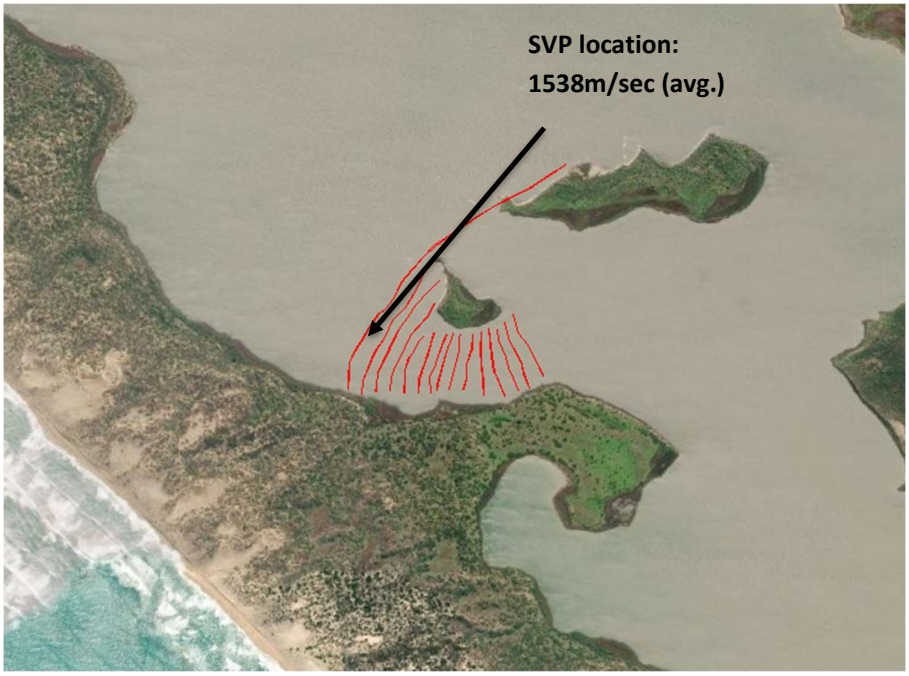

Figure 4.19: 30 Mar 21 Sound Velocity Profile

4.6.8 31 Mar 21

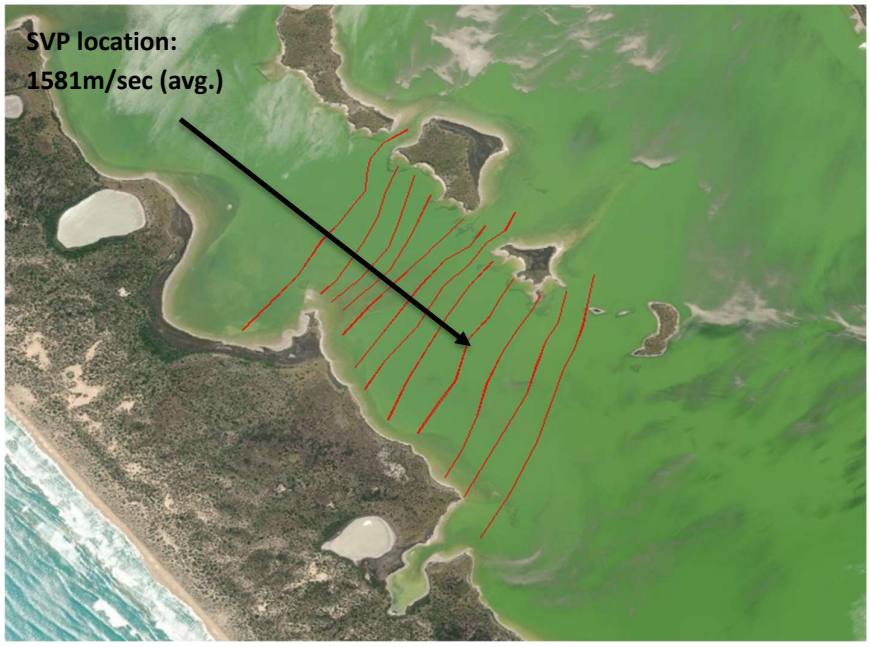

Figure 4.20: 31 Mar 21 Sound Velocity Profile

4.6.9 01 Apr 21

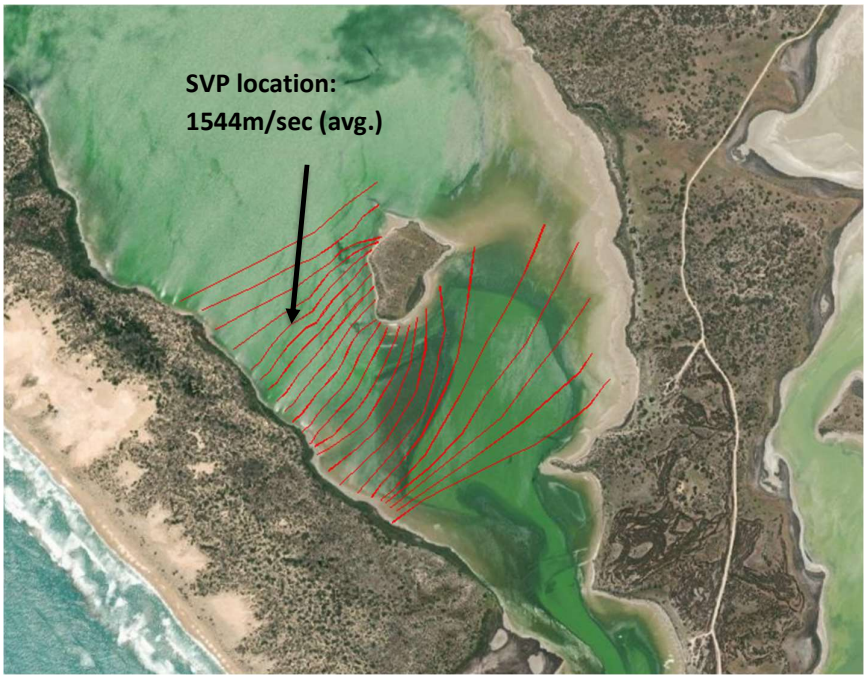

Figure 4.21: 01 Apr 21 Sound Velocity Profile

4.7 Total Propagated Uncertainty/Error Budget

The Total Propagated Uncertainty (TPU) is a measure for the accuracy to be expected for a hydrographic survey data point when all relevant error / uncertainty sources are considered. Instead of "TPU", the term "error budget" is also used. The TPU is split into two components, Total Horizontal Uncertainty (THU) and Total vertical Uncertainty (TVU).

4.7.1 Total Horizontal Uncertainty (THU) – LBS

THU for land-based survey operations was calculated through an a-posteriori assessment. The THU value highlighted in section 1.3.3 has been derived through the propagation of horizontal errors including horizontal datum uncertainty of established secondary control, RTK equipment accuracy based on maximum baseline length and relative accuracy noted during LBS RTK GNSS checks.

4.7.2 Total Horizontal Uncertainty (THU) – SBES

The assignment of a THU value for SBES operations has been derived through an a priori assessment. The THU value highlighted in section 1.3.3 has been derived through the assessment of expected error sources associated with SBES data collection. The following image highlights the potential error sources and resultant horizontal error with depth.

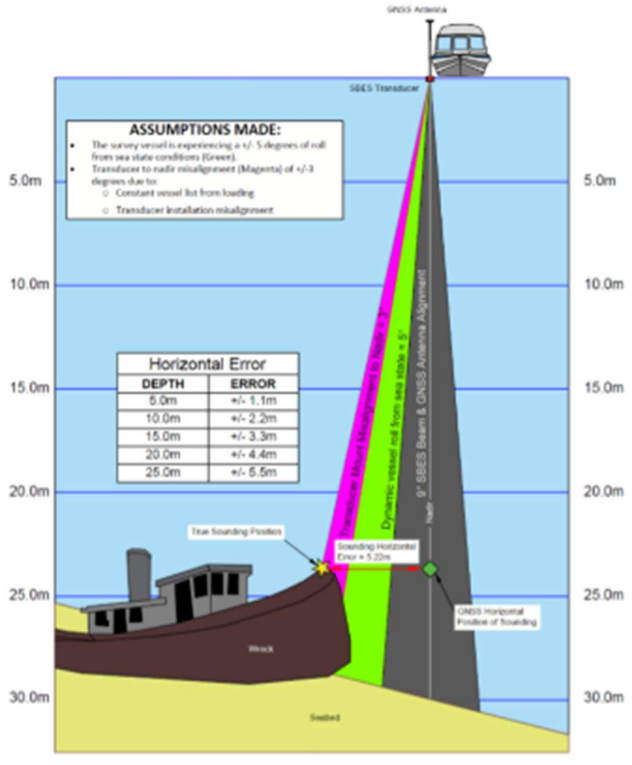

Figure 4.22: THU – a priori assessment of SBES (Total Hydrographics – 2021)

4.7.3 Total Vertical Uncertainty (TVU) – LBS

TVU for land-based survey operations was calculated through an a-posteriori assessment. The TVU value highlighted in section 1.3.4 has been derived through the propagation of vertical errors including vertical datum uncertainty of established secondary control, RTK equipment accuracy based on maximum baseline length and relative accuracy derived from LBS RTK GNSS checks.

4.7.4 Total Vertical Uncertainty (TVU) – SBES

SBES TVU was also calculated through an a-posteriori assessment. The TVU value highlighted in section 1.3.4 has been derived through the propagation of vertical errors including SBES and ancillary equipment accuracies, vertical datum uncertainty of established secondary control and relative agreement of SBES data as noted during Cross Line comparisons.

5. Survey operations

Data collection operations were conducted from 17 March to 01 April 2021. Office processing and final deliverable generation was carried out between 02 April – 17 April 2021. A summary of the sequence of events is highlighted below.

Table 5-1: Summary of Events

Date	Activity
17 March 2021	Field crew mobilised to the Coorong, arrived at Parnka Point 0700 Toolbox Talk conducted, project SWMS reviewed and signed by all field crew Establishment of Parnka Point Geodetic control SBES and LBS positioning equipment verified against established control SBES 'Bar Check' conducted prior to data collection SBES and LBS data collected along transects within 'Southern' area, block between Parnka Point boat ramp and 1.5km Sth of boat ramp targeted SBES and LBS positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation
18 March 2021	Field crew arrived at Parnka Point 0700 (H.Thomas not in attendance) LBS positioning equipment verified against established control LBS data collected along transects within 'Southern' area, block between Parnka Point boat ramp and 1.5km Nth of boat ramp targeted LBS positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation
19 March 2021	Field crew arrived at Parnka Point 0700 Pre-start meeting conducted SBES and LBS positioning equipment verified against established control SBES and LBS data collected along transects within 'Southern' area, block between Parnka Point boat ramp and 2.5km Nth of boat ramp targeted SBES and LBS positioning equipment verified against control at completion of daily data collection activities Field crew returned to Adelaide for the weekend Daily review of data and backups conducted
22 March 2021	Field crew mobilised to the Coorong, arrived at Parnka Point 0700 Pre-start meeting conducted SBES and LBS positioning equipment verified against established control SBES 'Bar Check' conducted prior to data collection SBES and LBS data collected along transects within 'Southern' area, block situated between 1km and 5km Sth of boat ramp targeted SBES and LBS positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation
23 March 2021	Field crew arrived at Parnka Point 0700 Pre-start meeting conducted SBES and LBS positioning equipment verified against established control SBES and LBS data collected along transects within 'Southern' area, block between Parnka Point boat ramp and 2.5km Nth of boat ramp targeted SBES operations called off early (1400) due to weather

Date	Activity
	SBES and LBS positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation
24 March 2021	Field crew arrived at Parnka Point 0700 No SBES operations due to strong winds LBS positioning equipment verified against established control LBS data collected along transects within 'Southern' area, remaining LBS transects to the Sth of the Parnka Point boat ramp targeted LBS positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation, LBS component within the 'Southern' area identified to be completed
25 March 2021	Field crew arrived at Parnka Point 0700 No SBES operations due to strong winds LBS positioning equipment verified against established control LBS data collected along transects within 'Northern' area, block between the Sth extent and 2.5km Nth of the Sth extent targeted LBS positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation,
26 March 2021	Field crew arrived at Parnka Point 0700 Pre-start meeting conducted SBES and LBS positioning equipment verified against established control SBES and LBS data collected along transects within 'Northern' area, block between the Sth extent and 3.5km Nth of the Sth extent targeted SBES and LBS positioning equipment verified against control at completion of daily data collection activities Field crew returned to Adelaide for the weekend Daily review of data and backups conducted
29 March 2021	Field crew mobilised to the Coorong, arrived at Parnka Point 0700 Pre-start meeting conducted SBES and LBS positioning equipment verified against established control SBES and LBS data collected along transects within 'Northern' area, block 1km from the Sth extent to the Nth extent targeted SBES LBS positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation
30 March 2021	Field crew arrived at Parnka Point 0700 Pre-start meeting conducted SBES and LBS positioning equipment verified against established control SBES and LBS data collected all remaining transects within 'Northern' area targeted SBES and LBS positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation, LBS component in the 'Northern' area identified to be completed. All LBS work now completed

Date	Activity
31 March 2021	Field crew arrived at Parnka Point 0700 Pre-start meeting conducted SBES positioning equipment verified against established control SBES data collected in the 'Southern' area, all remaining transects and 'deepest' route to Parnka Point boat ramp collected SBES positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted at accommodation
01 April 2021	Field crew arrived at Parnka Point 0700 Pre-start meeting conducted SBES positioning equipment verified against established control SBES 'Bar Check' conducted prior to data collection SBES data collected in the 'Northern' and 'Southern' areas, all remaining transects within the Nth extents of the 'Southerm' area and 'deepest' route from the most Nth extents to the Parnka Point boat ramp collected SBES positioning equipment verified against control at completion of daily data collection activities Daily review of data and backups conducted on-site confirmed data collection had been completed Remaining Field crew demobilised
02 – 17 April 2021	Raw data processing QC analysis of final LBS and SBES datasets Merging of LBS and SBES datasets Report of Survey compilation Creation of survey plots

6. Data Processing

Multiple levels of data processing were carried out both during and after data collection activities. The following sections outlines the data processing stages for both LBS and SBES datasets.

6.1 LBS Data Processing

Due to the relatively final nature of in field LBS observations, the data processing requirement to arrive at the final dataset is minimal. The following summary outlines the data processing workflow for LBS datasets.

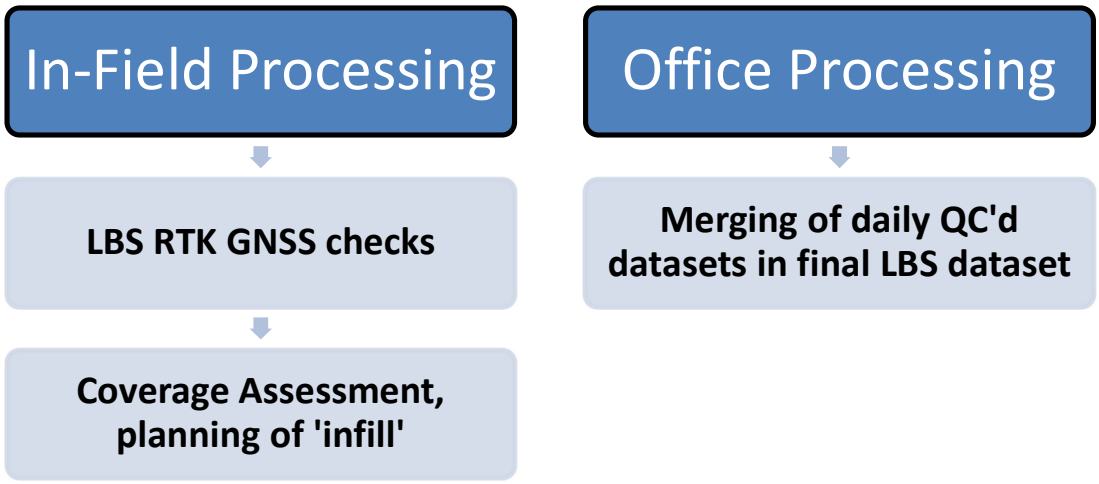

Figure 6.1: LBS data processing workflow

6.2 SBES Data Processing

As SBES data collection is a form of remote sensing rather than physical measurement, a much higher degree of data processing is required to ensure the accuracy and integrity of the final datasets. The following sections highlight the data processing workflow for SBES datasets.

`

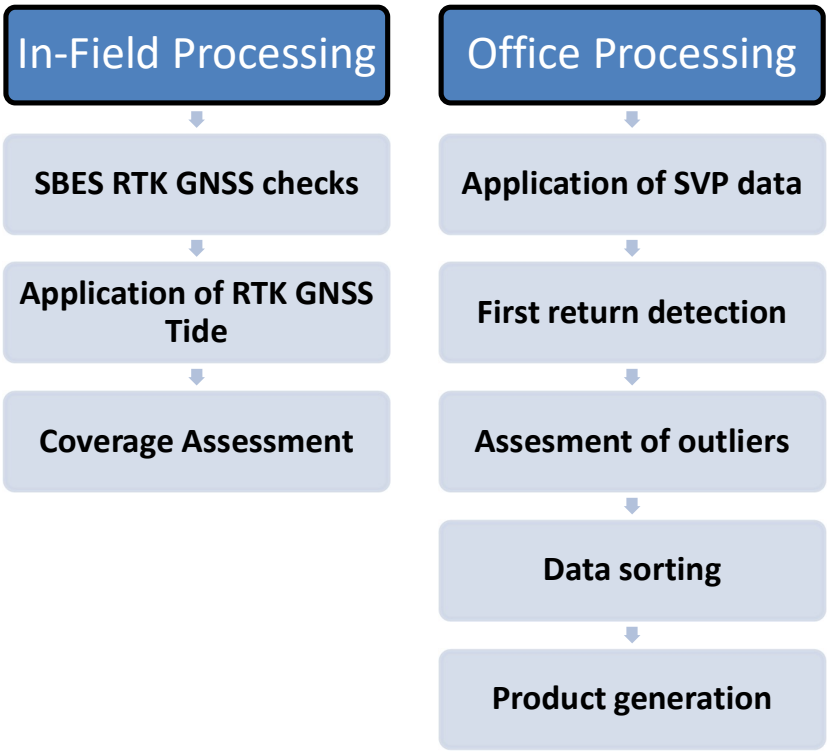

Figure 6.2: SBES data processing workflow

6.2.1 In Field Processing and QC

6.2.1.1 SBES RTK GNSS Checks

As highlighted in section 4.2, the SBES RTK GNSS checks were conducted and assessed in-field to ensure the correct operation of the SBES horizontal and vertical positioning systems during daily operations. Although not required, any transects conducted between daily RTK GNSS checks with high residuals would be isolated and subject to vertical transformation based on the residual results.

6.2.1.2 Application of RTK GNSS Tide

The accurate determination of the face of the SBES transduce relative to AHD, the subsequent reduction of bathymetric data to AHD and real-time heave compensation is controlled by the application of 'RTK tides' and a 'Fixed RTK' solution within the online acquisition software. After daily operations, each transect was interrogated to ensure the application of the correct RTK

GNSS solution and to identify the existence of any erroneous RTK tide data. In the event RTK tide data was identified to be out of spec, the associated transect was written up to be resurveyed.

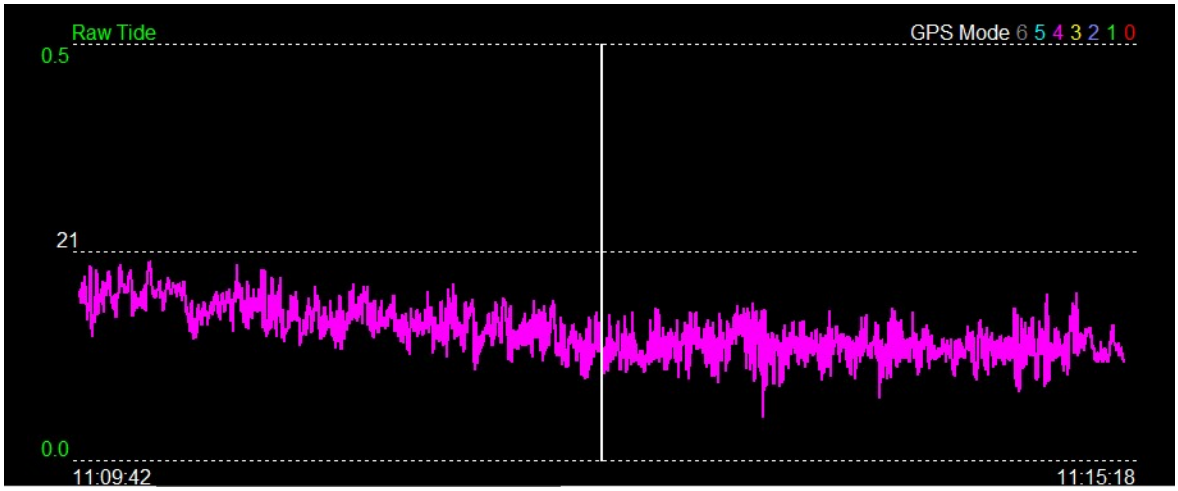

Figure 6.3: Normal RTK profile with correct 'Fixed' RTK Solution – Magenta / GPS mode 4

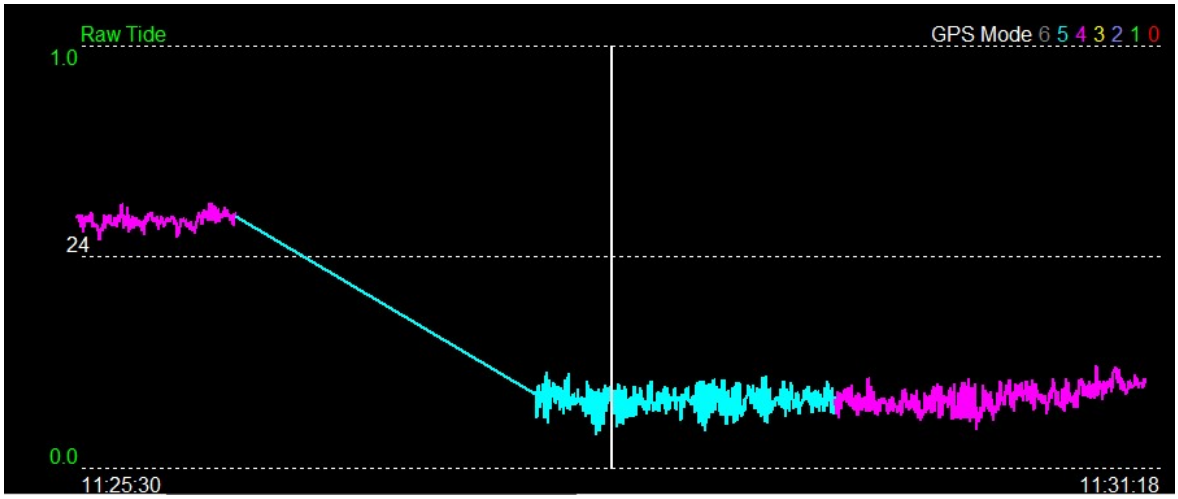

Figure 6.4: Erroneous RTK profile with data 'dropout' and incorrect 'Float' RTK Solution – Light Blue / GPS mode 5

6.2.1.3 Coverage Assessment

To ensure all transects were completed, SBES data was downloaded daily and visually interrogated using CAD software. A 'survey line log' was kept to track progress and identify remaining transects and centerline segments to be completed.

6.2.2 Office Processing and QC

6.2.2.1 Application of SVP Data

During the importing of SBES data in the data processing software, SVP measurements were applied to the raw data to adjust soundings by the measured SV value. The correct application of SV data was checked within the processing software before editing commenced.

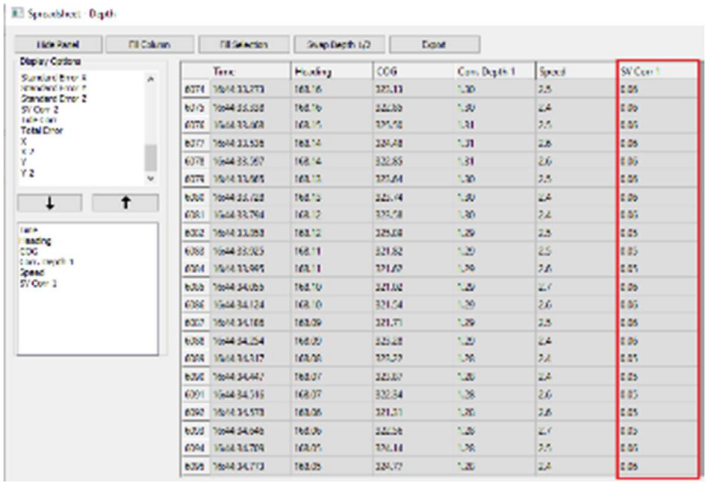

Figure 6.5: SV Correction applied

6.2.2.2 First Return Detection

The main objective of the survey was to provide DEW with an accurate representation of the lagoon bed elevation along transect lines. With the lagoon bed being extremely soft in areas and SBES acoustics tending to 'seek' the hardest return, it was critical to assess the raw data echogram and confirm the 'first return' was being captured. The raw data echogram was checked for each transect and edited to ensure the 'first return' surface was identified.

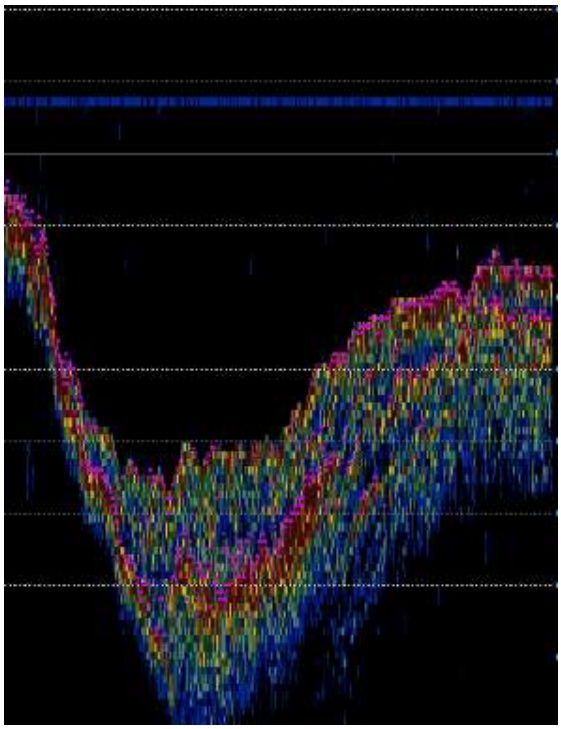

Figure 6.6: Ambiguity between 'First Return' and harder Sub Strata

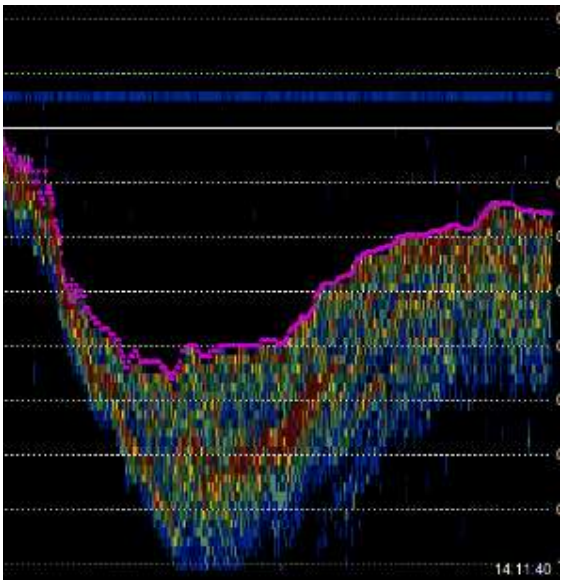

Figure 6.7: Edited Echogram capturing 'First Return'

6.2.2.3 Assessment of Outliers

The final stage data editing was to check each transect and centerline segment for outlying data points missed during the initial first return assessment. Using the profile tool within the data processing software, outliers were disproved then deleted.

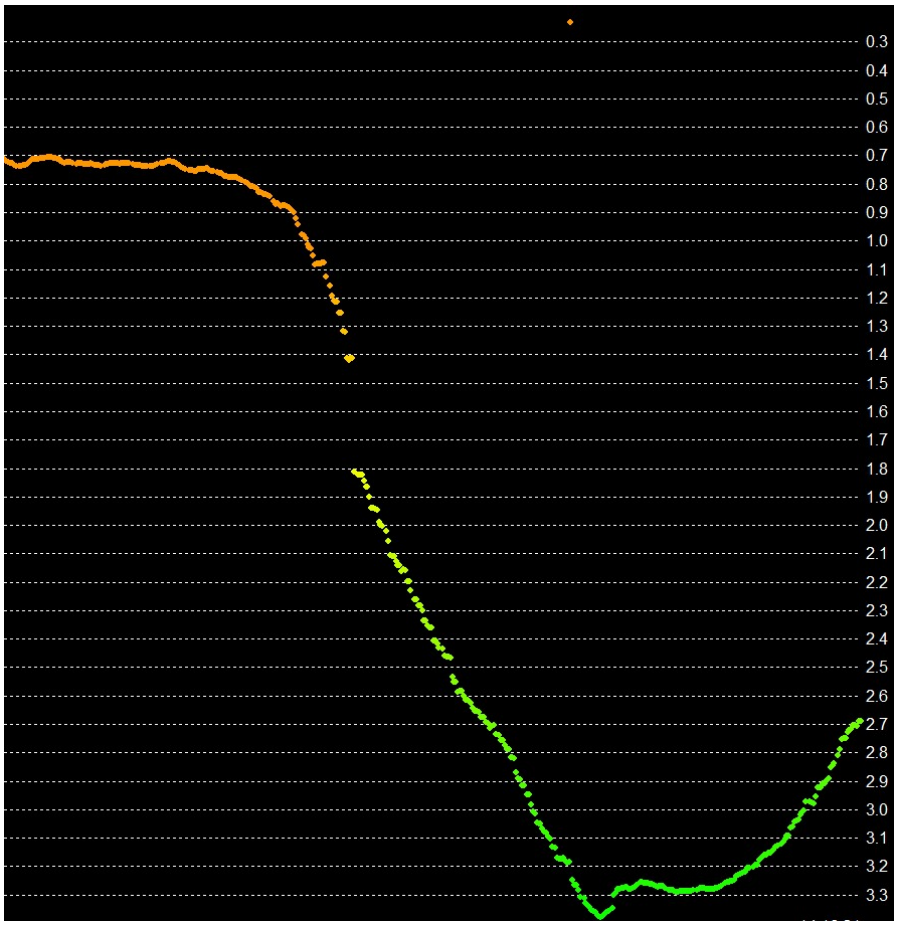

Figure 6.8: Outlying data identified above 0.3m

6.2.2.4 Data Sorting

The process of data sorting was conducted to filter the 'final edited' dataset for two reasons:

1. Filter the data to the required resolution and retain the shoalest sounding at its true position
2. Minimise the overall dataset size

The 'Sort' program within Hypack was used to filter the final datasets using a 'shoal biased – true position' filter. This filter selects the shallowest sounding from within a 0.75m circle of influence, retaining its true position.

6.2.2.5 Product Generation

The final stage of data processing was to produce deliverables using the sorted datasets. All X, Y, Z data was generated using the Hypack processing software while all CAD based deliverables suck as survey plots were created using Autodesk's Civil3d.

7. Results

In general, good overall coverage was achieved along the majority of the transects and the deepest part of the main channel between The Needles and Hack Point. The survey area can be categorised as extremely shallow in nature with most of the surveyed depths between 0 – 1.5m in depth (AHD). The deepest section of the survey area can be found between the Parnka Point boat ramp and 1km upstream where depths of approximately 4.3m (AHD) were noted.

There were however several environmental factors that posed a safety risk to crew that hampered data collection activities and the overall ability to collect seamless coverage between LBS and SBES datasets along the survey objectives.

The extents of LBS data were largely conducted on lagoon bed that was solid underfoot with coverage terminating 10-20m from the extents of SBES coverage. Extremely soft lagoon bed and areas to shallow to access by the survey Kayak were encountered and as a result gaps between LBS and SBES datasets exits in both the Northern and Southern areas.

Figure 7.1: Example of gaps between the LBS (red) and SBES (green) datasets. Note: Imagery not collected during data collection and does not represent the actual pool level

As can be seen in Figure 7.2, current pool levels in the survey are at the lower extents of the seasonal range. The low pool level created several hardships that in instances resulted in less than optimal SBES coverage. Primarily within the northern survey area, the low pool level and increased presence of rock outcrops and reef / coral structure created issues with line keeping and overall coverage in areas only accessible by the survey kayak.

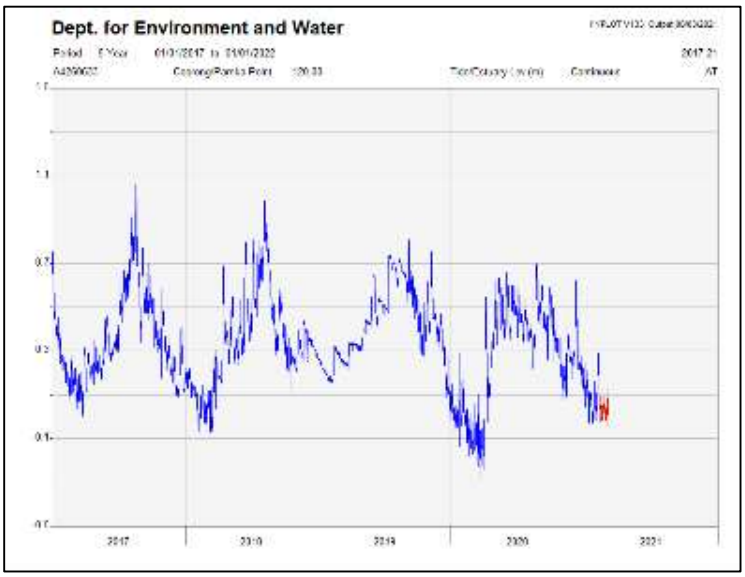

Figure 7.2: Pool levels from the Parnka Point Station

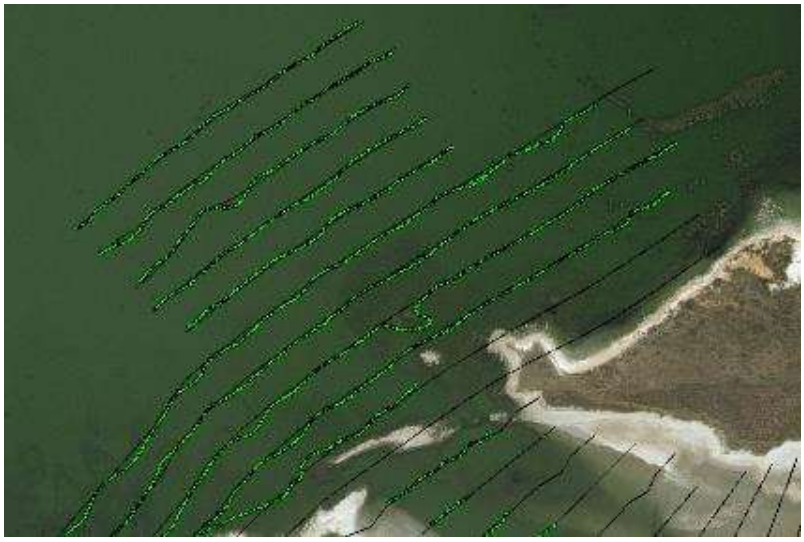

Figure 7.3: Line keeping and coverage gaps due to lagoon bed obstructions

The methodology used to derive the deepest route between The Needles and Hack Point was to assess each of the surveyed transects then adopt a 'point to point' process linking the deepest part of each of the surveyed transects. Due to the low pool level, shallow nature of the lagoon and rock / reef obstructions, there were instances where the deepest route was unable to be safely navigated and passed over shallow regions were LBS and SBES data collection was not possible. As a result, some gaps exist along this track.

The majority of issues relating to data gaps and inaccessibility is a direct result of pool levels in the region. It is advised if further investigations into lagoon bed depths or an increase in data destiny is required, survey operations should be scheduled during the higher extents of the seasonal range to optimise SBES efficiency and coverage.