



# **NSW OCEAN AND RIVER ENTRANCE TIDAL LEVELS AND AIR PRESSURE ANNUAL SUMMARY 2020–2021**

Report MHL2856  
May 2022

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NSW Department of Planning, Industry and Environment  
Biodiversity and Conservation Division

Cover photograph: Ocean pool during Blood Moon high tide  
South Curl Curl, NSW, 28 May 2021  
Photo courtesy of James Tan

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# Foreword

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Manly Hydraulics Laboratory (MHL) is a business unit within the Water Group of the NSW Department of Planning, Industry and Environment. MHL operates and maintains ocean river entrance tidal and barometric recording stations along the NSW coast under a service level agreement with the Biodiversity and Conservation Division of the NSW Department of Planning, Industry and Environment.

The NSW ocean tide database developed by MHL supports a number of Biodiversity and Conservation Division programs associated with coastal, floodplain and estuary management. These include the operations of ports and marine facilities, water level forecasts, fisheries management, determining property boundaries and developing a detailed understanding of oceanic processes. The monitoring service and outputs are available to local government and other organisations, both in Australia and overseas.

This summary provides information on how to access the ocean tide and barometric database and the data analysis capabilities of MHL.

The standards adopted for the program are those specified by the National Permanent Committee on Tides and Mean Sea Level hosted by the Australian Hydrographic Office.

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<http://www.mhl.nsw.gov.au> under the 'Publications' menu.

# Executive summary

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This annual summary presents ocean and river entrance tidal levels and coastal air pressure data captured by the automatic tide level and barometric sensor recording stations along the coastline of NSW over the period 1 July 2020 to 30 June 2021. It provides a catalogue of all ocean and river entrance tidal data collected in NSW by MHL for the Biodiversity and Conservation Division.

The 2020–2021 target recovery rate of over 95% for the 15-minute ocean tide data (99.5%) and barometric data (98.6%) was achieved. The offshore tide recovery rate (80.8%) fell below this target due to battery and sensor failures during extended deployments caused by the COVID-19 work restrictions and exceptional wet weather.

This report contains:

- a brief description of the ocean and river entrance tidal measurement program
- guidelines on how to use this report
- information on how to access the database
- a description of significant events which occurred in 2020–2021
- [Appendix A](#), the annual data summaries for each ocean tide site (see [Figure 1.1](#) for site locations)
- [Appendix B](#), the annual data summaries for each barometric site (see [Figure 2.1](#) for site locations)
- [Appendix C](#), current tidal station data
- [Appendix D](#), detailing the historical tidal data available
- [Appendix E](#), a glossary of terms
- [Appendix F](#), a list of other publications which may be of interest.

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# 1. Tidal network measurement program

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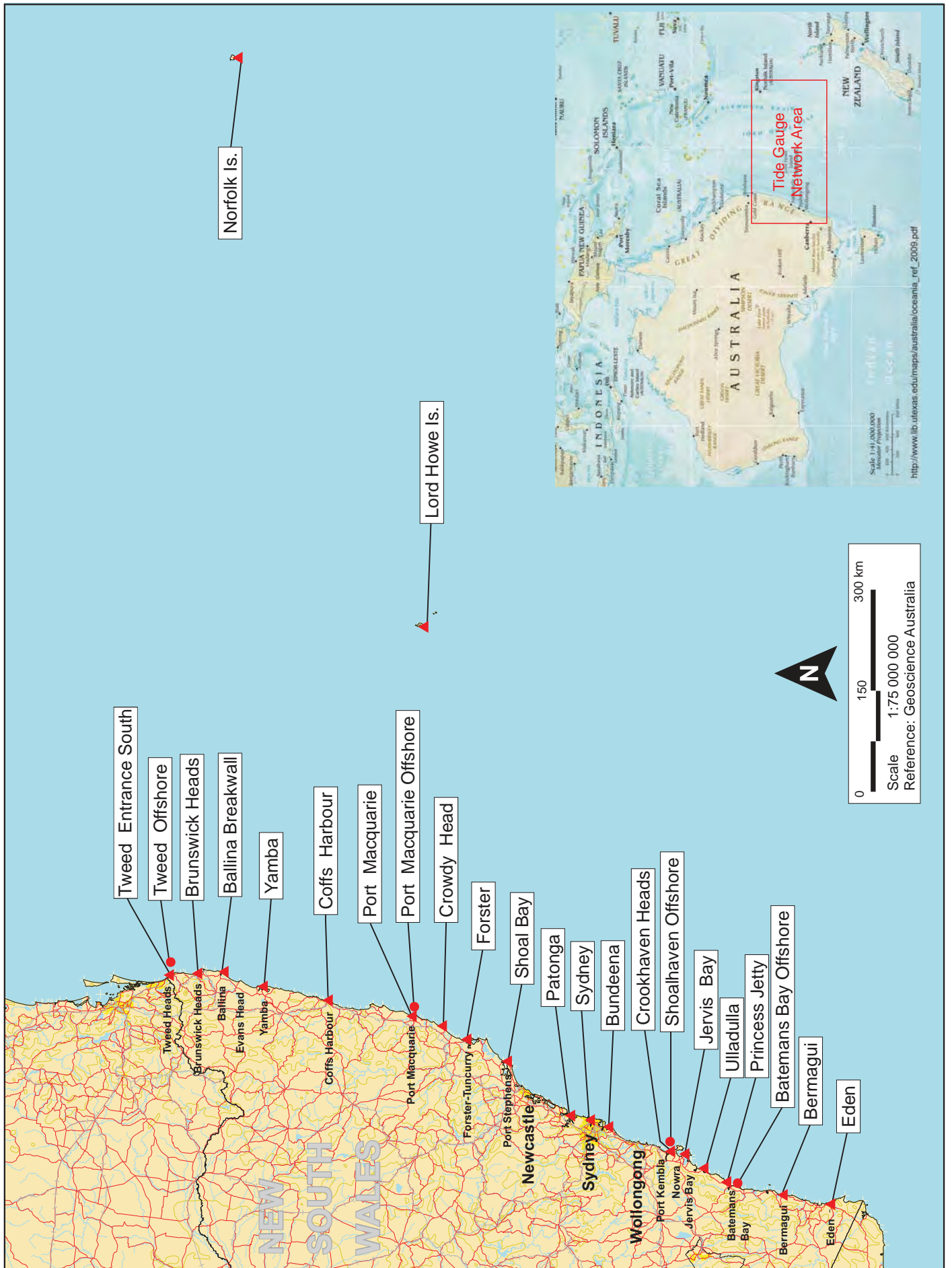
This report presents the thirty-fifth year of data collected by automatic ocean tide level recorders for the State of NSW. MHL provides tide data through a network of recorders and an efficient service of associated analysis routines.

The present program is based on a network of automatic ocean tide level recording stations installed at 18 coastal and four offshore sites, and one open ocean site located on Lord Howe Island. Additional data for Norfolk Island is provided by the Bureau of Meteorology's National Tidal Unit (NTU) ([Figure 1.1](#)). The ocean tide monitoring network features three distinctive system types for data capture: radar, vented pressure sensor and submersed water level pressure recorder. Electromagnetic tide poles and solid state floatwells were also previously used to collect water level data in the ocean tide program. For further details of the monitoring equipment types and the associated metadata for each individual monitoring station refer to MHL Report 2546 *Review of NSW OEH Automatic Water Level Recorder Network* ([MHL 2020](#)).

Tidal data is transferred to the NSW Government Data Centre and to MHL's data server using an internet protocol (IP) network and landline telephone (Lord Howe Island). The last seven days of 15-minute tide data is available online in tables or as plots. One-minute and some 1-second data is also available on request (see MHL 2020). All data presented in this report are in Australian Eastern Standard Time (AEST). Allowance for daylight saving time needs to be made by the user of the data if required.

The data quality control process for onshore water level information can be found in Appendix D of MHL Report 2855 *NSW Estuary and River Water Levels Annual Summary* (MHL 2022).

The station data summaries for 2020–2021 are presented in [Appendix A](#).



OCEAN TIDE GAUGE NETWORK

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Figure  
1.1

DRAWING 2856-01-01.cdr

## 2. Air pressure program

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Manly Hydraulics Laboratory has measured air pressure along the NSW coast since 1987. Barometers developed by MHL, utilising a SPX100 pressure transducer, were installed at six Waverider buoy receiving stations until the network was decommissioned during late 1999. The original SPX100 barometer network was superseded by a more comprehensive coastal air pressure monitoring system between August 1999 and February 2000 ([Figure 2.1](#)). This data is recorded to allow the correction of water level data recorded by total pressure transducers and to provide barometric information to assist understanding of water levels associated with ocean storms.

The barometer network utilises Vaisala digital barometers that sample air pressure every 5 to 15 minutes in the range 50 hPa to 1100 hPa at  $\pm 0.2$  hPa. At the barometer station air pressure data is corrected to mean sea level and stored by a data logger before it is downloaded to MHL's central server. Communications have been upgraded to the Virtual Private Network (VPN) with barometric data now uploading every 15 minutes with the water level data.

The station data summaries for 2020–2021 are presented in [Appendix B](#).



NEW SOUTH WALES  
COASTAL BAROMETER LOCATIONS

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Hydraulics  
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Figure  
2.1

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## 3. Tidal data access, metadata and analysis

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### 3.1 Using and accessing the data

This annual summary presents ocean and river entrance tidal data captured by the automatic tide level recording stations along the coastline of NSW over the period 1 July 2020 to 30 June 2021. The stations are located offshore, in bays, harbours and the entrances of major rivers.

To establish if data is available, first identify the relevant station on the ocean tide gauge network map ([Figure 1.1](#)), then refer to the relevant figure for that station. Location maps of each station can be found in [MHL 2020](#) with the plot of the data from that station provided in [Appendix A](#). The plot confirms the availability of data for the fiscal year 2020–2021. For the availability of historical data which has been collected, refer to [Appendices C](#) and [D](#).

Once a selection of data has been made the analysis and/or presentation can be obtained in a variety of formats: graphical plots, time series data, tidal analyses, tidal level ranking and tidal predictions.

MHL provides a full on-line data access service via the internet for its clients, and a limited service for the general public at <http://www.mhl.nsw.gov.au>.

Typically, the last seven days of data are available online in a non-quality-controlled form to aid quick access to raw data records. The on-line service for clients can provide access to all data catalogued in [Appendices C](#) and [D](#).

Quality controlled data may be ordered via the MHL web page (<http://www.mhl.nsw.gov.au>), by emailing [data-request@mhl.nsw.gov.au](mailto:data-request@mhl.nsw.gov.au), or via customised decision support tools that can be provided on request.

### 3.2 Station location terminology

Tidal station locations can be referred to in several ways. As described in [Appendix C](#), each station has a regional context (NSW coastal region), a catchment or port context (river catchment or port), a site context (specific locality, river port, harbour) and a specific location context (absolute location, e.g. on a specific jetty, bank of one side of the river, on a breakwater). Each context description of the location may be useful at different times, depending on what aspect of the data is being considered. The specific latitude and longitude details of stations are distributed as part of the metadata on request. In this report, the station name, as shown in [Table C1](#), has been used throughout the report to avoid any naming convention confusion. The only exception is where references to other work are made, in which case the naming convention of the original author(s) is retained.

### 3.3 Datums

Most ocean tide water levels are recorded in the local port datum which generally equates to Indian Spring Low Water (ISLW). An indicative adjustment of each station from Australian Height Datum (AHD) to local port datum is shown in [Table 3.1](#). Low water datums were calculated circa 1990 for MHL by NSW Public Works Survey, using range ratio method and tidal harmonic analysis over varying time periods. AHD values should be used with caution, as AHD levels are revised from time to time and improvements to surveying techniques may provide additional refinement.

Offshore sites are not related to a datum, but are adjusted by harmonic analysis to the Mean Sea Level (MSL) of each instrument deployment. They provide valuable astronomical constituent and anomaly information. There is no AHD survey information available for Norfolk Island and Lord Howe Island. The survey information for these two stations relates to the local datums.

**Table 3.1 Summary of adjustment from AHD to local port datum**

Station	Station datum (SD)	Adjustment (SD = AHD + Adjustment)
Tweed Entrance South	Tweed River Hydro Datum	0.893
Tweed Offshore	Mean Sea Level	N/A
Brunswick Heads	Brunswick River Flood Mitigation Datum	0.024
Ballina Breakwall	Richmond River Valley Datum	0.860
Yamba	Iluka Port Datum	0.895
Coffs Harbour	Coffs Port Datum	0.882
Port Macquarie	Australian Height Datum	0.000
Port Macquarie Offshore	Mean Sea Level	N/A
Crowdy Head	Crowdy Head Datum	0.911
Forster	Forster Hydro Datum	1.061
Shoal Bay	Port Stephens Hydro Datum	0.944
Patonga	Australian Height Datum	0.000
Sydney	Zero Fort Denison	0.925
Fort Denison (Sydney Ports)	Zero Fort Denison	0.925
Bundeena	Zero Fort Denison	0.925
Crookhaven Heads	Australian Height Datum	0.000
Shoalhaven Offshore	Mean Sea Level	N/A
Jervis Bay	Chart Datum	1.070
Ulladulla	Australian Height Datum	0.000
Princess Jetty	Australian Height Datum	0.000
Batemans Bay Offshore	Mean Sea Level	N/A
Bermagui	Bermagui Local Hydro Datum	0.714
Eden	Twofold Bay Hydro Datum	0.924
Lord Howe Island	Lord Howe Island Hydro Datum	Not available
Norfolk Island	Lowest Astronomical Tide	Not available

Data for Norfolk Island since 2015 provided by Bureau of Meteorology's National Tidal Unit (NTU).

### 3.4 Tidal planes and tidal forecasts

MHL uses the Foreman (1977) method to calculate the significant tidal constituents and tidal planes from data recorded at the ocean tide sites. From these tidal planes, MHL investigated the tidal ranges at NSW ocean tide sites (MHL 2005) and concluded that there is a general trend of increasing tidal range from south to north, however, there may be local variations to this trend. Nearshore sites located in river entrances displayed total ranges lower than the closest offshore sites, suggesting that the river entrances attenuate the tide as it progresses into the estuaries.

In 2012, a further analysis of tidal planes was completed for 188 MHL water level stations including the ocean tide stations (MHL 2012).

It is important to recognise tidal plane and constituent variations when applying data from the ocean tide sites. Variations between sites may significantly influence investigation outcomes. For example, the difference between the sites when used as the boundary conditions for numerical hydrodynamic models may significantly influence the model results. Such variations between sites reinforce the importance of the data being used in a manner which is fit for the purpose it is intended.

A long-term forecast was produced in 2015 for each ocean tide site for the full data range of historical data and predicted to 2021. The methodology determined the average of the yearly constituent values and then converted them to a single average phase and amplitude value (including  $Z_0$  or MSL). The new constituent values were used to predict tidal forecasts up to 2021 (using the Foreman analysis). From these forecasts, the Highest Astronomical Tide (HAT) and Lowest Astronomical Tide (LAT) were determined for the tidal datum epoch (1995 to 2014). HAT, LAT and mean sea level (MSL) values were calculated to local low water datums, as well as to AHD, as shown in [Table 3.2](#).

This report will be the final year in which the 1995–2014 epoch HAT and LAT values will be presented. Updated values will be referenced from analysis of the tidal epoch of 2001–2020 which is currently under review. The updated tidal planes, HAT and LAT values are calculated by the Foreman method outlined in MHL 2012 which includes automated threshold flood removal.

**Table 3.2 Ocean and river entrance tide HAT and LAT values**

Site	Period 1995–2014				Range (HAT-LAT)	Period 1995–2014	
	HAT <sup>^</sup>	LAT <sup>^</sup>	HAT (AHD)*	LAT (AHD)*		MSL	MSL (AHD)*
Tweed Heads	1.99	0.02	1.10	-0.87	1.97	0.93	0.04
Brunswick Heads	1.22	-0.85	1.17	-0.90	2.07	0.07	0.02
Ballina Breakwall	2.02	0.04	1.16	-0.82	1.98	0.89	0.03
Yamba	2.01	0.07	1.12	-0.83	1.94	0.95	0.05
Coffs Harbour	2.12	-0.11	1.24	-0.99	2.23	0.9	0.02
Port Macquarie	1.04	-0.74	1.04	-0.74	1.78	0.02	0.02
Crowdy Head	2.1	-0.09	1.19	-1.00	2.19	0.88	-0.03
Forster	1.93	0.17	0.87	-0.89	1.76	1.03	-0.03
Tomaree (Port Stephens)	2.08	-0.03	1.14	-0.97	2.11	0.92	-0.02
Patonga	1.16	-0.88	1.16	-0.88	2.04	0.06	0.06
Sydney	2.07	0.03	1.15	-0.90	2.04	0.96	0.03
Port Hacking	2.11	0.09	1.19	-0.84	2.02	1.00	0.08
Crookhaven Heads	1.01	-0.08	1.01	-0.08	1.09	0.03	0.03
Jervis Bay	2.19	0.10	1.12	-0.97	2.09	1.09	0.02
Ulladulla	1.20	-0.90	1.20	-0.90	2.10	0.05	0.05
Princess Jetty	1.06	-0.79	1.06	-0.79	1.85	0.06	0.06
Bermagui	1.72	-0.18	1.01	-0.89	1.90	0.69	-0.02
Eden	1.92	-0.11	1.00	-1.03	2.03	0.84	-0.08
Lord Howe Island	2.35	-0.06	n/a	n/a	2.41	1.10	n/a
Norfolk Island	1.97	0.03	n/a	n/a	1.94	0.97	n/a

\* Conversion from AHD to local port datum given in [Table 3.1](#)

<sup>^</sup> Local port datum

Data for Norfolk Island since 2015 provided by Bureau of Meteorology's National Tidal Unit (NTU).

## 4. Significant tidal events 2020–2021

The data recovery statistics are shown in [Table 4.1](#).

**Table 4.1 Data recovery July 2020 to June 2021**

Data stream	Data recovery (%)	Comments
15-minute ocean tide data	99.9	Small percentage of 1-minute data loss due to radar instrument noise.
1-minute ocean tide data	99.4	
5-minute and 60-minute offshore data	80.8	Port Macquarie: Battery leakage in the primary offshore pressure logger (RBR) caused failure and lost data. The Aanderaa backup was able to provide the tidal data until marine growth on the pressure sensor caused failure (85% data recovery). Batemans Bay: The sensor recovery at Batemans Bay was delayed due to COVID restrictions and poor visibility conditions due to exceptional wet weather. The instrument was deployed for an 18-month period. This length of time exceeded the RBR power budget, no memory is stored internally once the CPU time is lost so there was no recoverable data. There was no backup sensor during this deployment period (38% data recovery).

The 2022 NSW Tide Prediction Charts are available free of charge via download from the MHL public web page. The charts remain an authoritative reference for tides along the NSW coast ([Figure 4.1](#)). As for previous tide prediction publications, MHL adopts the Sydney tide gauge as the primary reference station, and the ocean tide predictions for NSW are based on an analysis of 15–minute tide levels recorded by this primary gauge. The time difference between the primary and secondary locations in NSW was obtained through analysis of the tide levels recorded at gauges at each of the secondary locations (MHL 2001).

### 4.1 Tidal anomalies

Tidal anomalies in this report are calculated as the difference between the recorded data and the long-term epoch forecasts as discussed in [Section 3.4](#).

The main drivers of anomalies are barometric pressure, wind setup, coastally trapped waves, and the influence of the East Australian Current (EAC). For onshore river entrance gauges, hydrological anomalies such as floods can also occur. Storms are usually associated with large barometric pressure changes and wind setup. The types of large scale storms affecting NSW include East Coast Lows (ECL) and the effects of tropical cyclones off the Queensland coast. Furthermore, tsunamis can cause waves that present on the onshore open ocean and onshore bay or port gauges as tidal anomalies.

The *NSW Extreme Ocean Water Levels* report (MHL 2018) investigated anomalies recorded on the NSW coast and considered their occurrence and forcing mechanisms.

The anomalies recorded on the NSW coast during the reporting period are compared across a selected group of stations in [Figure 4.2](#). The major anomalies, which are classified as greater than  $\pm 0.2$  m difference between recorded and forecast data, are identified on [Figure 4.2](#) and documented in more detail in [Figures 4.3](#) and [4.4](#). Most are driven by ECLs or large high pressure systems. [Figures 4.5–4.8](#) show the tidal anomalies recorded at each station during the reporting period. [Figure 4.9](#) shows the anomalies for the four offshore tide stations.

The Bureau of Meteorology (BoM) recorded one Tropical Low and one Tropical Cyclone in North Queensland during the 2020–2021 reporting period:

- 27 February to 5 March 2021, Severe Tropical Cyclone Niran formed off the coast of Northern Queensland on 1 March, the tropical low was upgraded into a tropical cyclone by the BoM. As the cyclone reached Category 2 it began to pull away from the coast of Australia. Tropical Cyclone Niran gradually intensified into Category 5 as it crossed into the Fiji Meteorological Services jurisdiction before weakening on 6 March.

## 4.2 Tsunami events

[Table 4.2](#) lists the tsunami events in the Pacific Region for the period of time corresponding to the 2020–2021 data in this report.

**Table 4.2 Recorded earthquake events July 2020 to June 2021**

Date (UTC)	Earthquake magnitude ( $M_w$ )	Location	Observable on NSW tide recordings
23/01/2021	6.9	Antarctica – Scotia Sea	No
10/02/2021	7.7	New Caledonia – Loyalty Islands	No
13/02/2021	7.1	Japan – Fukushima	No
04/03/2021	7.3	New Zealand – Gisborne	Yes
04/03/2021	7.4	New Zealand – Kermadec Islands	Yes
04/03/2021	8.1	New Zealand – Kermadec Islands	Yes

Source: NOAA National Geophysical Data Centre Tsunami Database <http://www.ngdc.noaa.gov/hazard/tsu.shtml>

The BoM and Geoscience Australia host the Joint Australian Tsunami Warning Centre (JATWC). The BoM collects specific tsunami data for issuing warnings, and the data can be requested from BoM for further use. On Friday 5 March 2021, JATWC warnings were issued as multiple earthquakes occurred ([Table 4.2](#)) in the Kermadec Islands region, about 1,000 kilometres from New Zealand's two main islands, as shown in [Figure 4.10](#).

The DPIE ocean tide gauge network shown in [Figure 4.10](#) detected the tsunami waves generated at multiple gauges up and down the NSW coast. Based on the earthquake epicentre locations, the north coast ocean tide gauges detected the strongest wave signal

due to the most direct line to the tsunami and the least wave refraction. Tsunami wave periods can range from 5 to 90 minutes; therefore higher resolution one minute and one second<sup>1</sup> data sets are used to analyse the tsunami waves.

The maximum overall tsunami waves recorded were in NSW trapped harbour embayments such as Coffs Harbour and Ulladulla. These experienced amplified water level oscillations due to the creation of a standing wave within the harbour boundaries. Coffs Harbour recorded up to 0.65 m waves, and continued for over 24 hours as shown in [Figure 4.11](#). A comparison of embayment area and its effect on a trapped wave is also evident in [Figure 4.11](#). The size of Crowdy Head harbour is considerably smaller than Coffs Harbour; this is evident when overlayed with the clear sinusoidal wave of Coffs Harbour having more wave interference and approximately half the period. The resulting seiching would be far more erratic inside Crowdy Head harbour.

The tsunami wave effects were far less evident in open river gauges compared to harbours and open bays. The tsunami waves were dampened at more open river sites, such as Tweed Heads and Ballina, shown in [Figure 4.12](#). In these locations, wave disturbances continued to travel upstream.

The pumping of ocean lake system water levels can occur during tsunami anomalies. Shoal Bay was measured with a maximum tsunami wave of 0.47 m. Water levels inside adjacent Lake Macquarie ([Figure 4.12](#)) have been raised by a 0.1 m anomaly. With a tidal range of 0.2 m inside Lake Macquarie the 0.1 m anomaly can cause certain parts of the lake to inundate without warning.

Any impacts to marine infrastructure and water craft were minimal. Long-term data is essential for the state of NSW to manage these events in addition to supporting warning services by the Bureau of Meteorology for public safety.

### 4.3 King tide events

Predicted king tides over the 2020–2021 financial year occurred on 15 December 2020, 27 May 2021 and 25 June 2021. The highest recorded actual water level associated with a king tide in Sydney was 1.23 m AHD in May 2021. This was also the highest recorded water level at the Sydney gauge during the 2020–2021 financial year.

The highest residual level recorded (difference between actual and predicted tide) at the Sydney gauge during the 2020–2021 financial year occurred on 28 July 2020, measuring 0.385 m AHD. This was during an intense low pressure system which brought flooding to the south coast, as highlighted in [Figure 4.4](#).

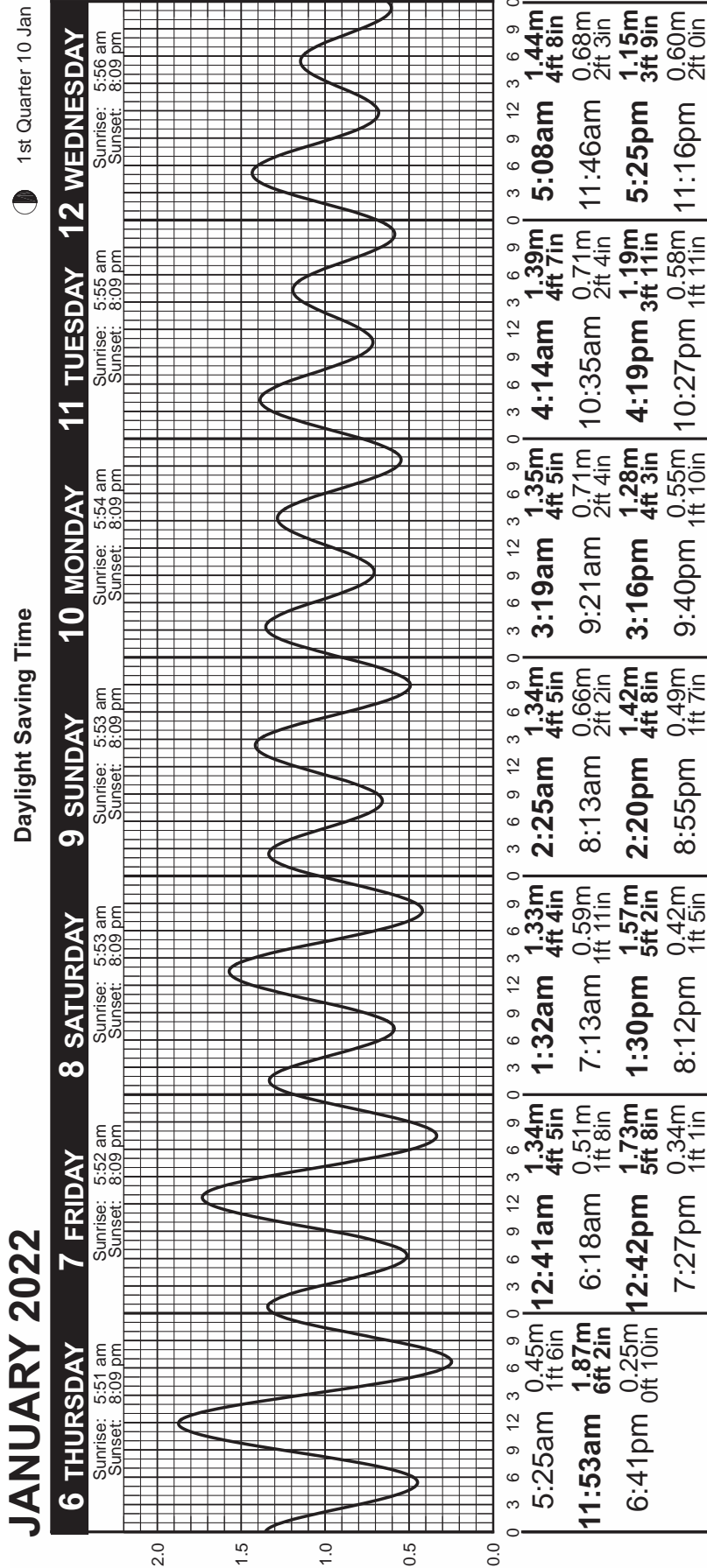
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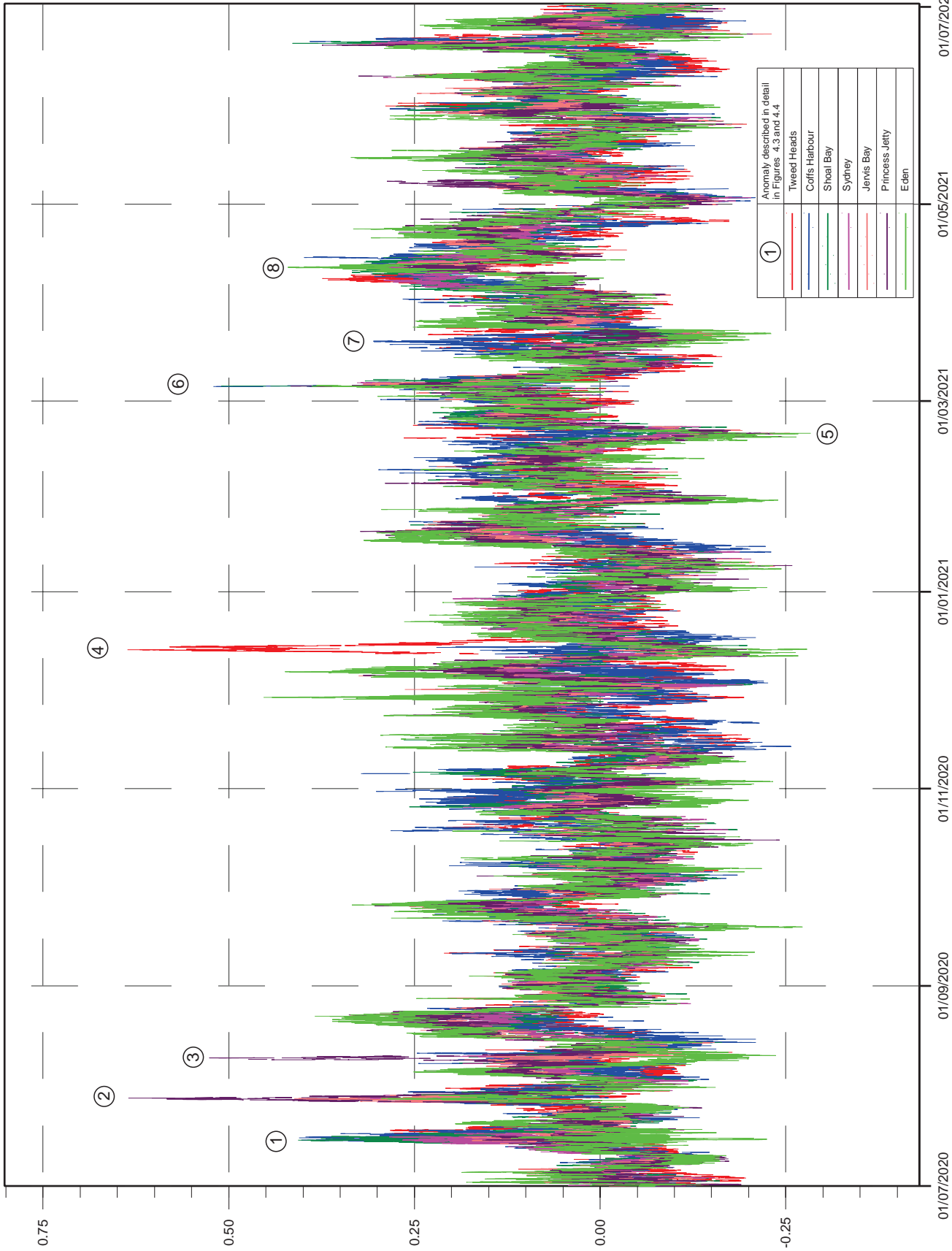
<sup>1</sup> One second data is only available at select locations.



NSW TIDAL PREDICTIONS  
EXTRACT FROM 'NSW TIDE CHARTS 2022'

Manly  
Hydraulics  
Laboratory  
Report MHL2856  
Figure  
4.1  
DRAWING 2856-04-01.cdr





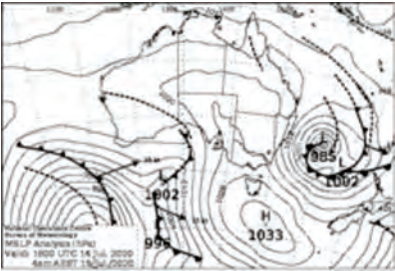
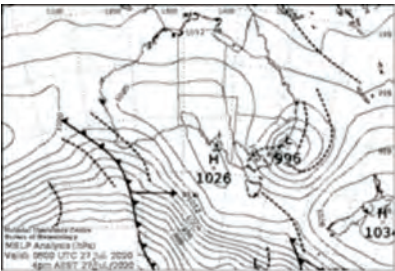
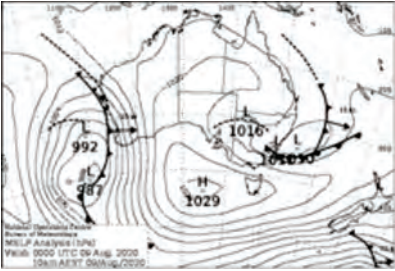
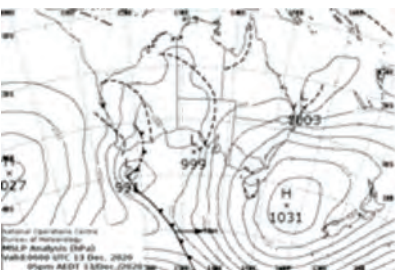
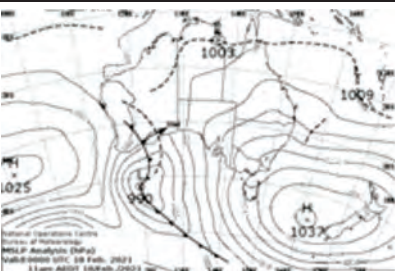
NSW TIDAL ANOMALIES PLOT 2019–2020

Manly  
Hydraulics  
Laboratory

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Figure  
4.2

DRAWING 2856-04-02.cdr

Event number (see Figure 4.2)	Event period	BoM weather map *  East Coast Low	Peak anomaly	Sites where anomaly > +/- 0.25m
1	14–16 July 2020	 <p>East Coast Low</p>	Site Port Macquarie Date 15/07/2020 Time 0145 Peak value 0.480	Tweed, Brunswick, Ballina, Yamba, Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena
2	27–29 July 2020	 <p>Low pressure system/flooding</p>	Site Princess Jetty Date 27/07/2020 Time 2230 Peak value 0.583	Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui
3	09–10 August 2020	 <p>South coast flooding</p>	Site Crookhaven Heads Date 10/08/2020 Time 0615 Peak value 0.664	Crookhaven Heads, Princess Jetty
4	13–16 December 2020	 <p>Tropical low</p>	Site Brunswick Heads Date 15/12/2020 Time 0100 Peak value 0.697	Tweed, Brunswick, Ballina, Yamba
5	18–19 February 2021	 <p>Large high pressure system</p>	Site Bermagui Date 18/02/2021 Time 2030 Peak value -0.296	Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden

\*Weather map images courtesy BoM © Commonwealth of Australia, Bureau of Meteorology



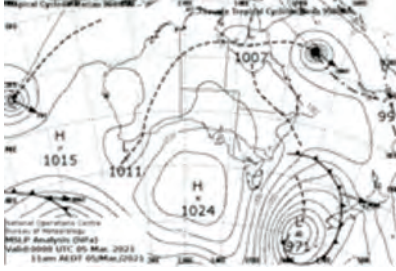
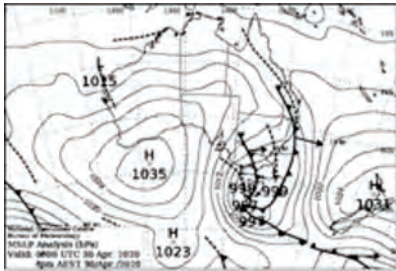
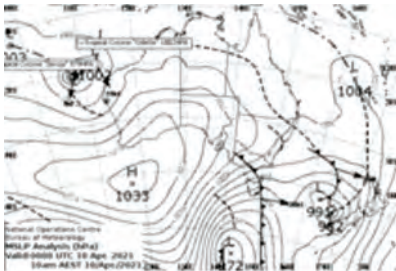
TIDAL ANOMALIES JULY 2020–JUNE 2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

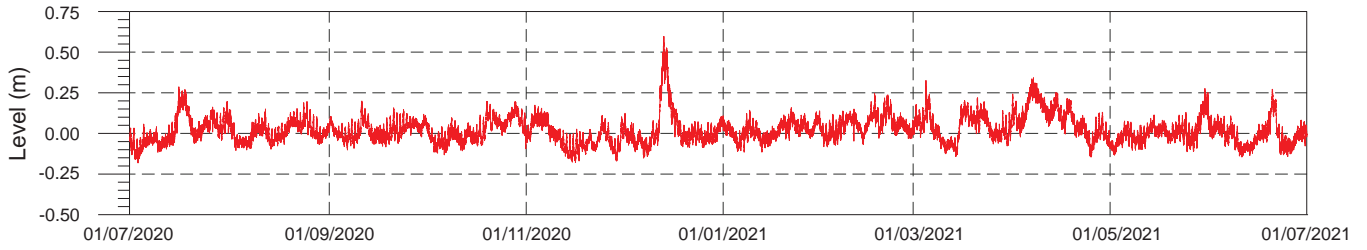
Figure  
4.3

DRAWING 2856-04-03.cdr

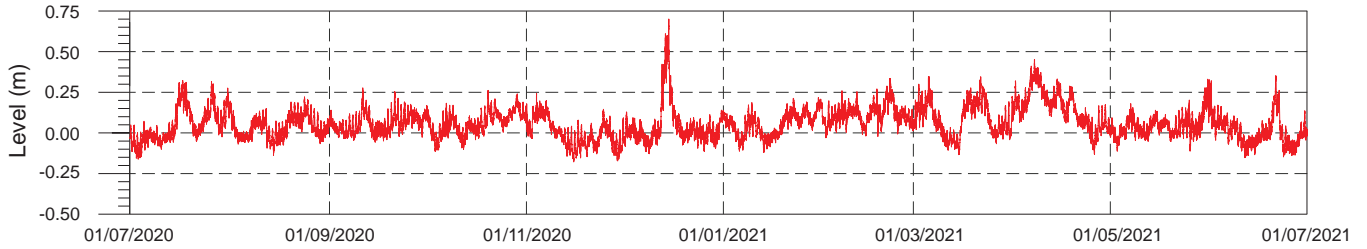
Event number (see Figure 4.2)	Event period	BoM weather map <sup>*</sup>	Peak anomaly	Sites where anomaly > +/- 0.25m
6	05 March 2021	 <p>New Zealand tsunami</p>	Site Coffs Harbour Date 05/03/2021 Time 1315 Peak value 0.550	Tweed, Brunswick, Ballina, Yamba, Coffs Harbour, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden
7	18–26 March 2021	 <p>March flood event</p>	Site Port Macquarie Date 20/03/2021 Time 0800 Peak value 2.199	Yamba, Port Macquarie, Forster, Crookhaven Heads
8	08–14 April 2021	 <p>Multiple lows</p>	Site Yamba Date 08/04/2021 Time 2330 Peak value 0.468	Tweed, Brunswick, Ballina, Yamba, Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Ulladulla, Princess Jetty, Bermagui, Eden

\*Weather map images courtesy BoM © Commonwealth of Australia, Bureau of Meteorology

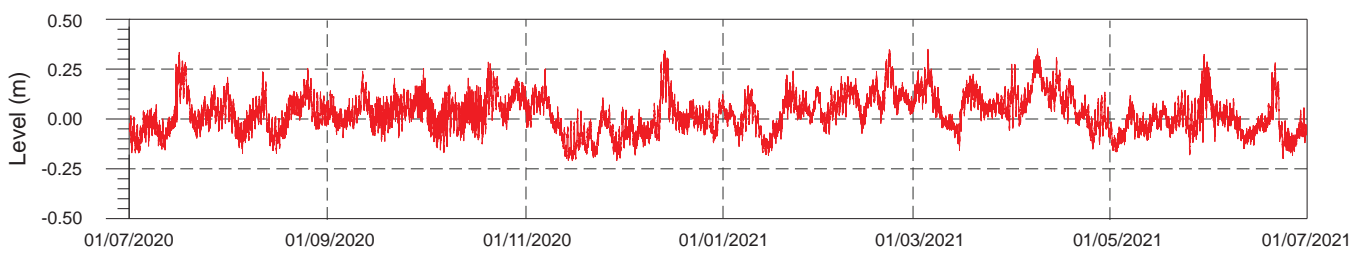
Tweed Entrance South



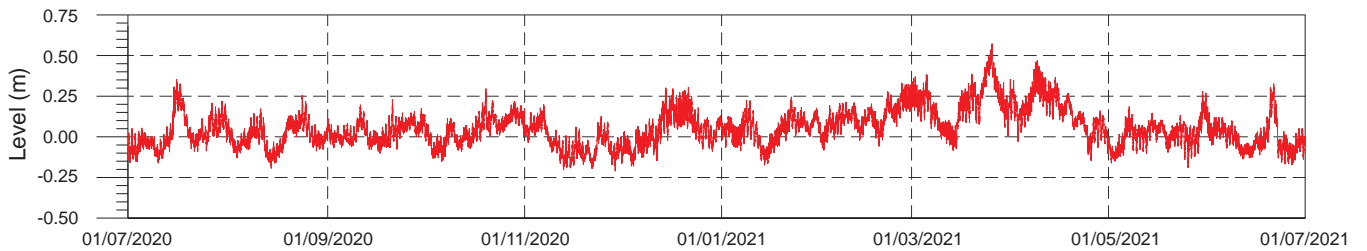
Brunswick Heads



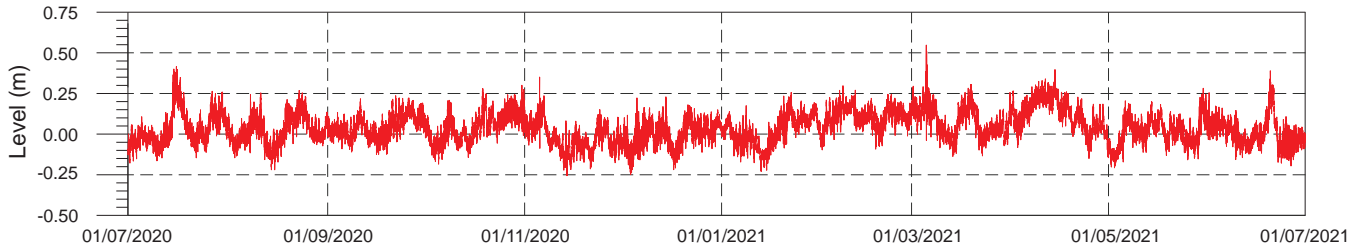
Ballina Breakwall



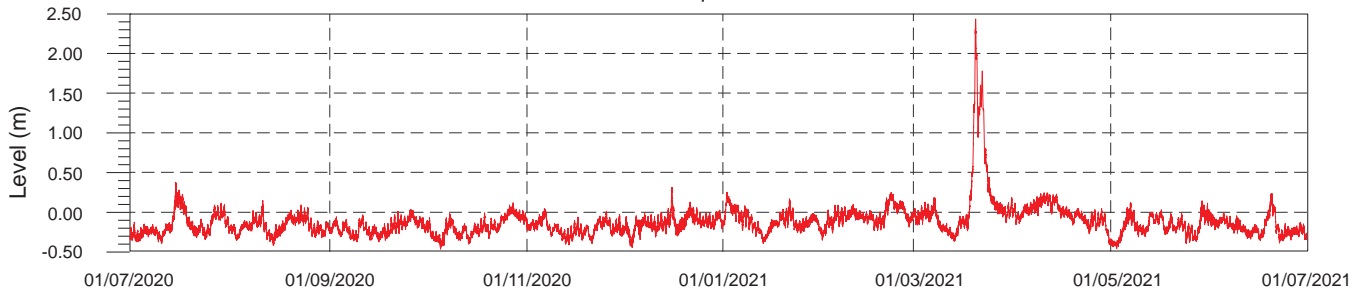
Yamba



Coffs Harbour



Port Macquarie



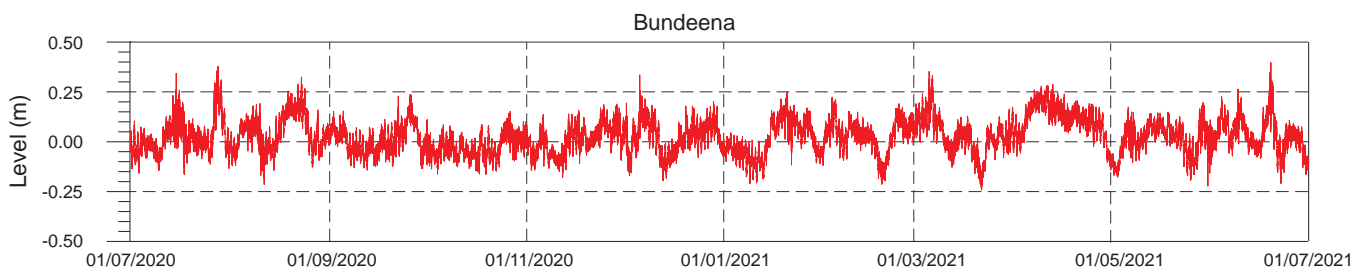
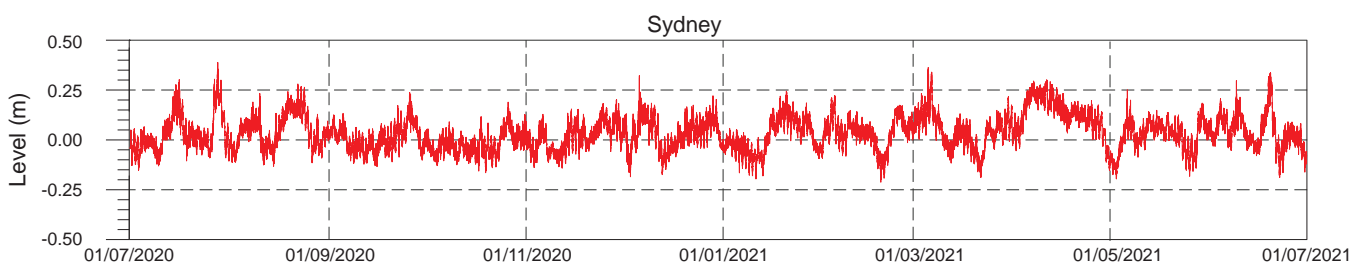
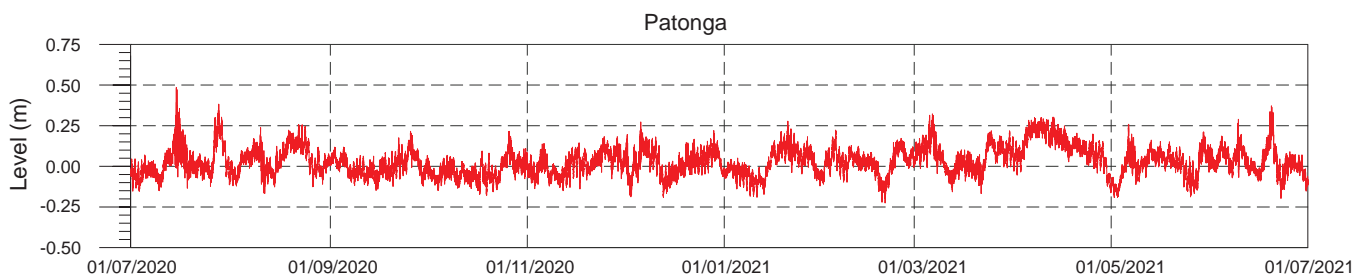
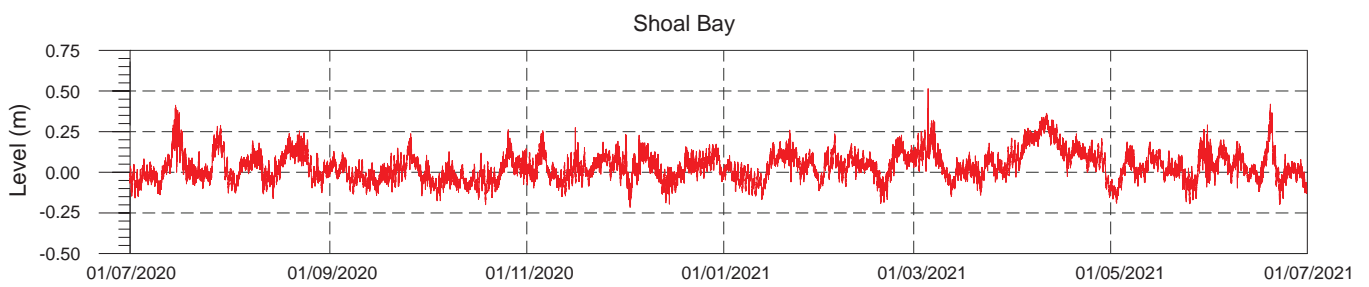
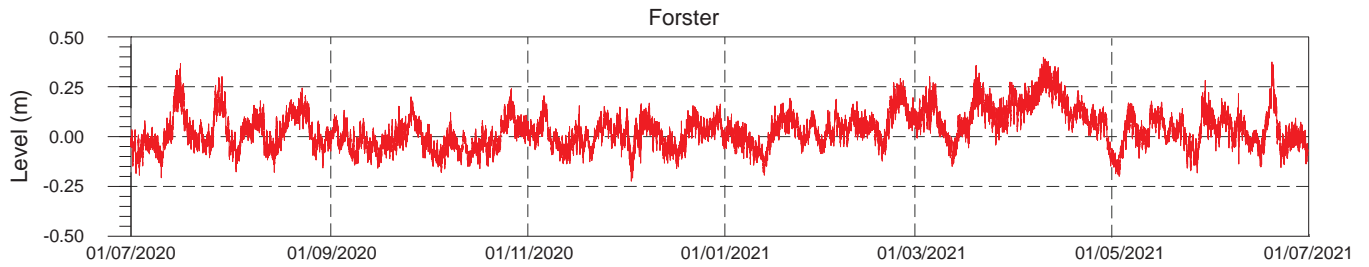
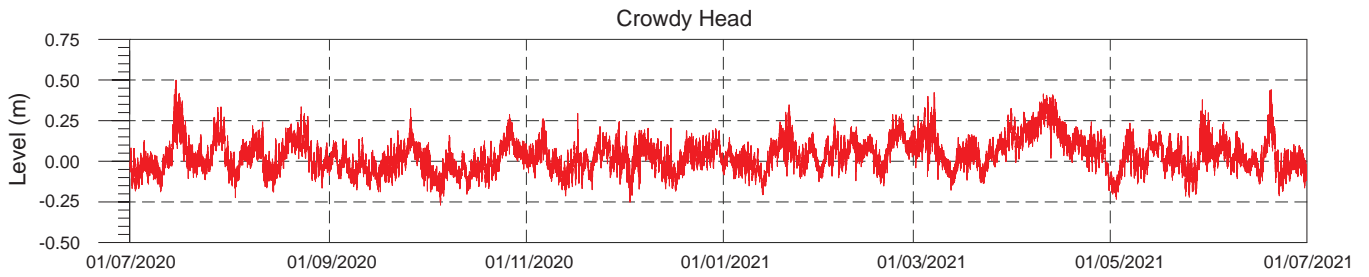
TIDAL ANOMALIES 2020–2021  
TWEED ENTRANCE SOUTH TO PORT MACQUARIE

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
4.5

DRAWING 2856-04-05.cdr



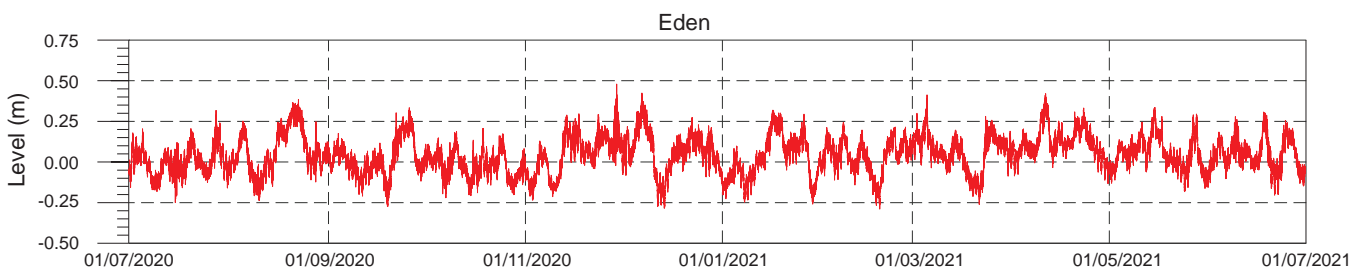
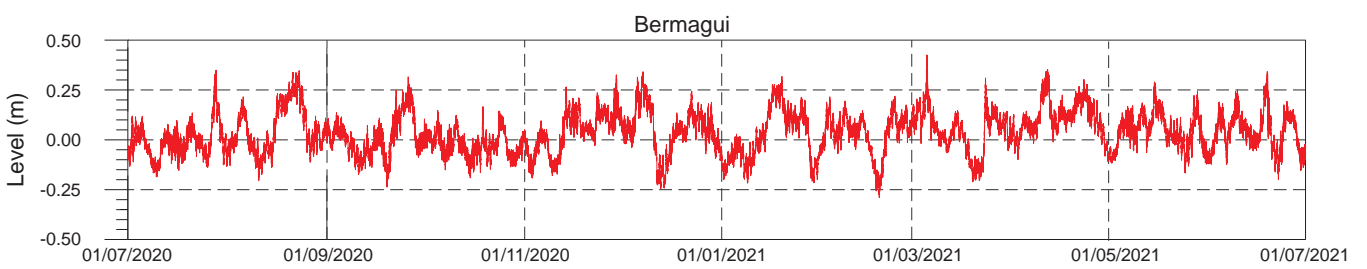
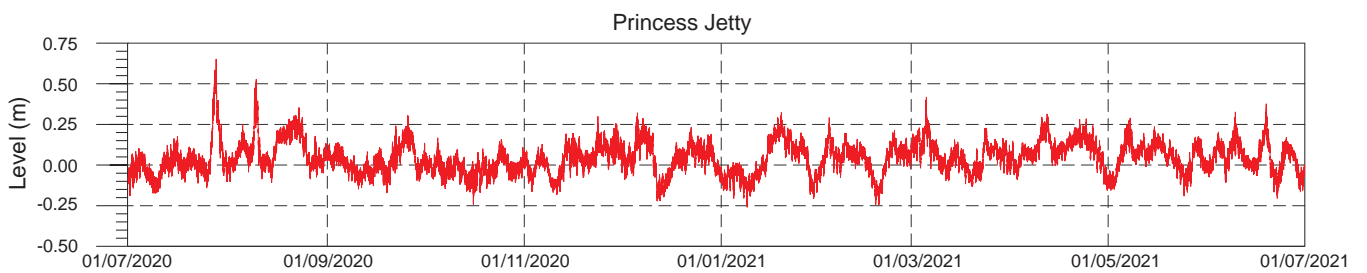
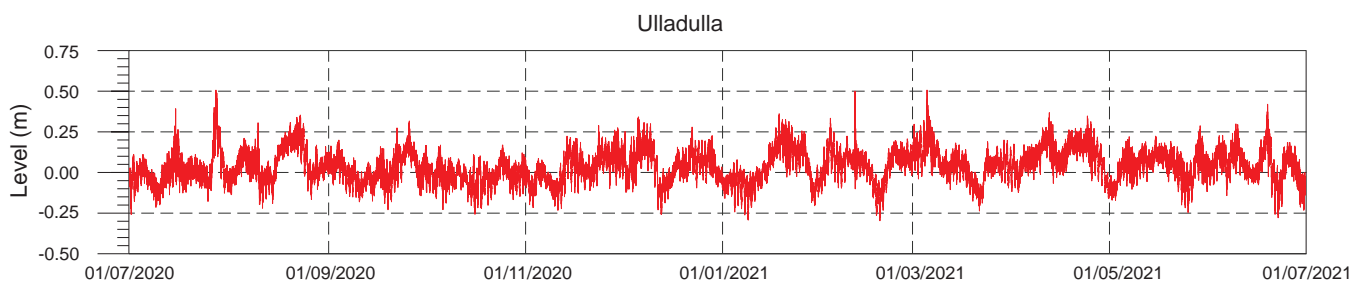
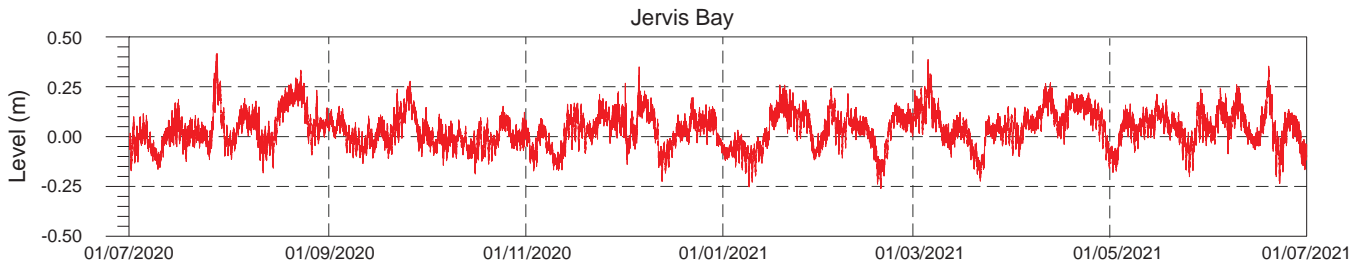
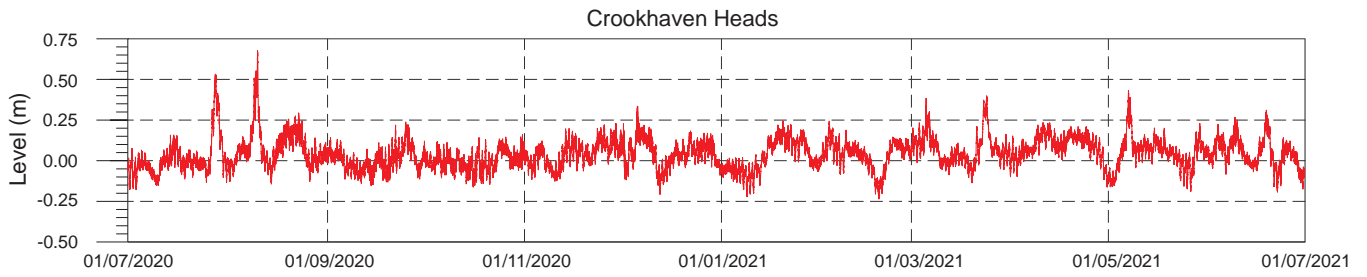
TIDAL ANOMALIES 2020–2021  
CROWDY HEAD TO BUNDEENA

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
4.6

DRAWING 2856-04-06.cdr



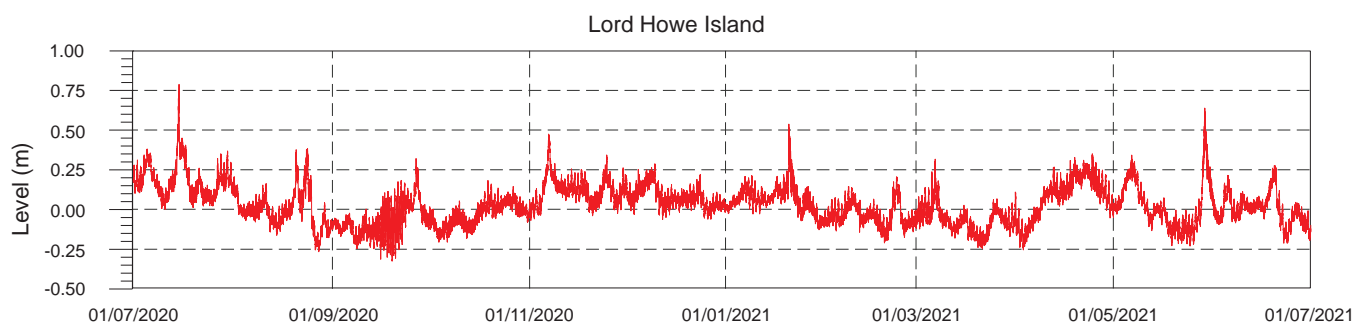
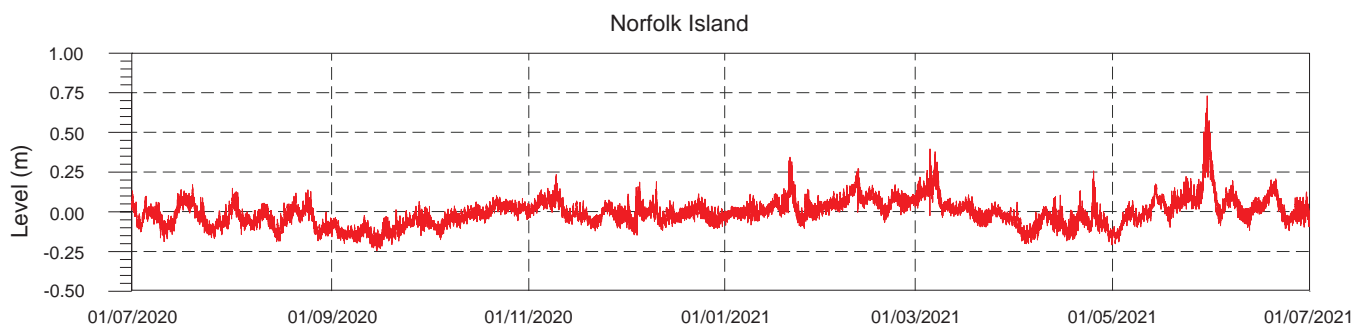
TIDAL ANOMALIES 2020–2021  
CROOKHAVEN HEADS TO EDEN

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
4.7

DRAWING 2856-04-07.cdr



Data for Norfolk Island provided by Bureau of Meteorology's National Tidal Unit (NTU)



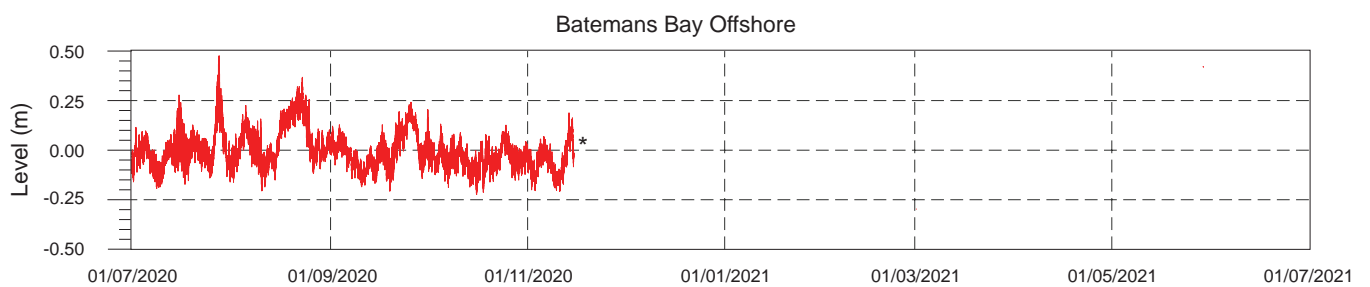
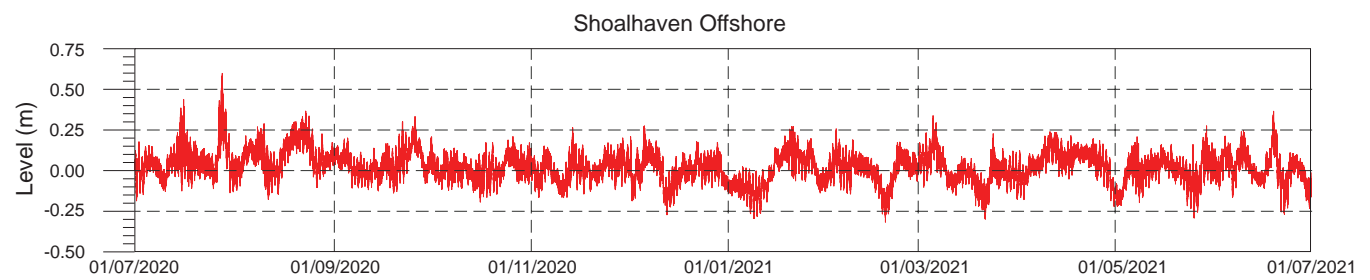
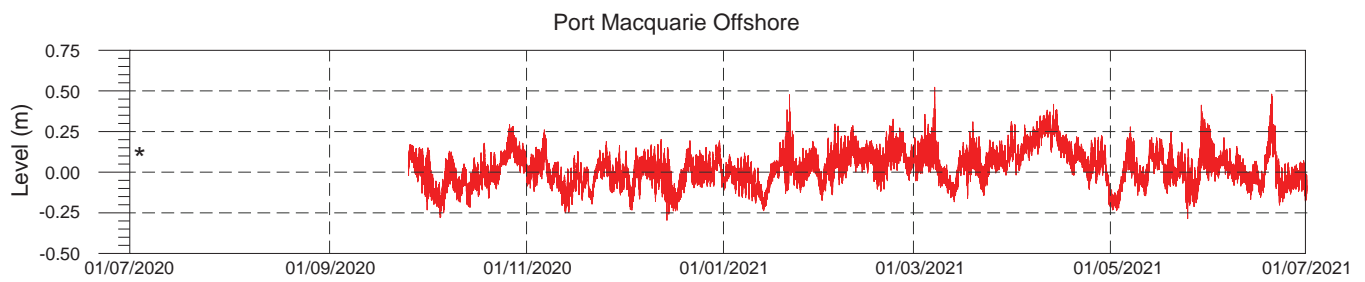
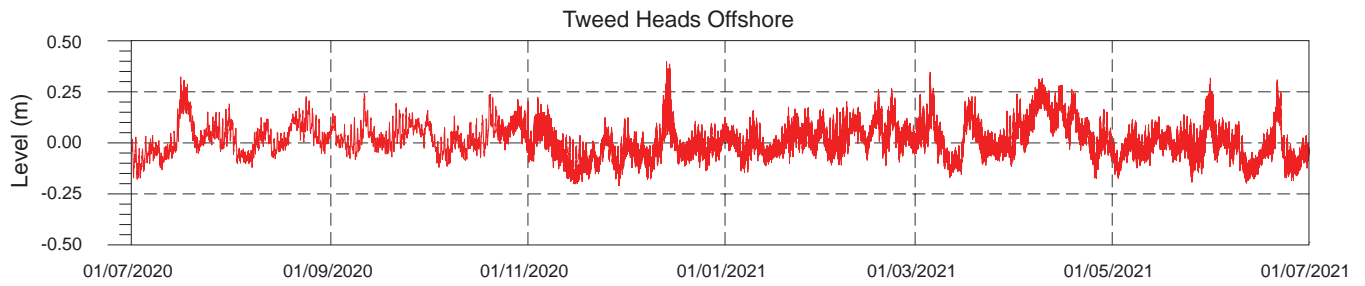
TIDAL ANOMALIES 2020–2021  
NORFOLK ISLAND AND LORD HOWE ISLAND

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
4.8

DRAWING 2856-04-08.cdr



\* Data loss at Port Macquarie and Batemans Bay both due to power failure and insufficient redundancy.



TIDAL ANOMALIES 2020–2021  
OFFSHORE TIDE GAUGES

Manly  
Hydraulics  
Laboratory

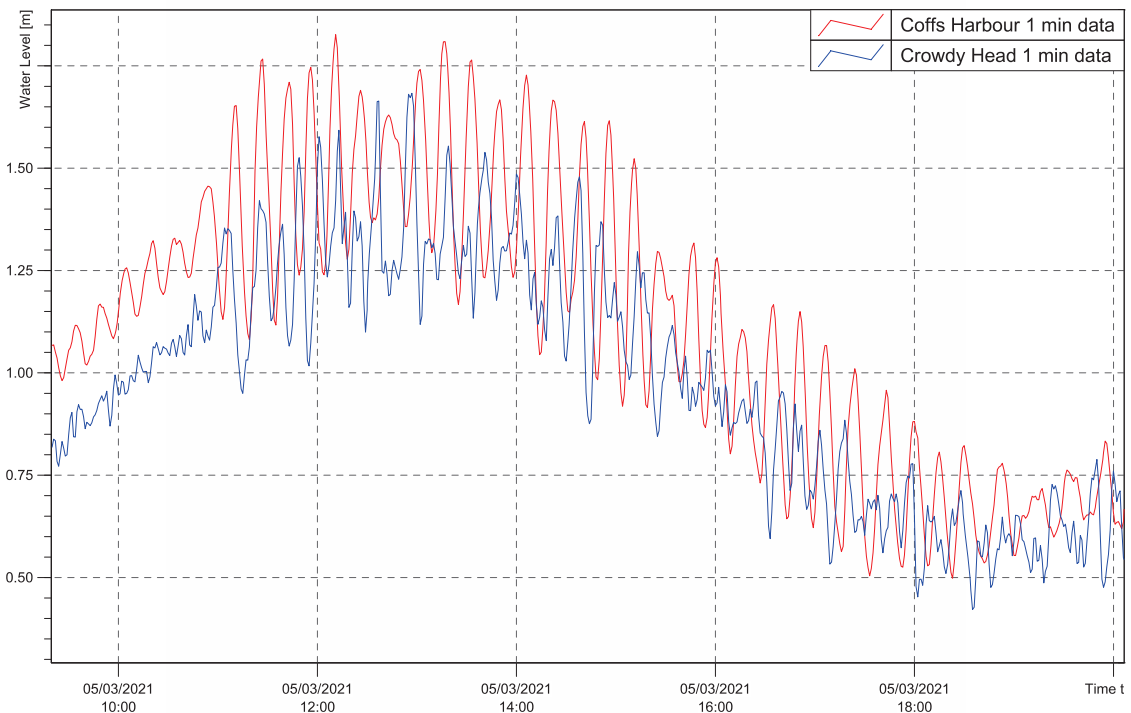
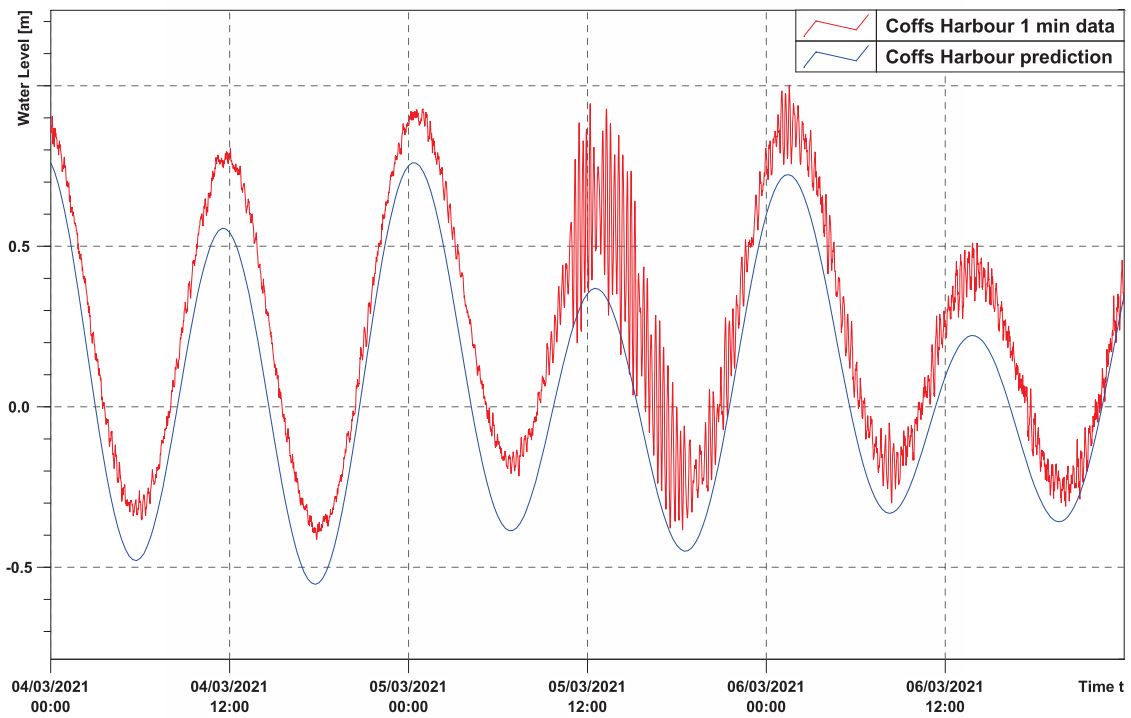
Report MHL2856

Figure  
4.9

DRAWING 2856-04-09.cdr



Source: abc.net.au



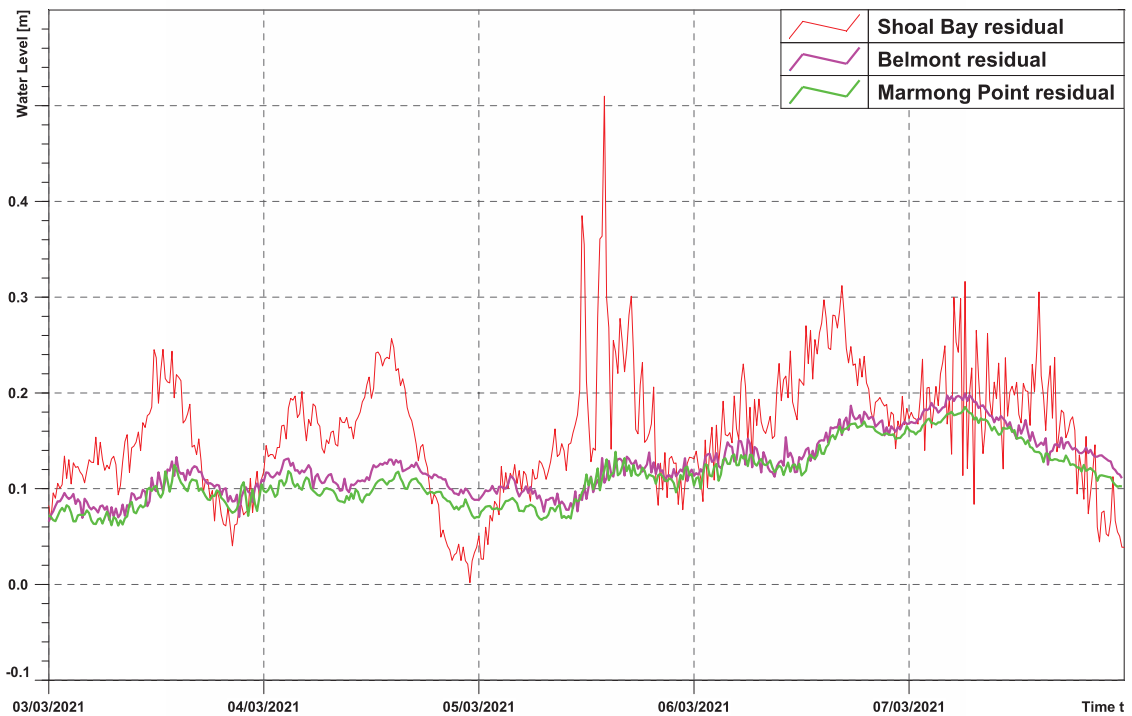
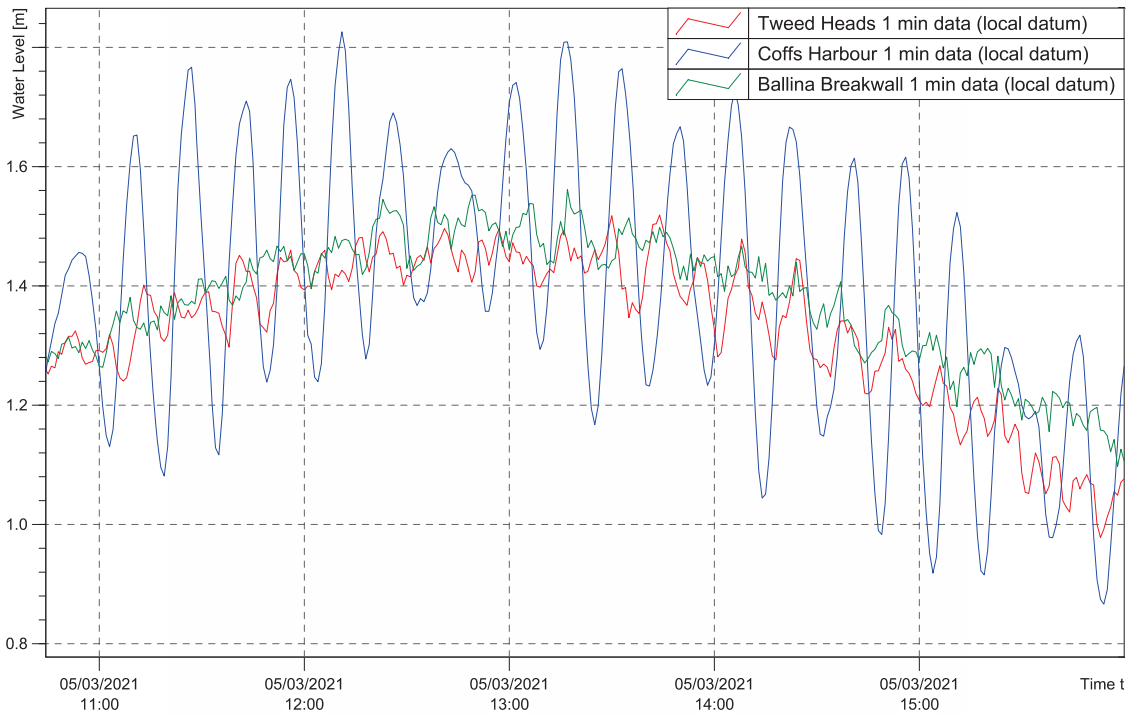
1-MINUTE DATA SEICHING IN NORTH COAST, NSW BAYS DUE TO TSUNAMI WAVES

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
4.11

DRAWING 2856-04-11.cdr



COMPARING TSUNAMI WAVE EFFECTS  
IN NSW COASTAL LAKES AND RIVERS

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
4.12

DRAWING 2856-04-12.cdr

## 5. Air pressure program summary 2020–2021

### 5.1 Data capture

During 2020–2021 the overall data recovery for all barometer stations was 98.6%. Monthly data recovery during the 2020–2021 year is shown in [Table 5.1](#). [Appendix B](#) provides plots of measured air pressure at each site.

**Table 5.1 New South Wales air pressure: 2020–2021 data capture**

Barometer / water level site	Data capture (%)												Total year	
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun		
Tweed Heads / Kingscliff	100	100	100	100	100	100	100	100	100	100	100	100	100	<b>100</b>
Yamba / Lake Wooloweyah	100	100	100	100	100	100	100	100	100	100	100	100	100	<b>100</b>
Port Macquarie / Settlement Point	100	100	100	100	100	100	100	100	100	100	100	100	100	<b>100</b>
Newcastle / Stockton Bridge	100	100	100	100	100	100	100	100	100	100	100	100	100	<b>100</b>
Sydney / Narrabeen Bridge	100	100	100	100	100	4	62	100	100	100	100	100	100	<b>89</b>
Jervis Bay / Currarong Creek	100	100	100	100	100	100	100	100	100	100	100	100	100	<b>100</b>
Tuross Head / Tuross Head	100	100	100	100	100	100	100	100	100	100	100	100	100	<b>100</b>
Eden / Wonboyn Lake	100	100	100	100	99	100	100	100	100	100	100	100	100	<b>100</b>

Data loss by the Sydney barometer during December 2020 to January 2021 was due to a loose wire connection between the barometer and logger.

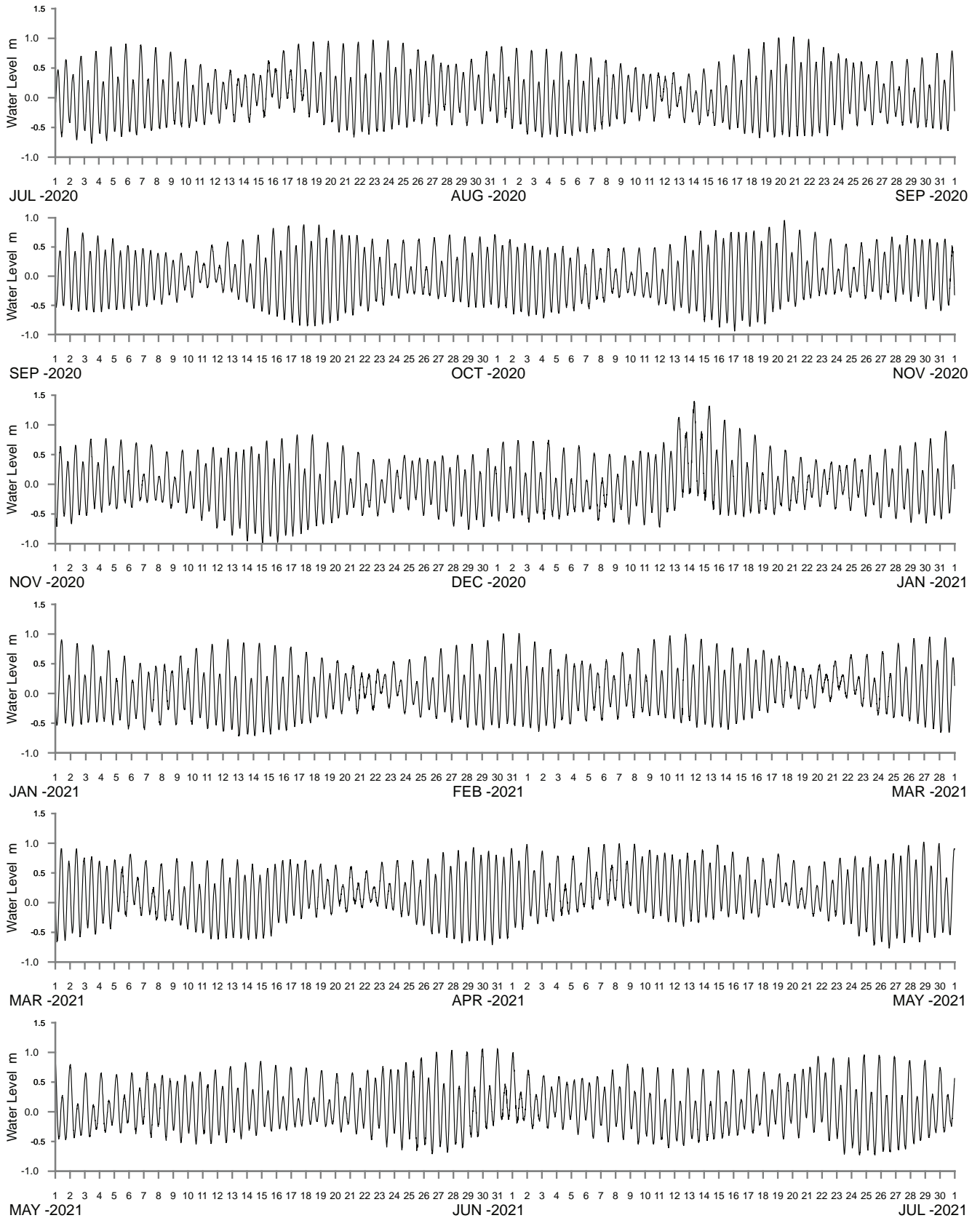
## 6. References

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- Foreman, MGG 1977, *Manual for tidal heights analysis and prediction*, Pac. Mar. Sci. Rep. 77-10, Inst. of Ocean Sciences, Patricia Bay, Sidney, B.C., 58pp (2004 revision).
- MHL 2001, *DLWC NSW Tidal Planes data Compilation 2000*, MHL Report 1098, February 2001.
- MHL 2005, *Investigation into Tidal Planes Compilation – NSW Tidal Planes Data Compilation Stage 3*, MHL Report 1269, November 2005.
- MHL 2012, *OEH NSW Tidal Planes Analysis 1990 – 2010 Harmonic Analysis*, MHL Report 2053, October 2012.
- MHL 2017, *NSW Ocean and River Entrance Tidal Levels Annual Summary*, MHL Report 2574, December 2017.
- MHL 2018, *NSW Extreme Ocean Water Levels*, MHL Report 2236, December 2018.
- MHL 2020, *Review of NSW OEH Automatic Water Level Recorder Network*, MHL Report 2546, March 2020.
- MHL 2022, *NSW Estuary and River Water Levels Annual Summary 2020–2021*, MHL Report 2855, April 2022.

# Appendix A Annual tidal data station summaries

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WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



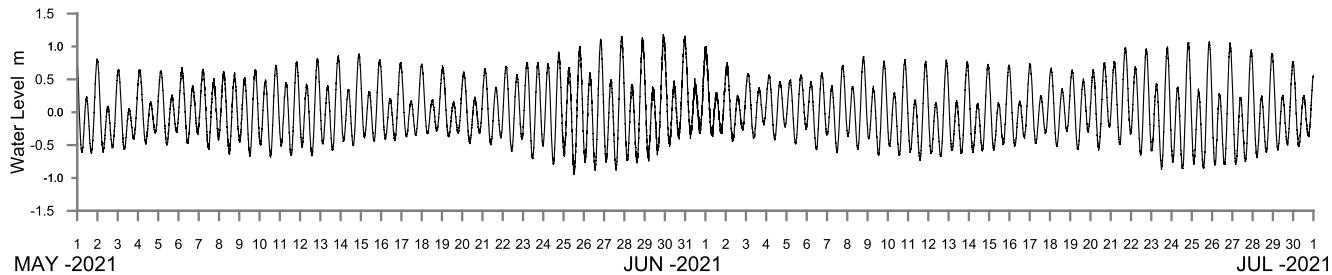
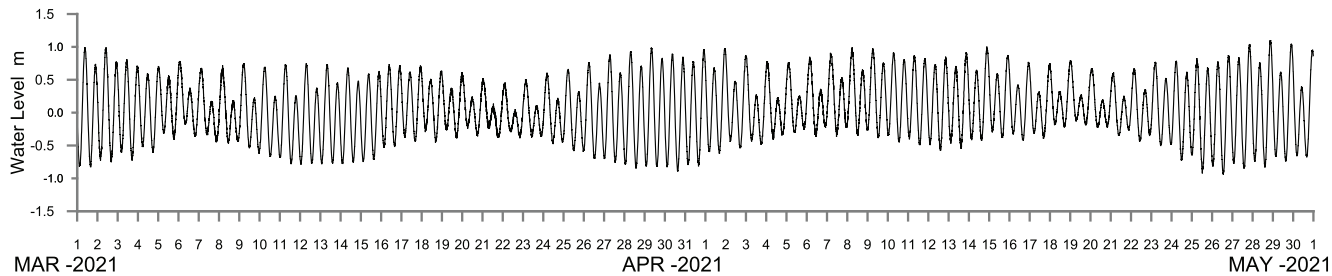
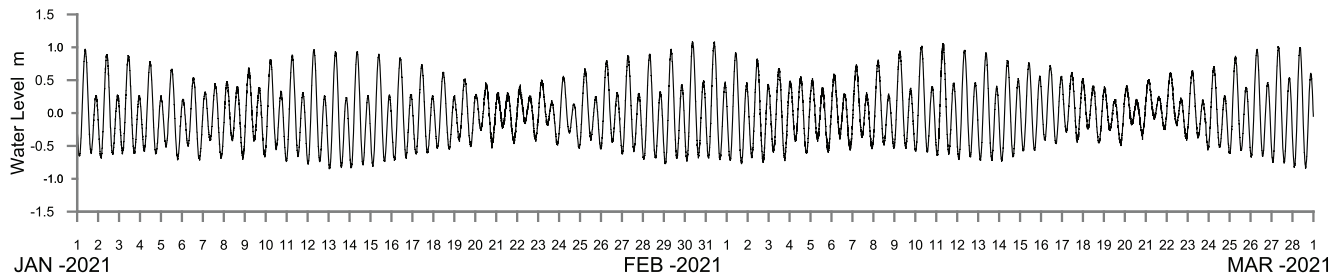
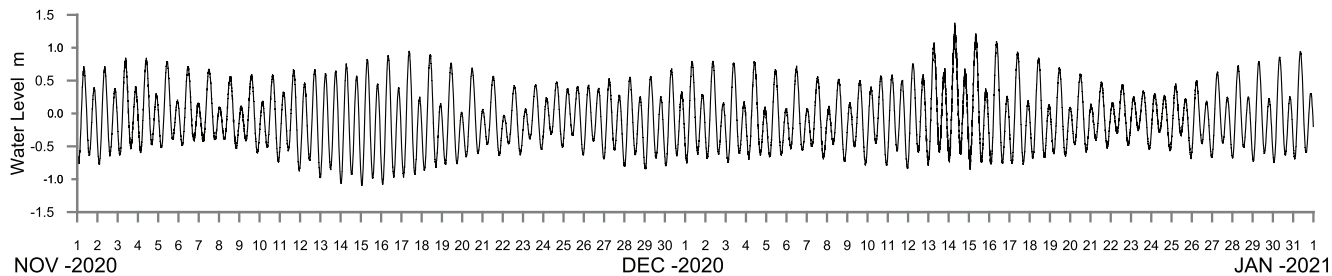
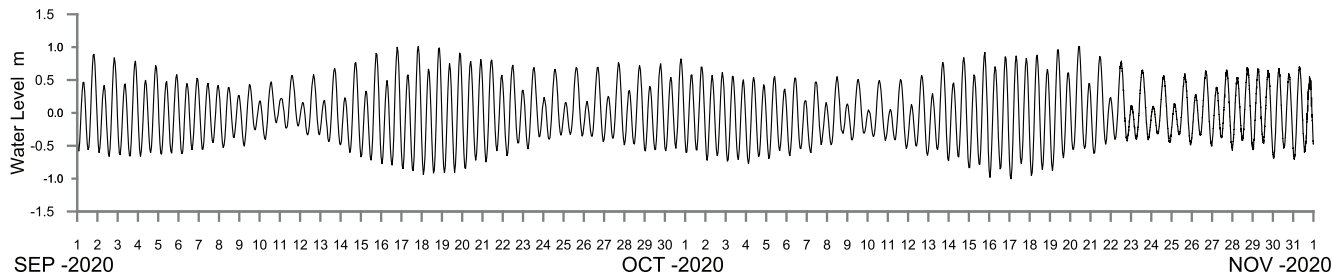
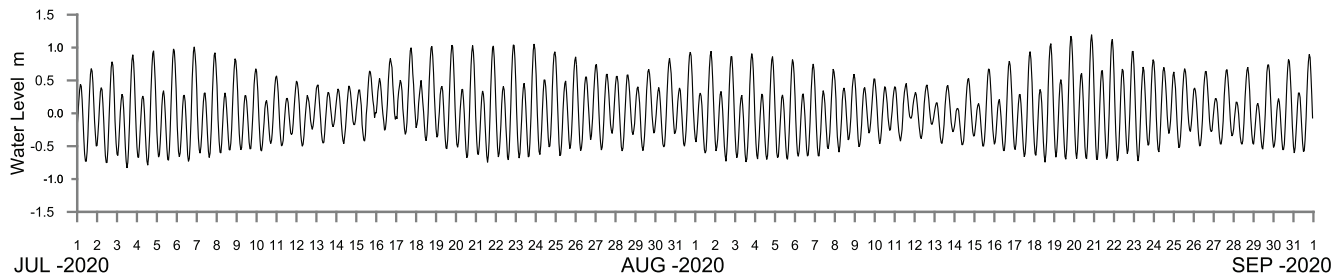
TWEED ENTRANCE SOUTH DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A1

DRAWING 2856-A1.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



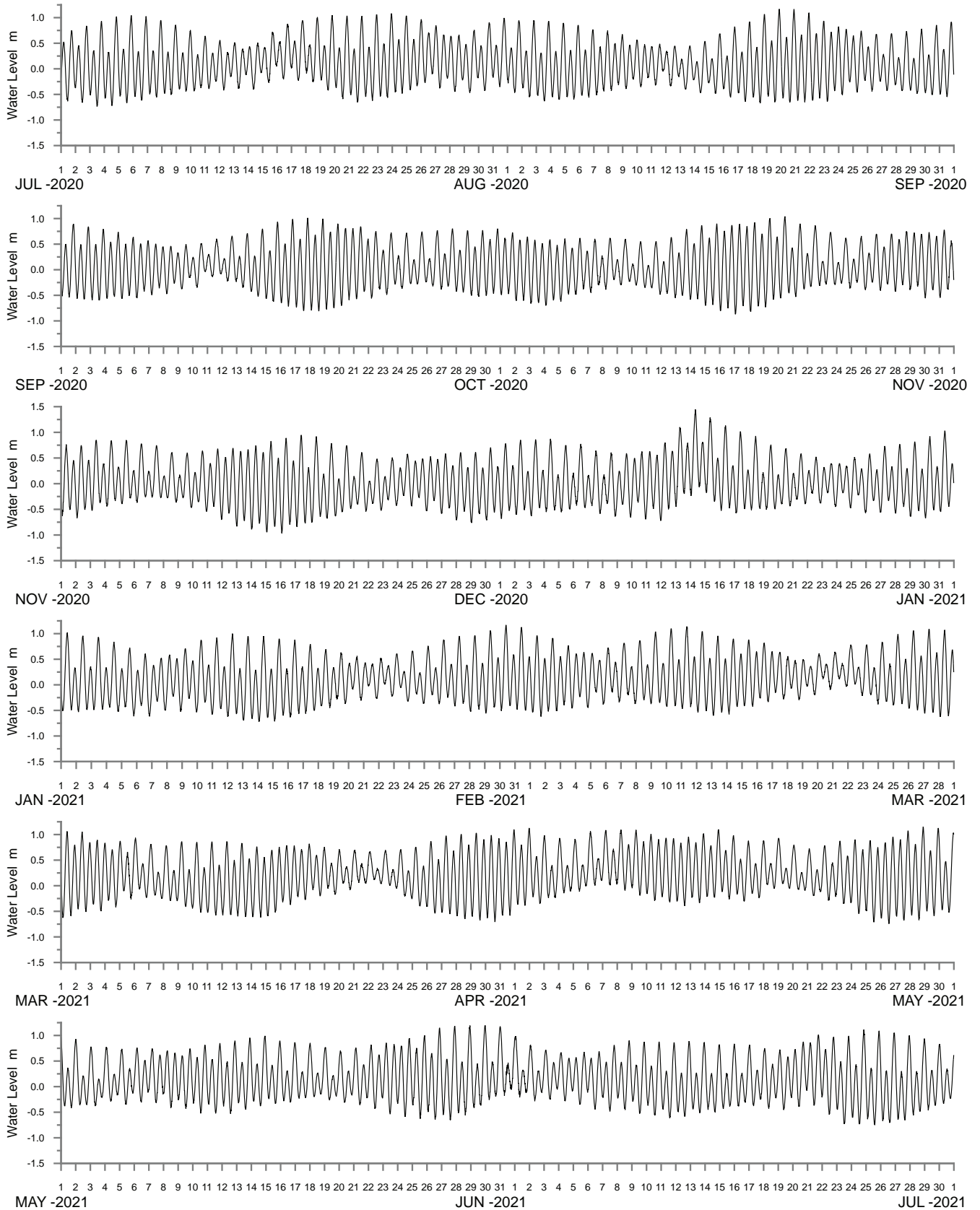
TWEED HEADS OFFSHORE DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A2

DRAWING 2856-A2.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



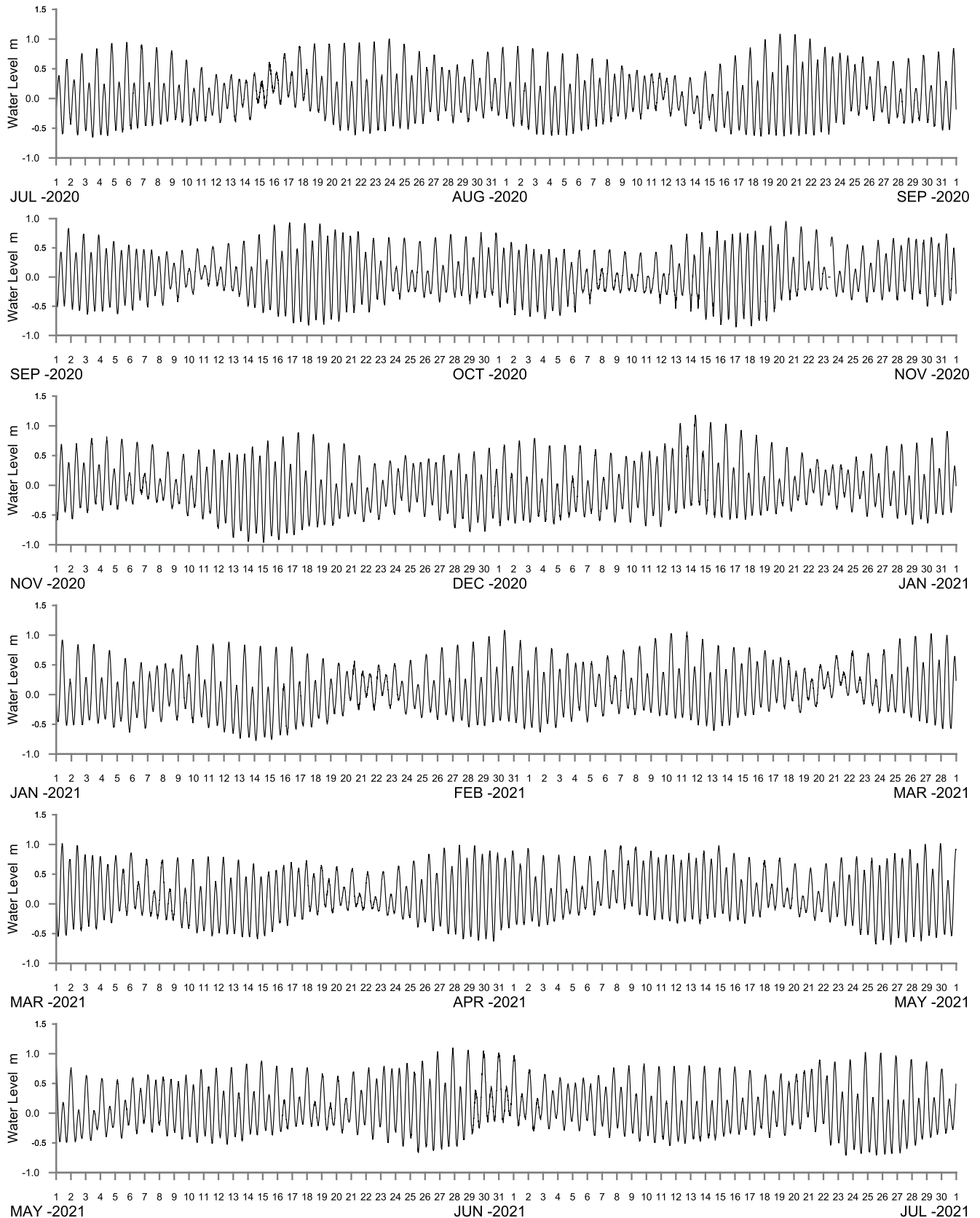
BRUNSWICK HEADS DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A3

DRAWING 2856-A3.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



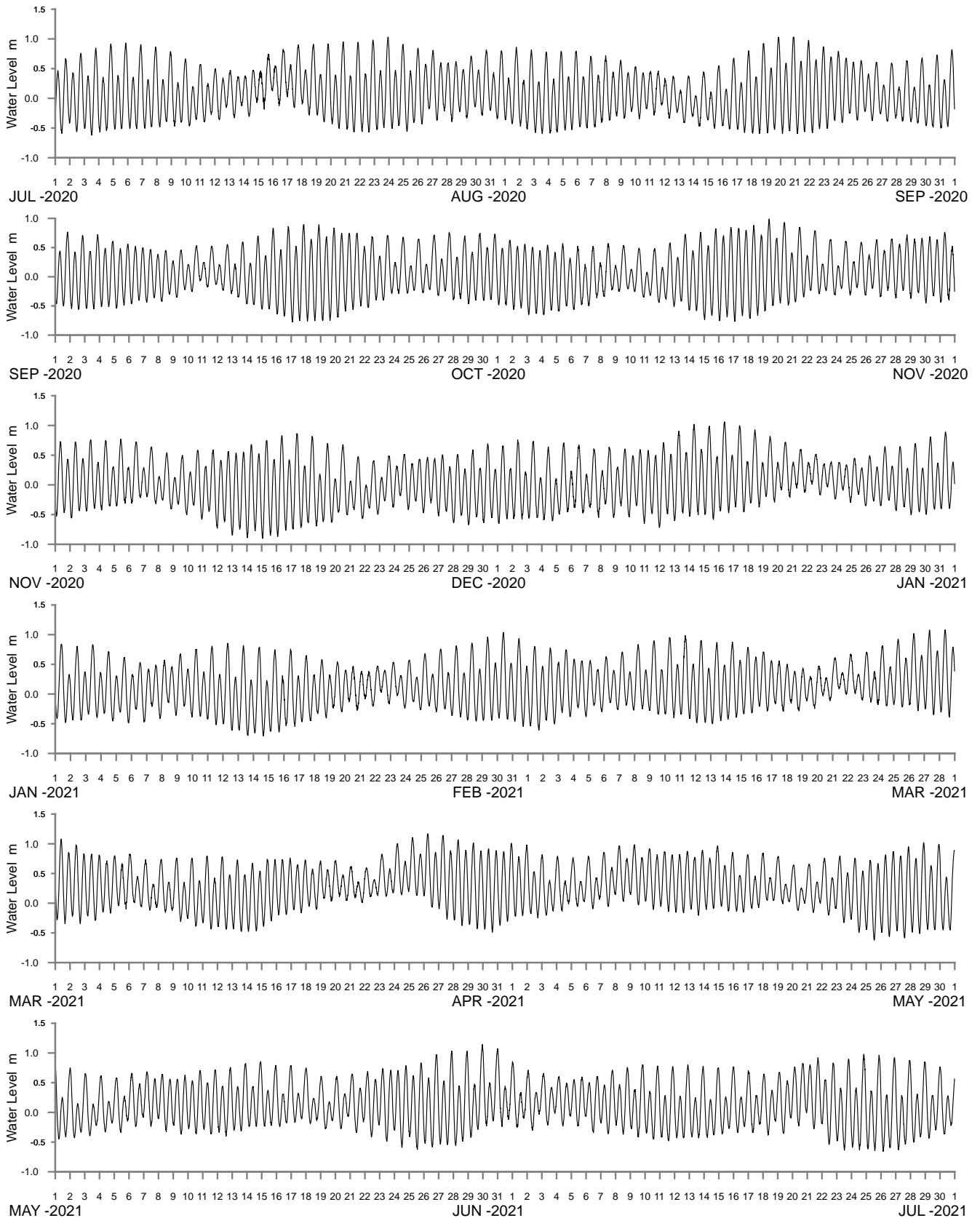
**BALLINA BREAKWALL DATA SUMMARY**  
2020–2021

**Manly  
Hydraulics  
Laboratory**

Report MHL2856

Figure  
A4

DRAWING 2856-A4.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



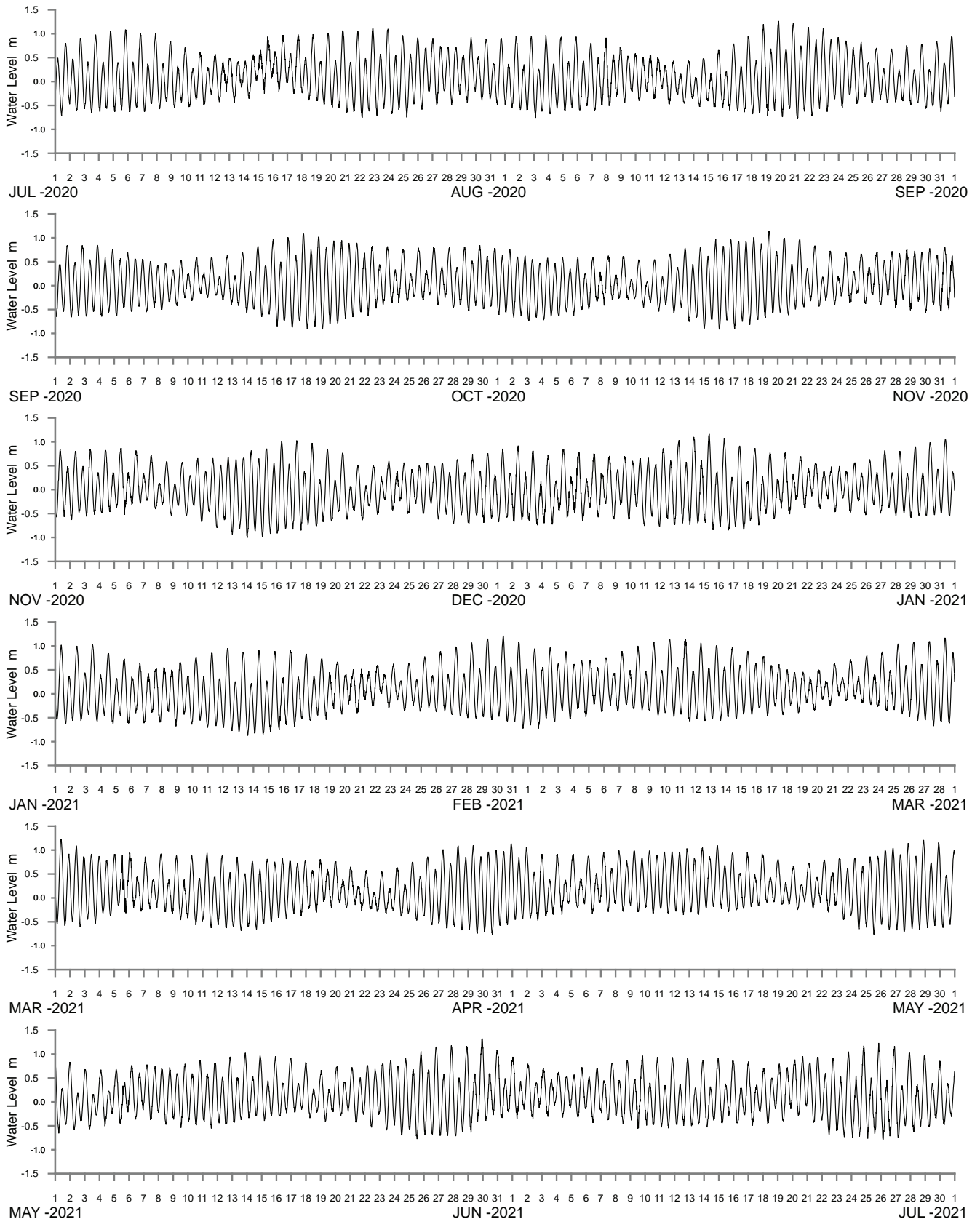
YAMBA DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A5

DRAWING 2856-A5.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



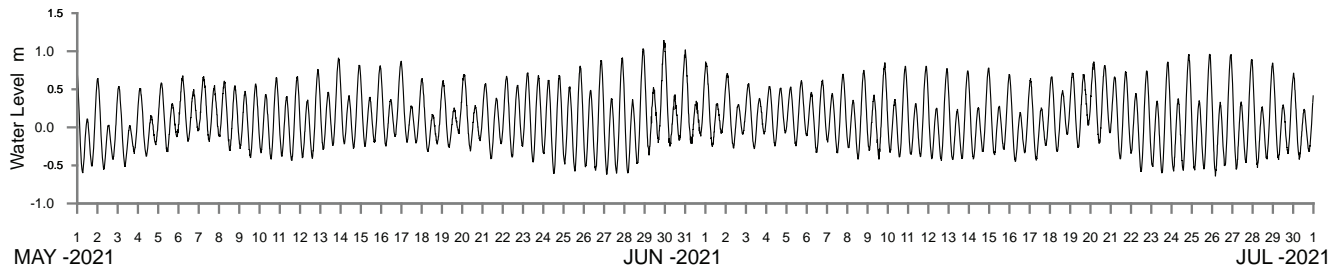
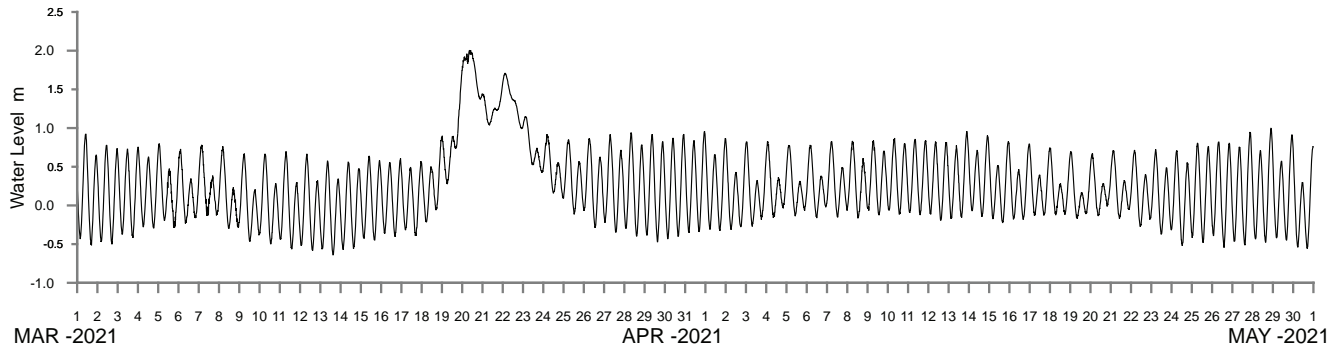
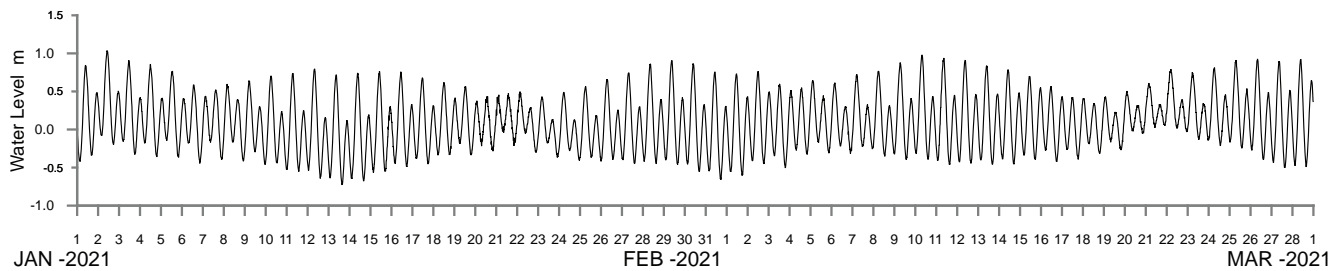
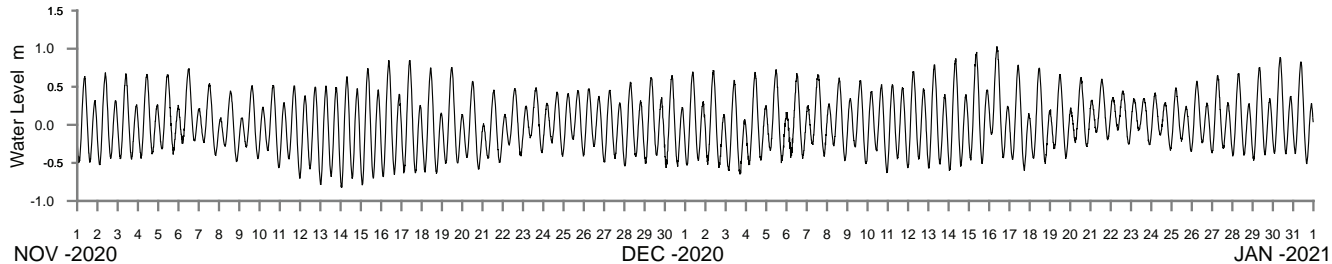
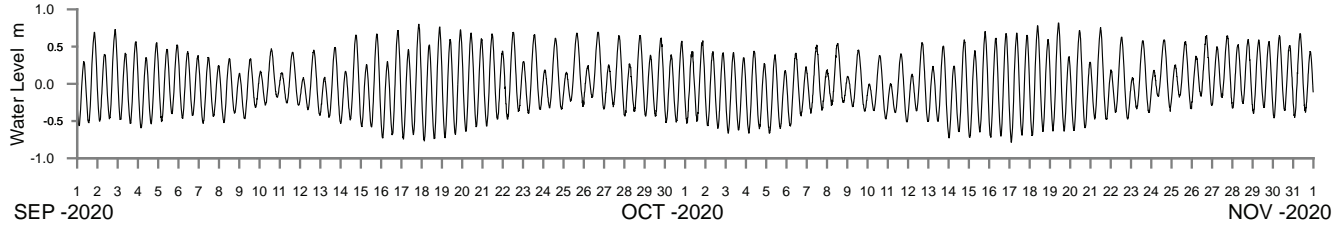
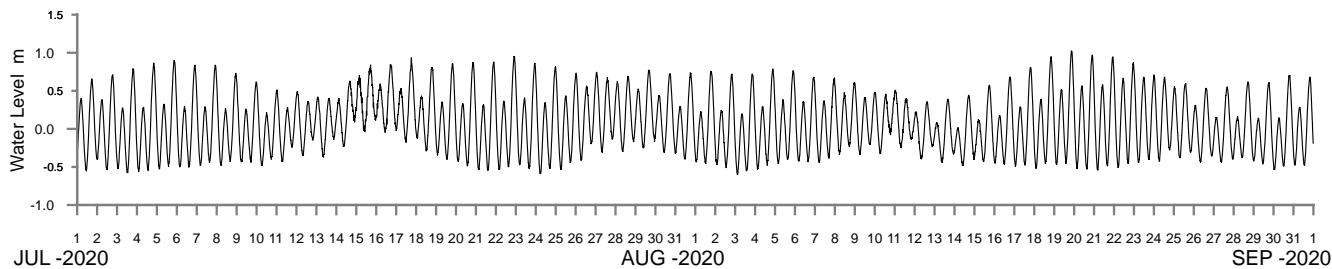
COFFS HARBOUR DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A6

DRAWING 2856-A6.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



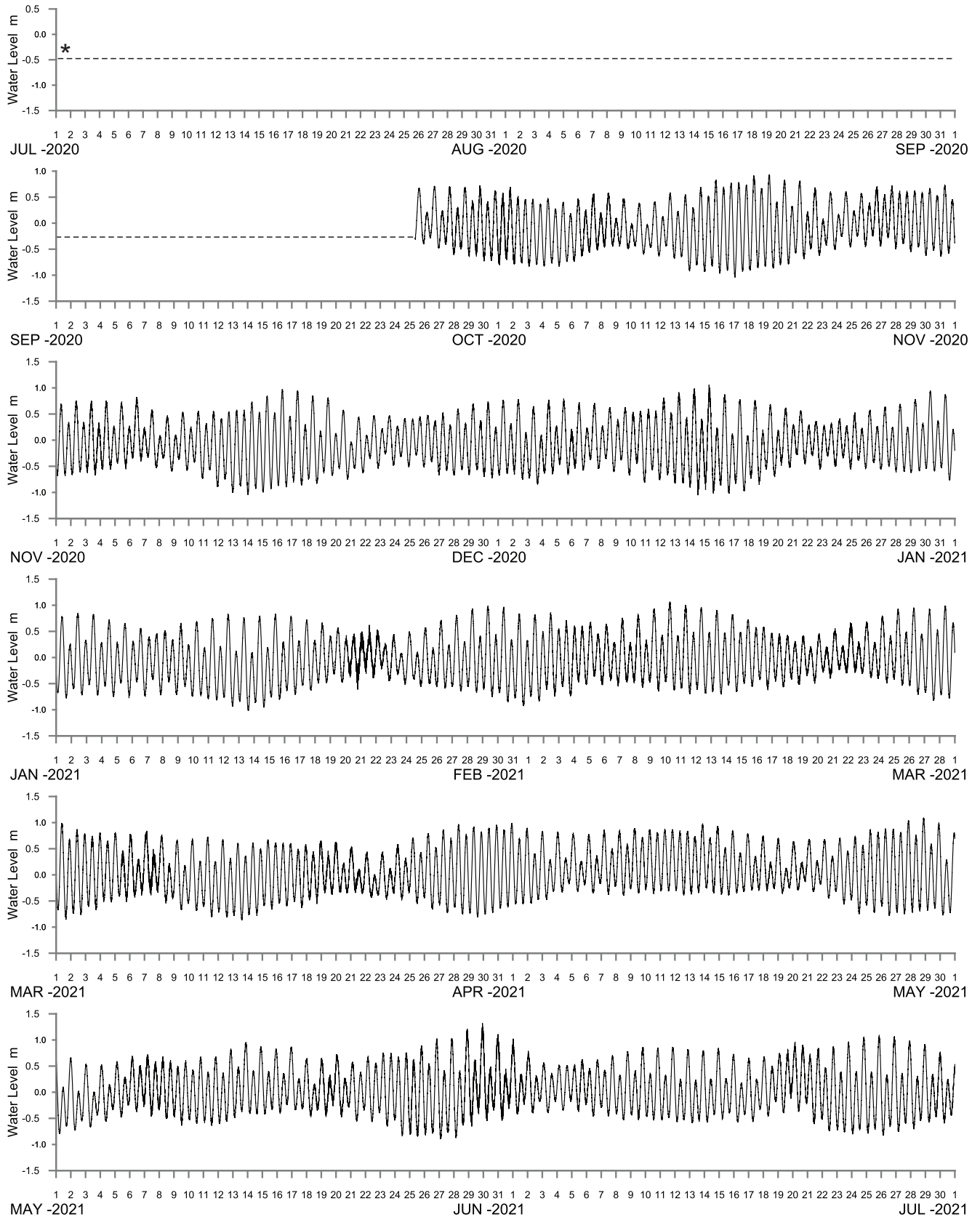
PORT MACQUARIE DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A7

DRAWING 2856-A7.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS

\*Data loss due to marine growth on the pressure sensor.



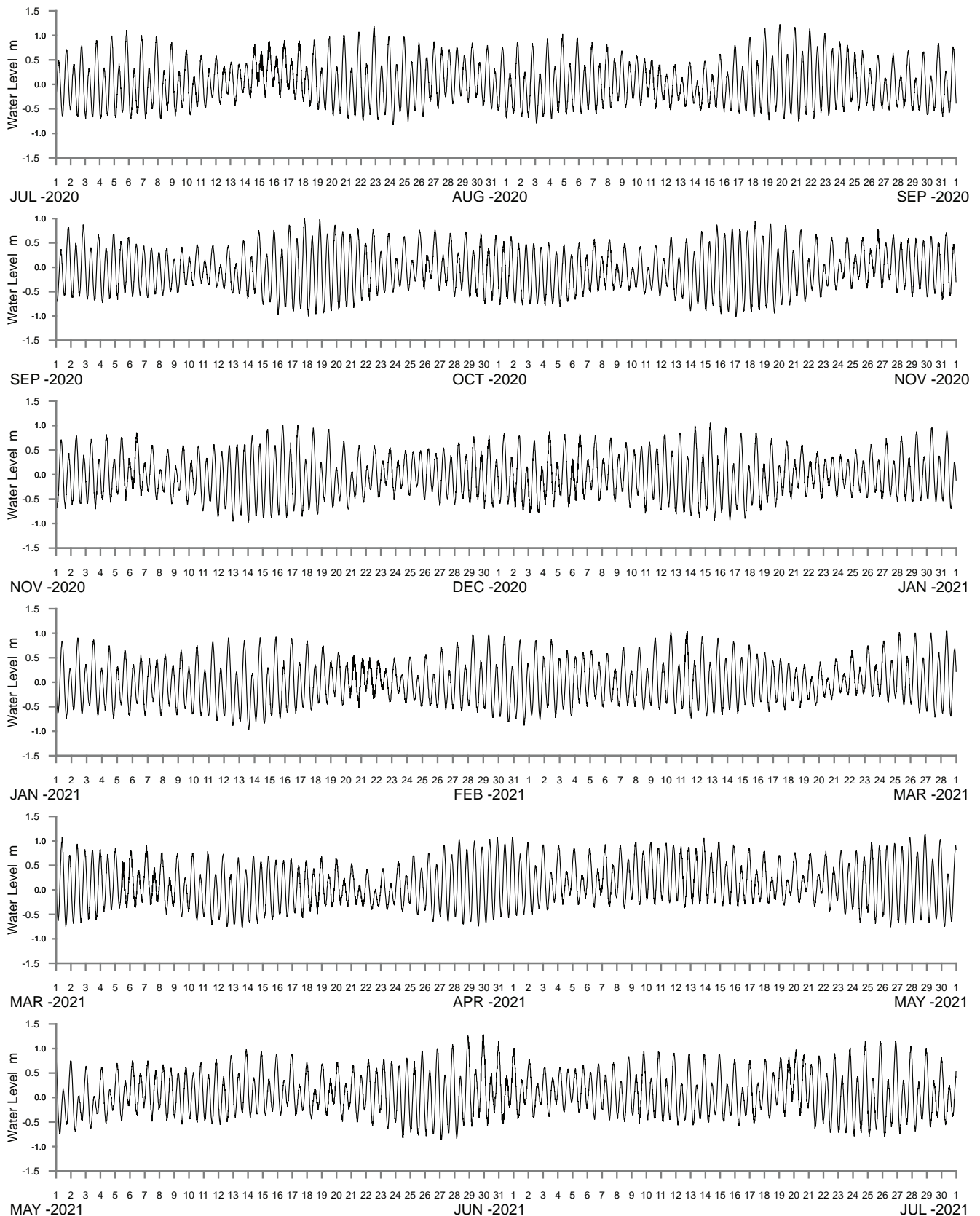
PORT MACQUARIE OFFSHORE DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A8

DRAWING 2856-A8.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



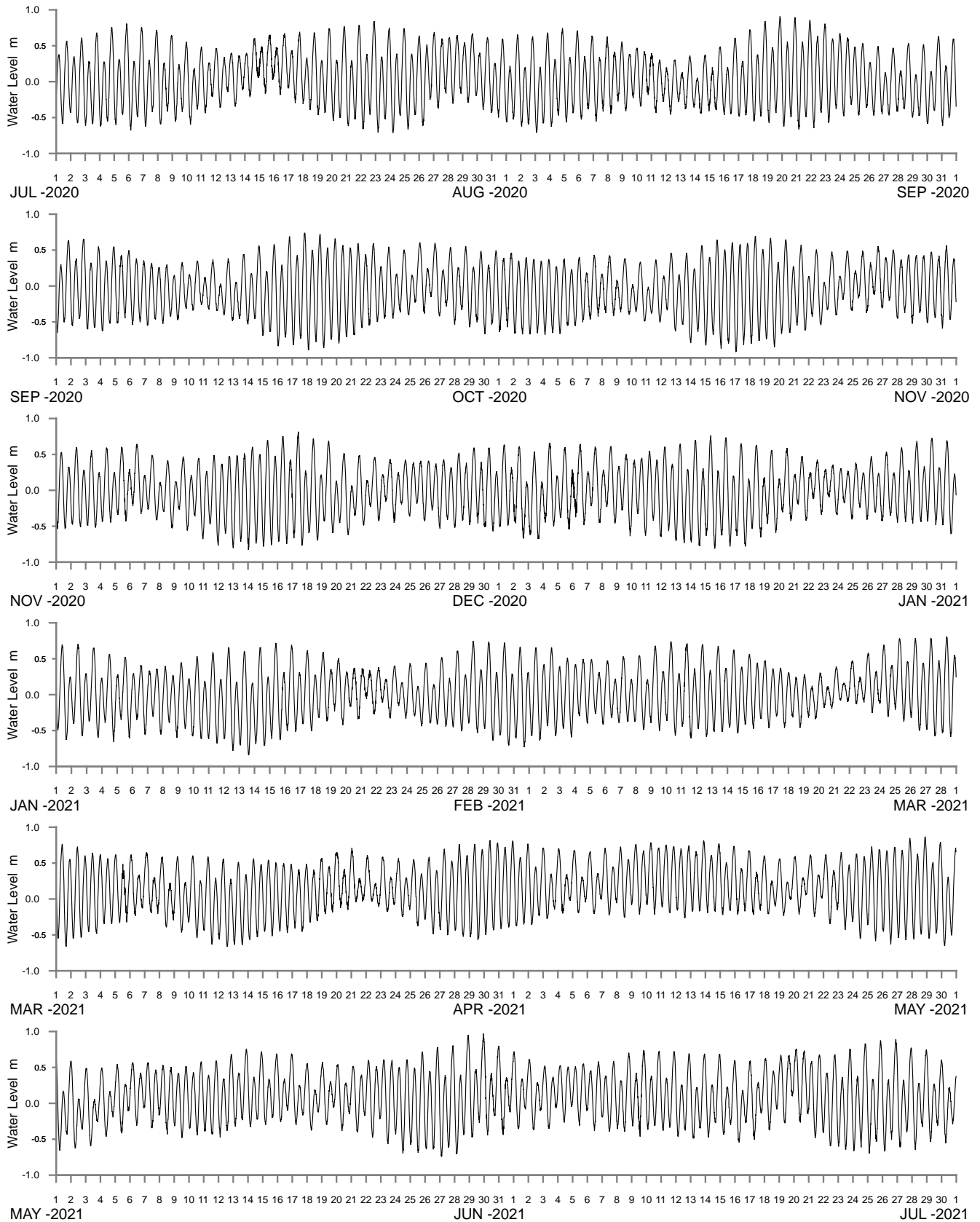
CROWDY HEAD DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A9

DRAWING 2856-A9.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



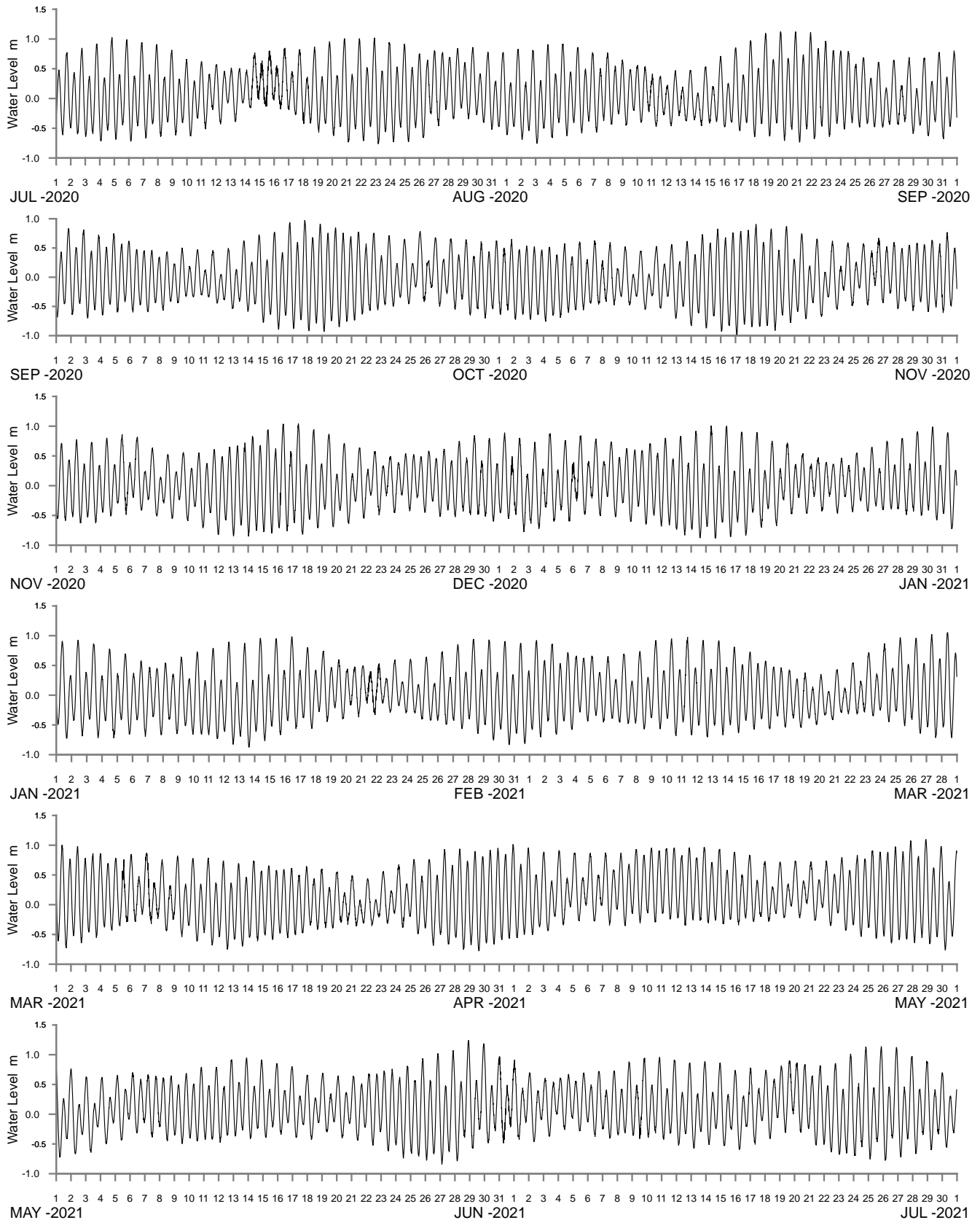
FORSTER DATA SUMMARY  
2020–20201

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A10

DRAWING 2856-A10.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



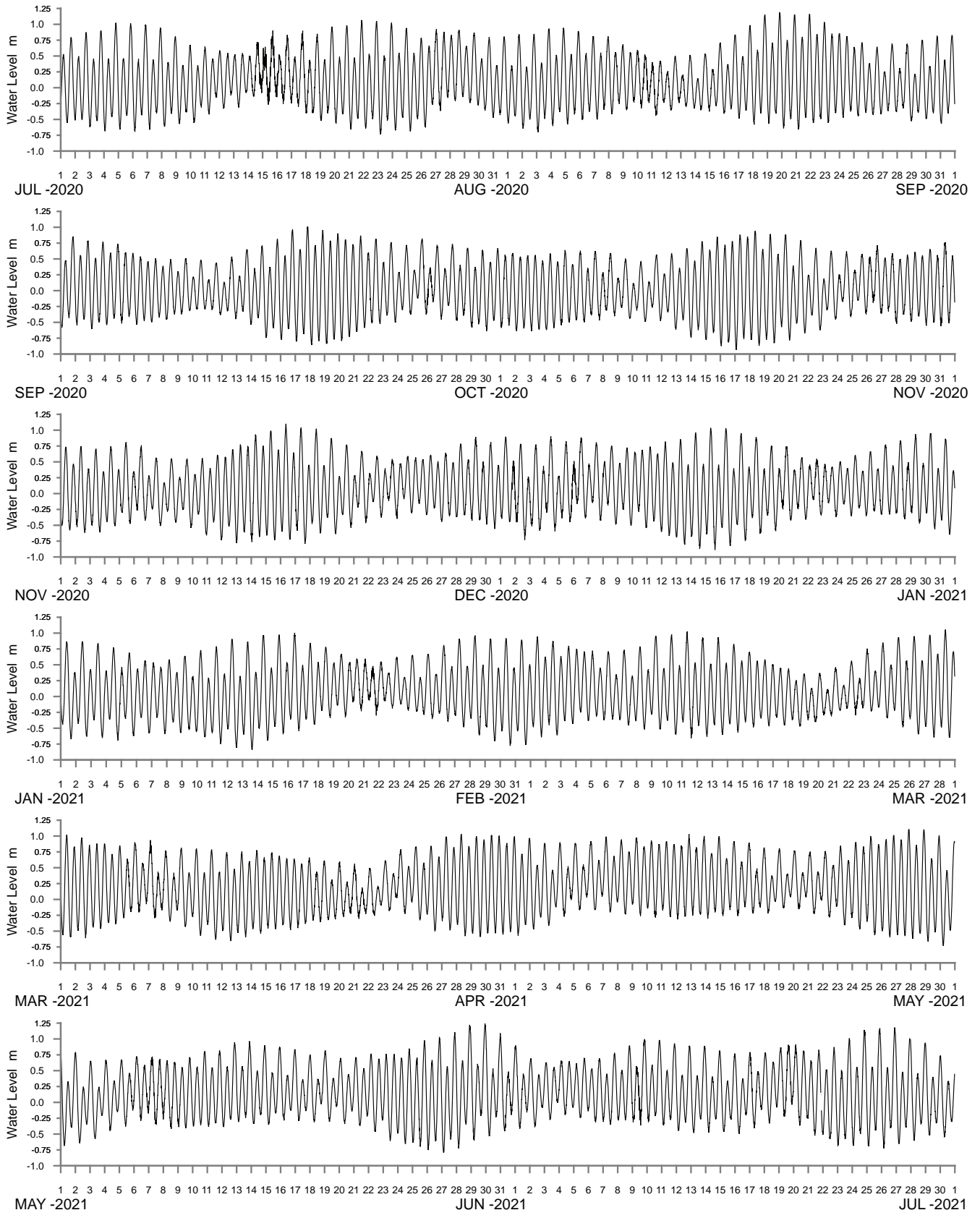
SHOAL BAY DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A11

DRAWING 2856-A11.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



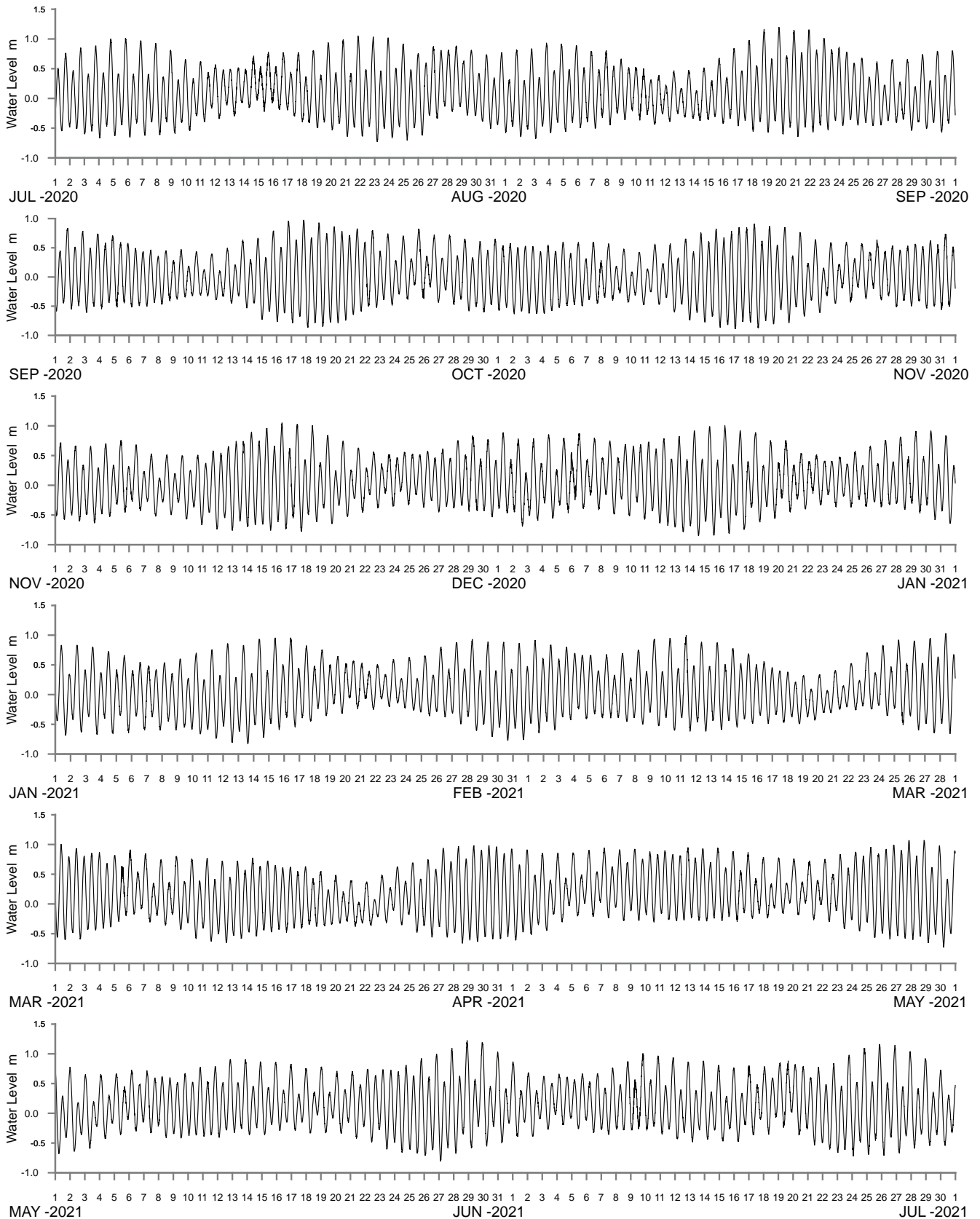
PATONGA DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A12

DRAWING 2856-A12.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



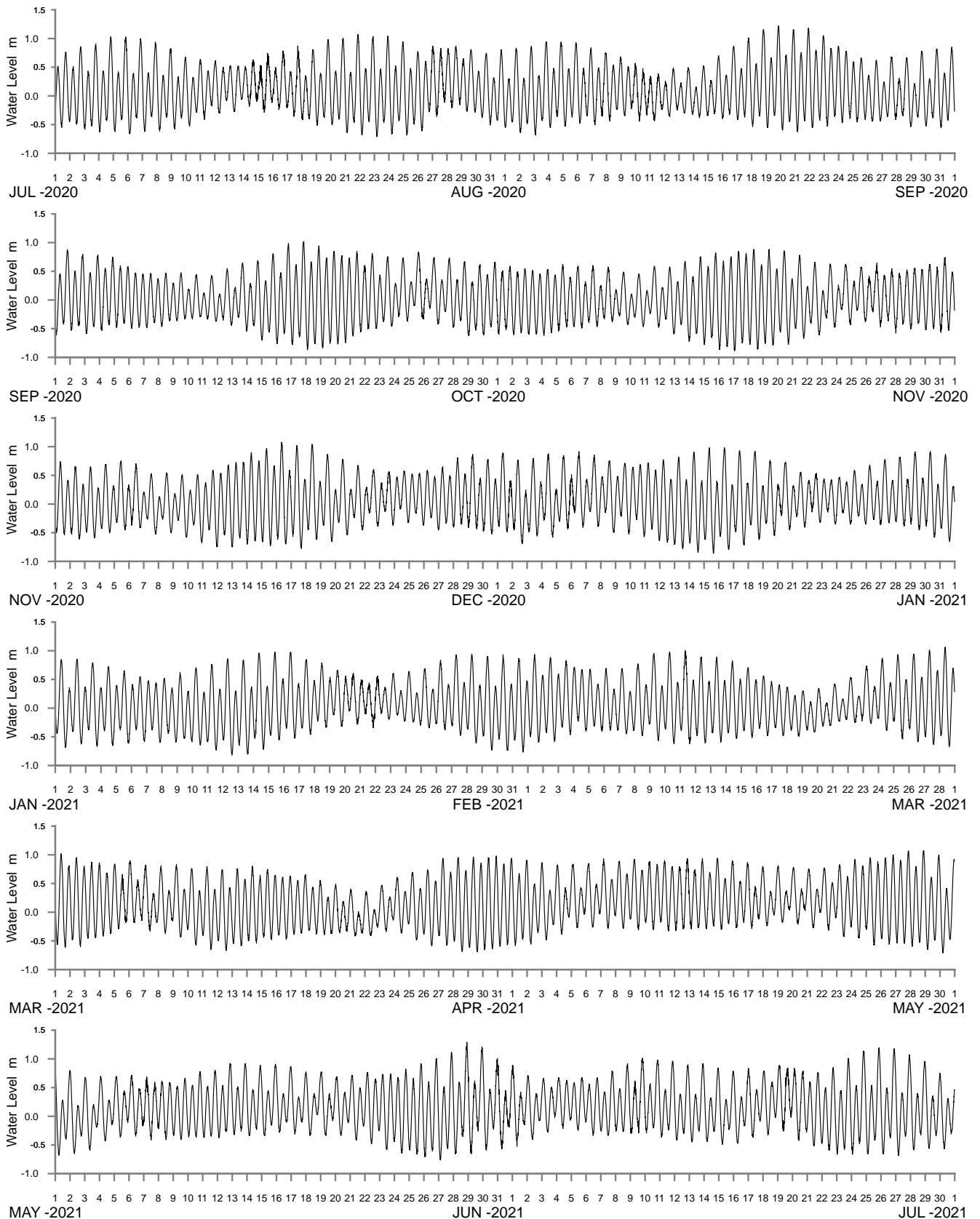
SYDNEY DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A13

DRAWING 2856-A13.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



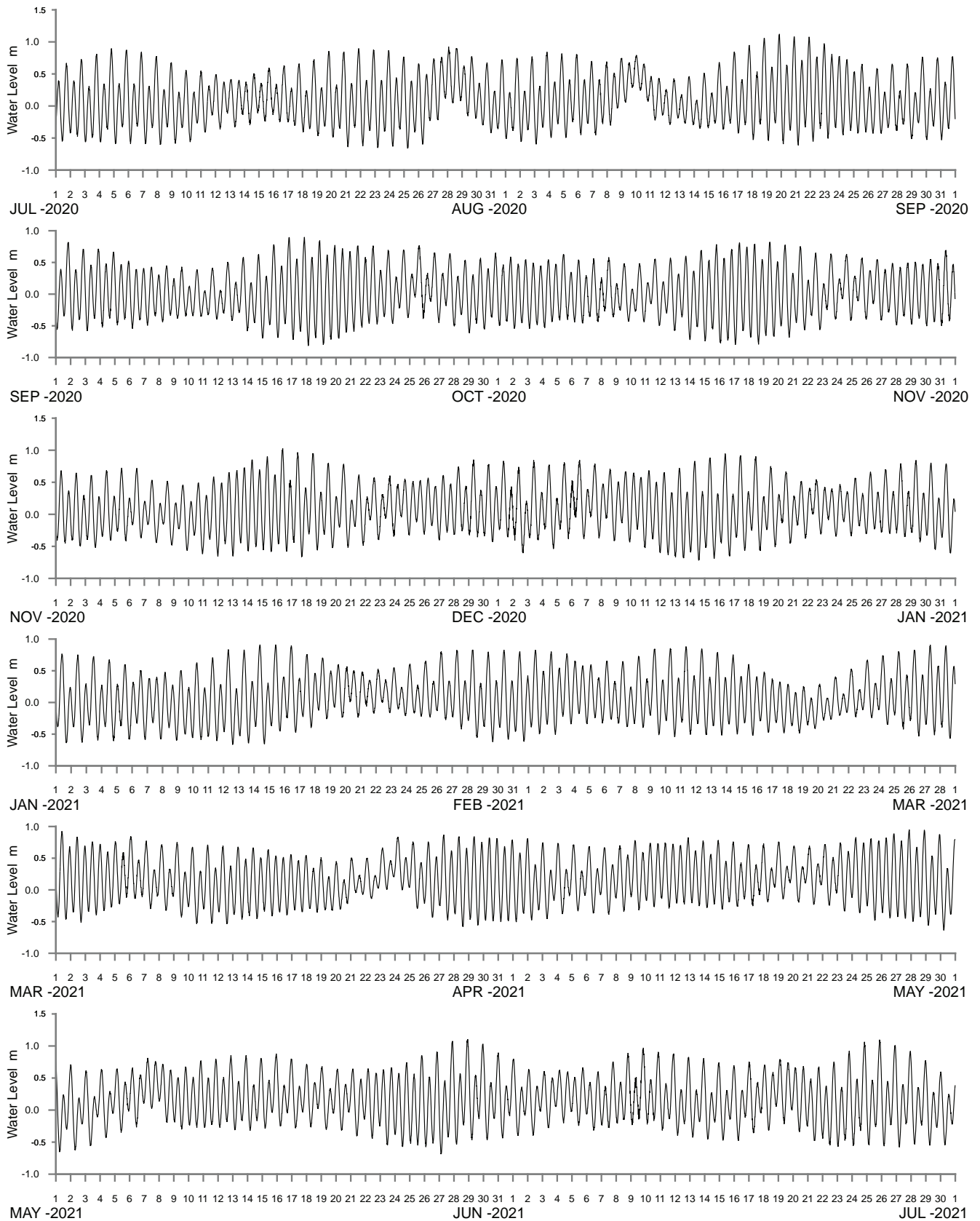
BUNDEENA DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A14

DRAWING 2856-A14.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



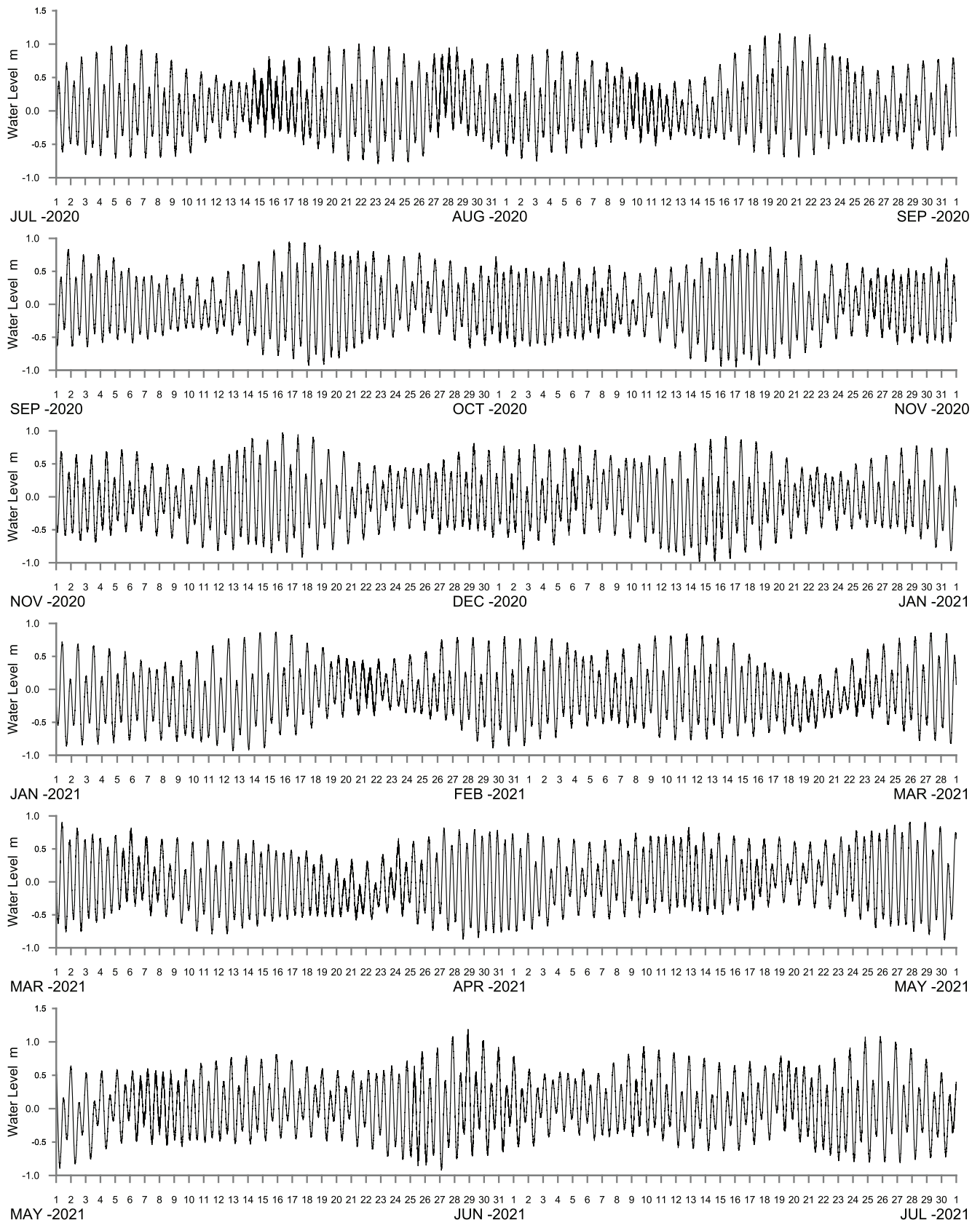
CROOKHAVEN HEADS DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A15

DRAWING 2856-A15.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



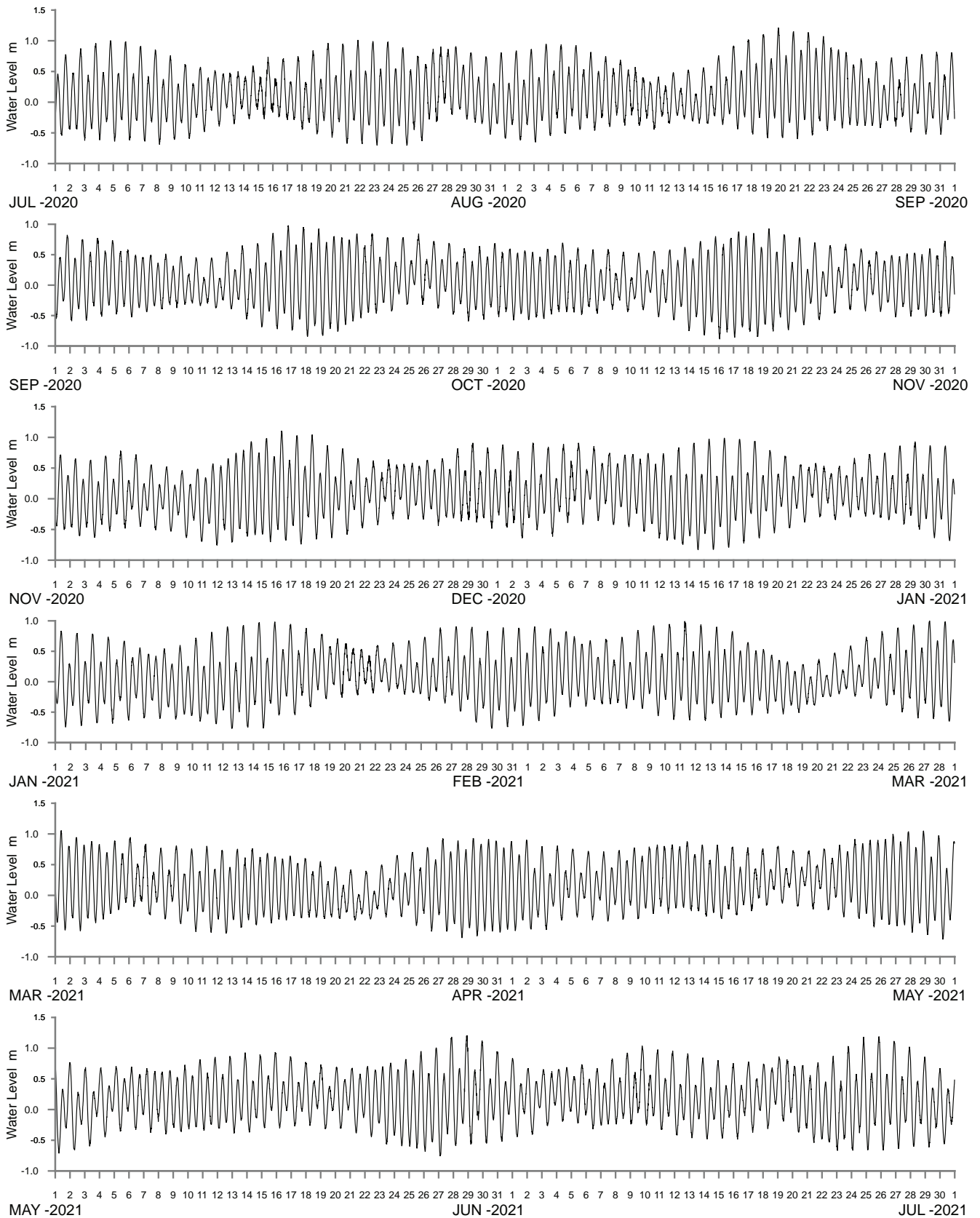
SHOALHAVEN OFFSHORE DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A16

DRAWING 2856-A16.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



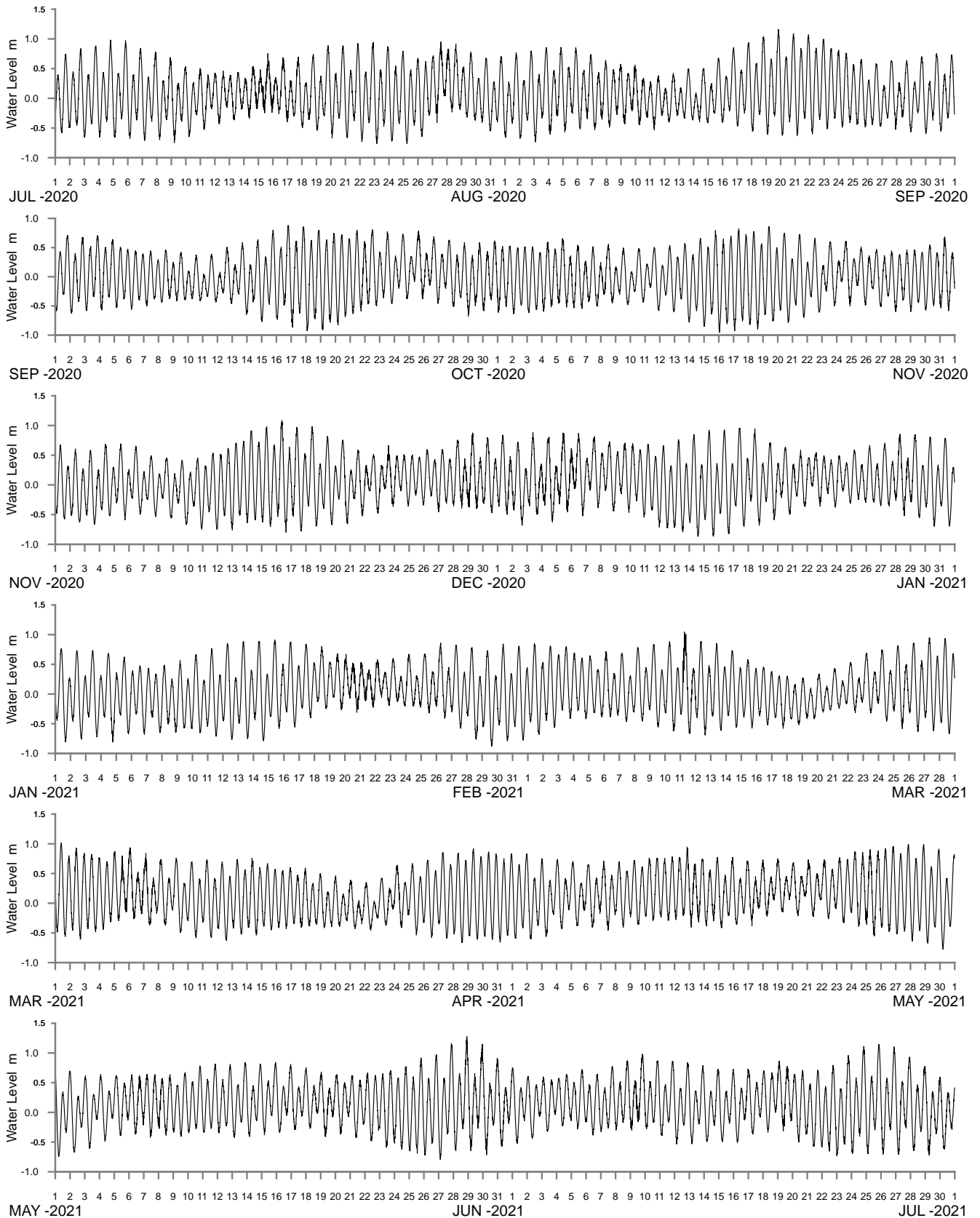
JERVIS BAY DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A17

DRAWING 2856-A17.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



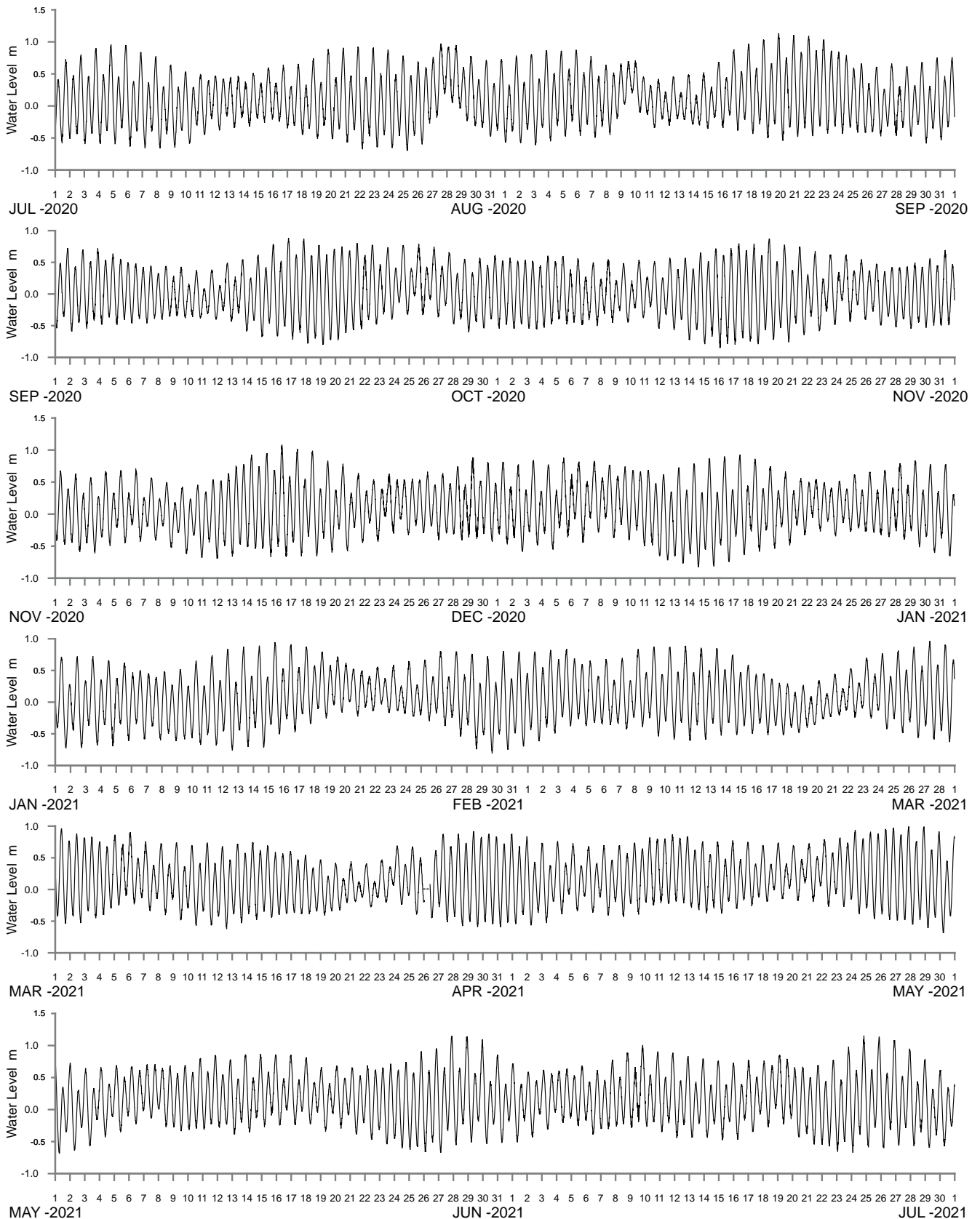
ULLADULLA DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A18

DRAWING 2856-A18.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



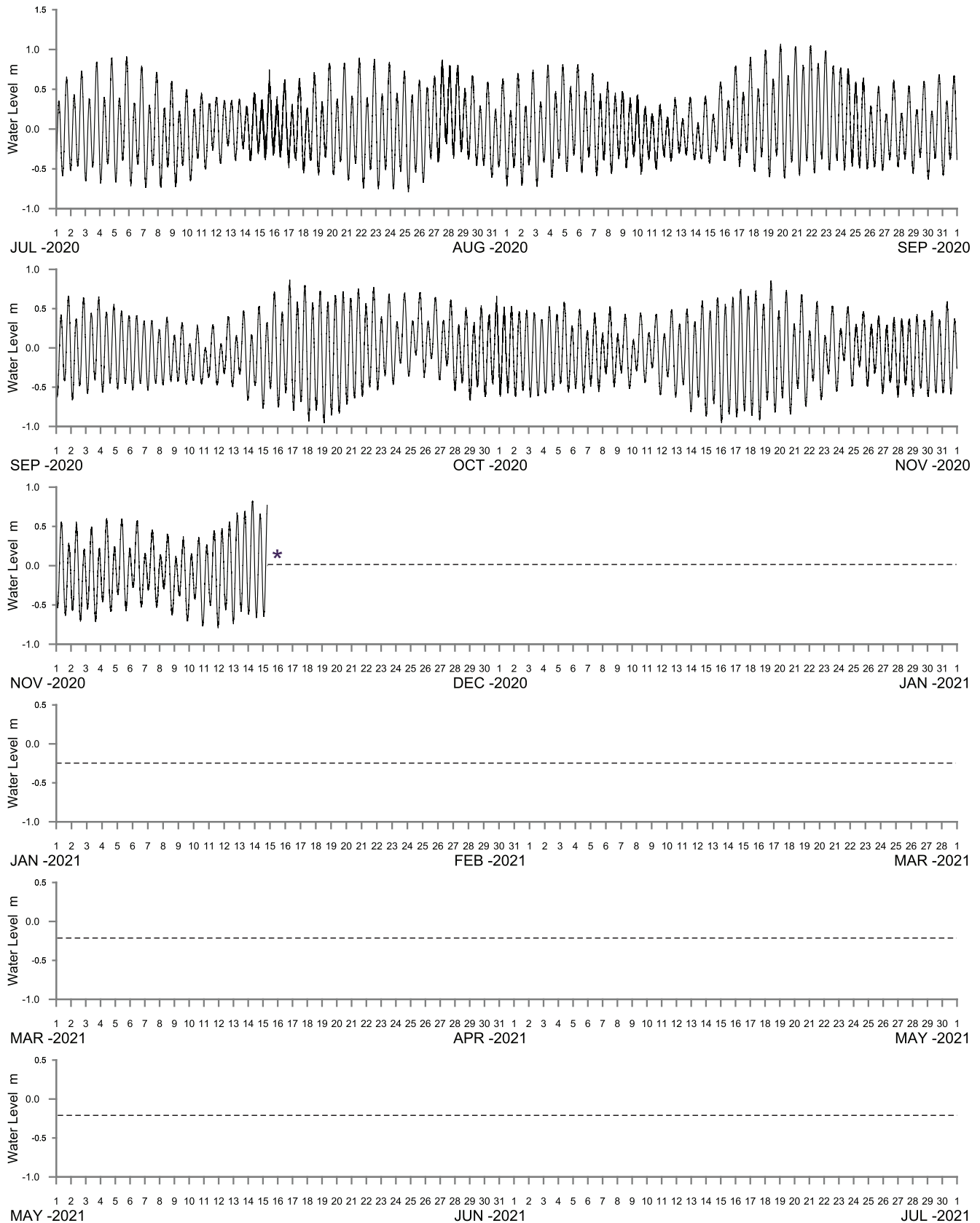
PRINCESS JETTY DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A19

DRAWING 2856-A19.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS

\*Data loss due to battery failure. No backup instrument available during this deployment period.



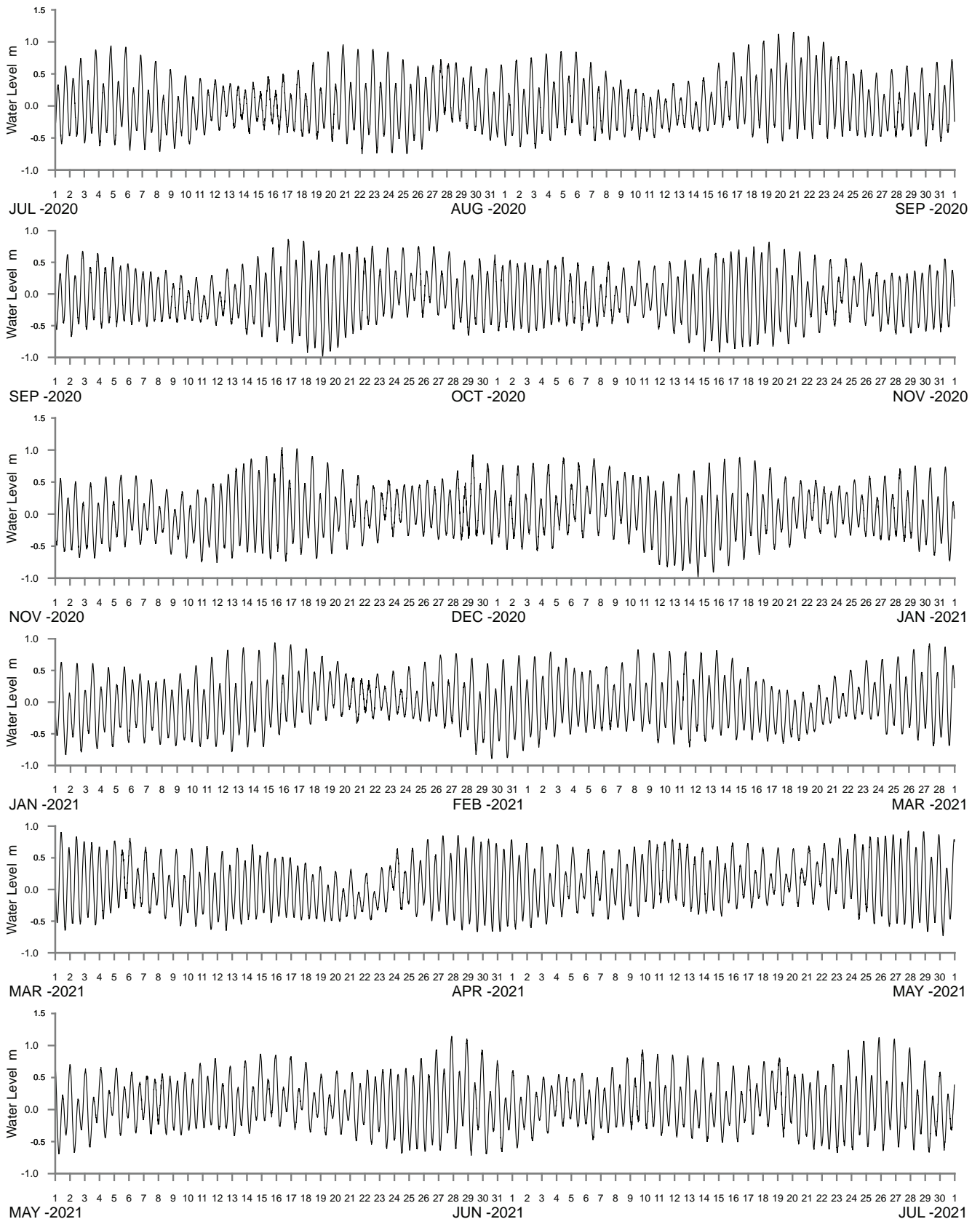
BATEMANS BAY OFFSHORE DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A20

DRAWING 2856-A20.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



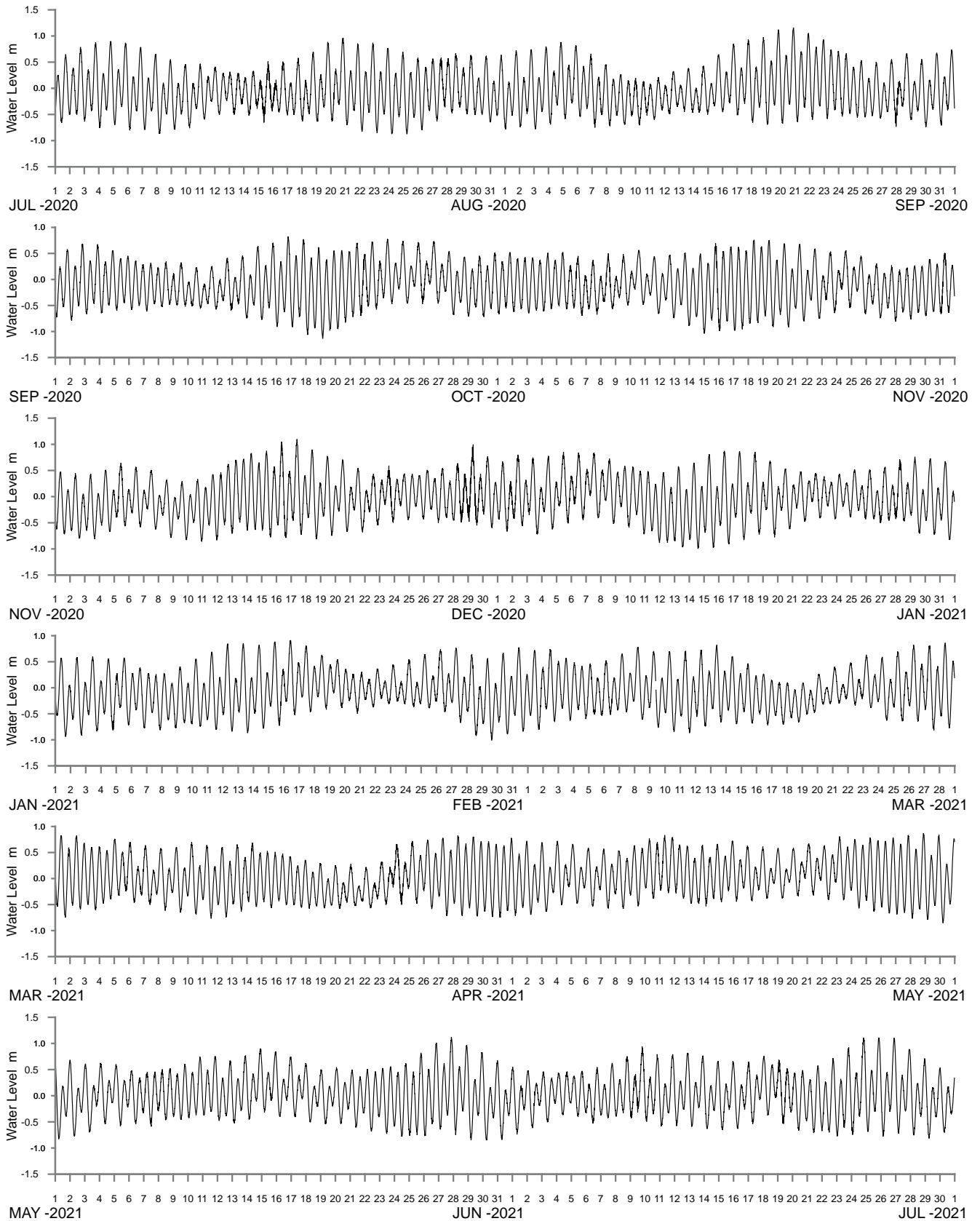
BERMAGUI DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A21

DRAWING 2856-A21.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

----- DATA LOSS



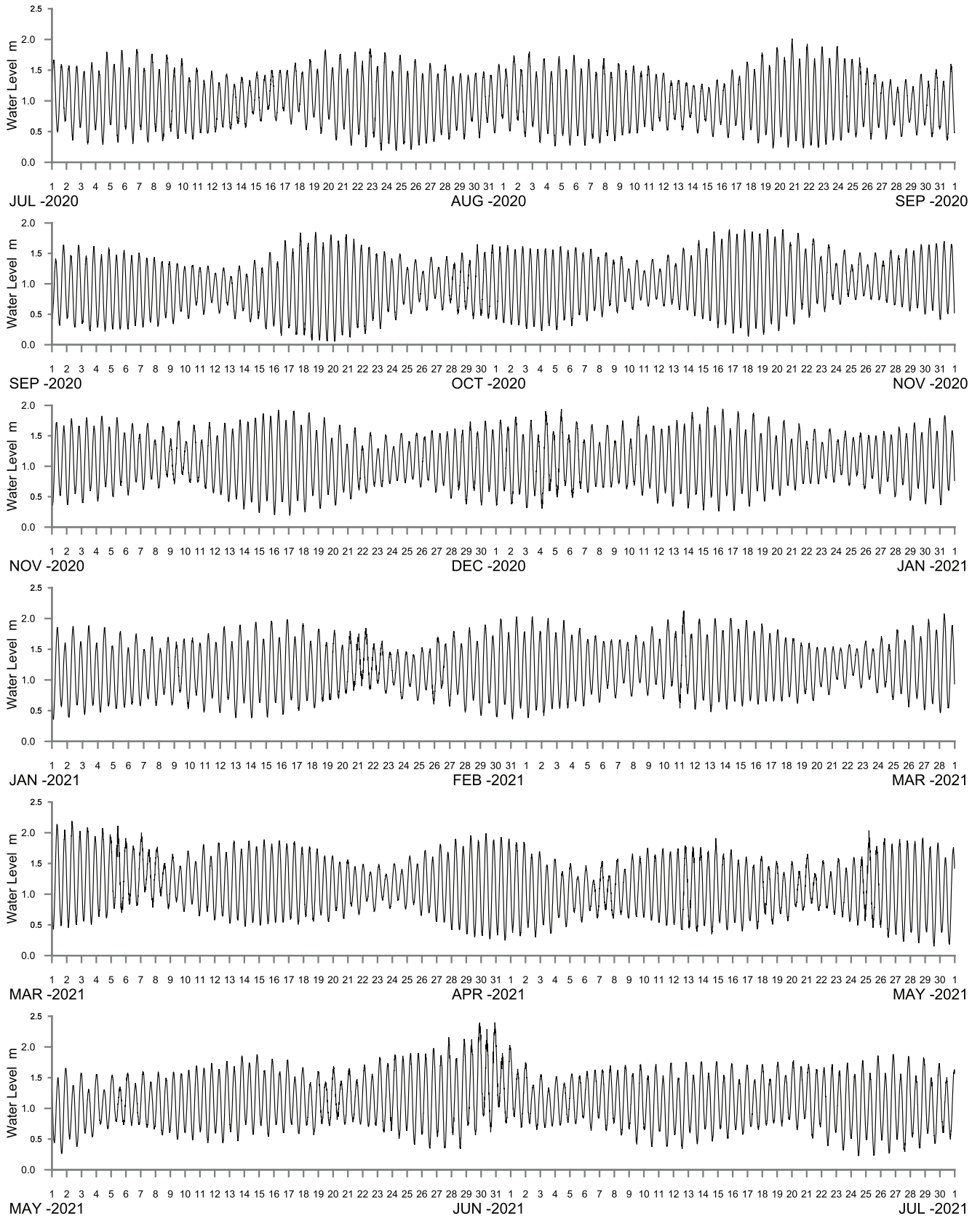
EDEN BOAT HARBOUR DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A22

DRAWING 2856-A22.cdr



WATER LEVEL REFERENCED TO LOWEST ASTRONOMICAL TIDE

----- DATA LOSS

Data provided courtesy of Bureau of Meteorology's National Tidal Unit



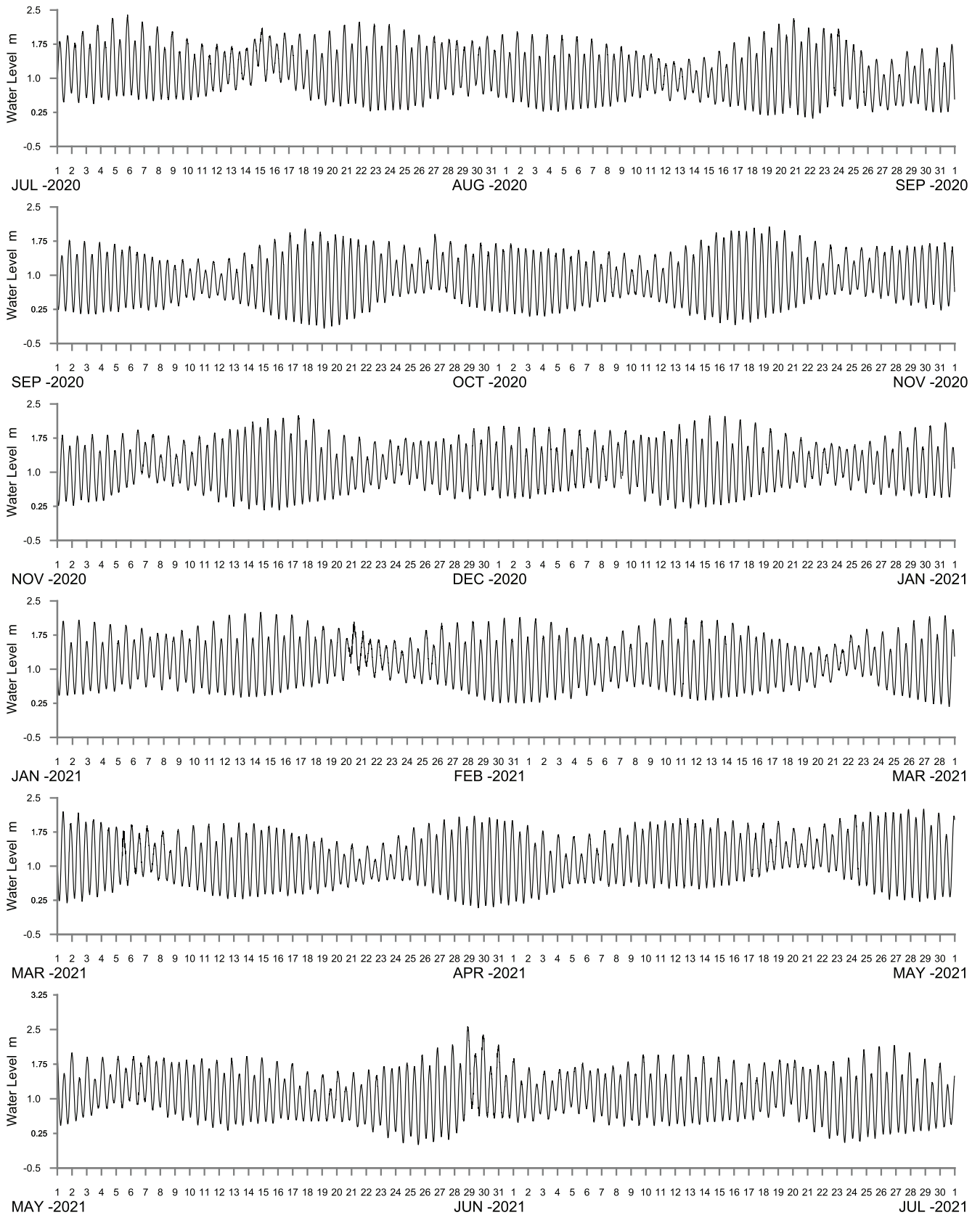
NORFOLK ISLAND DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
A23

DRAWING 2856-A23.cdr



WATER LEVEL REFERENCED TO LORD HOWE ISLAND TIDAL DATUM

----- DATA LOSS



LORD HOWE ISLAND DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

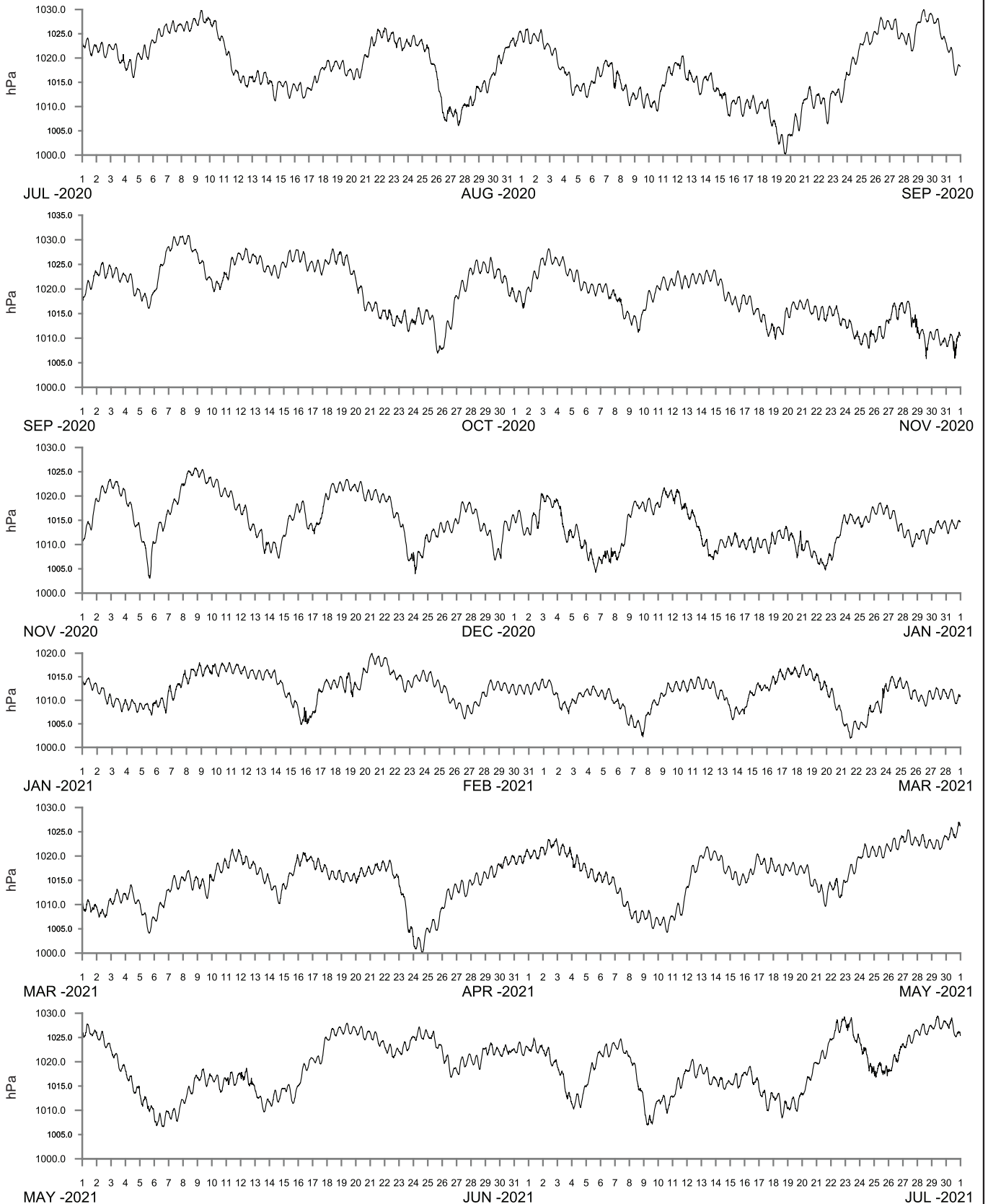
Report MHL2856

Figure  
A24

DRAWING 2856-A24.cdr

# Appendix B Annual barometric data station summaries

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BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



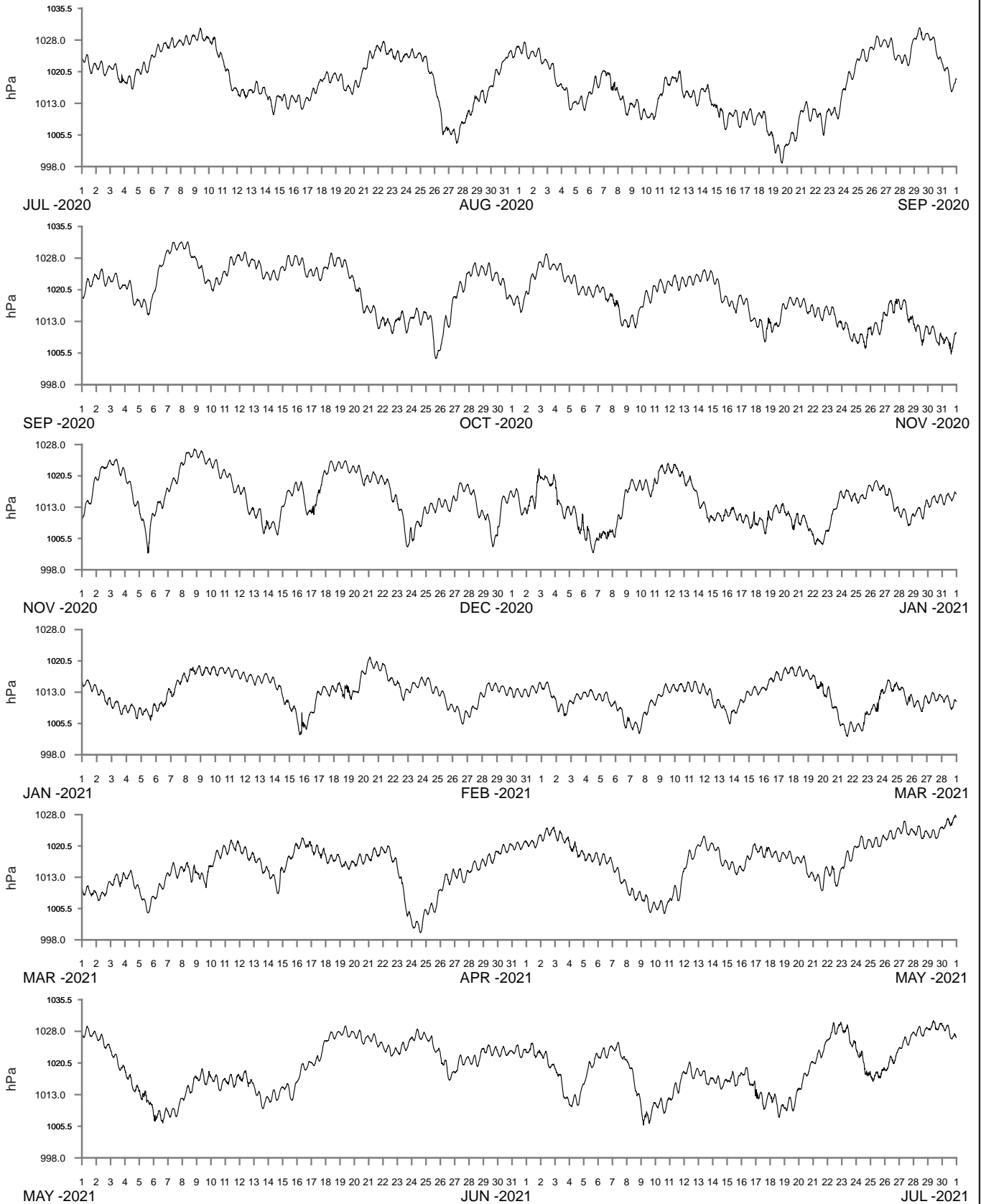
KINGSCLIFF DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
B1

DRAWING 2856-B1.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



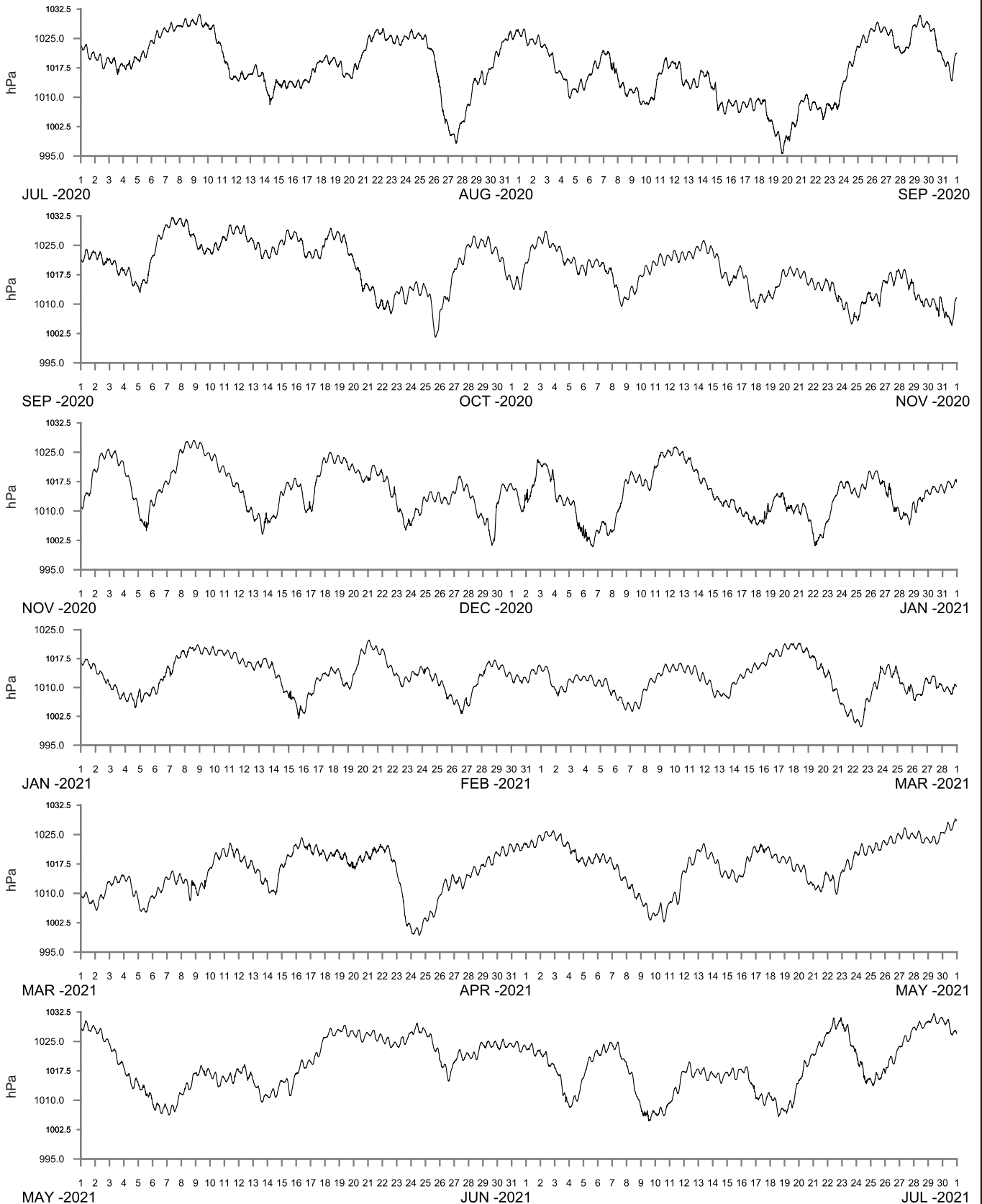
LAKE WOLOWEYAH DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
B2

DRAWING 2856-B2.cdr



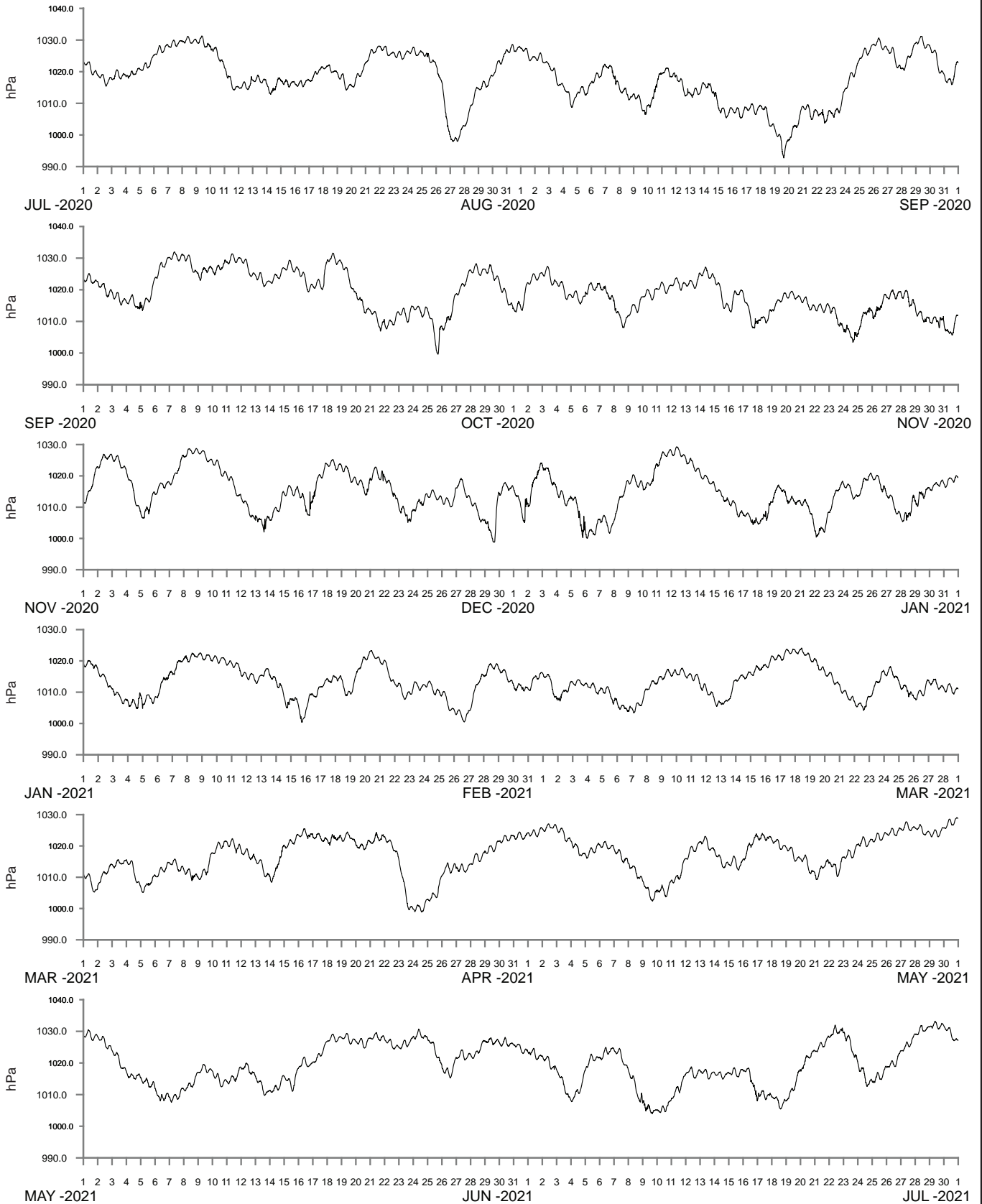
SETTLEMENT POINT DATA SUMMARY  
 2020-2021

Manly  
 Hydraulics  
 Laboratory

Report MHL2856

Figure  
 B3

DRAWING 2856-B3.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



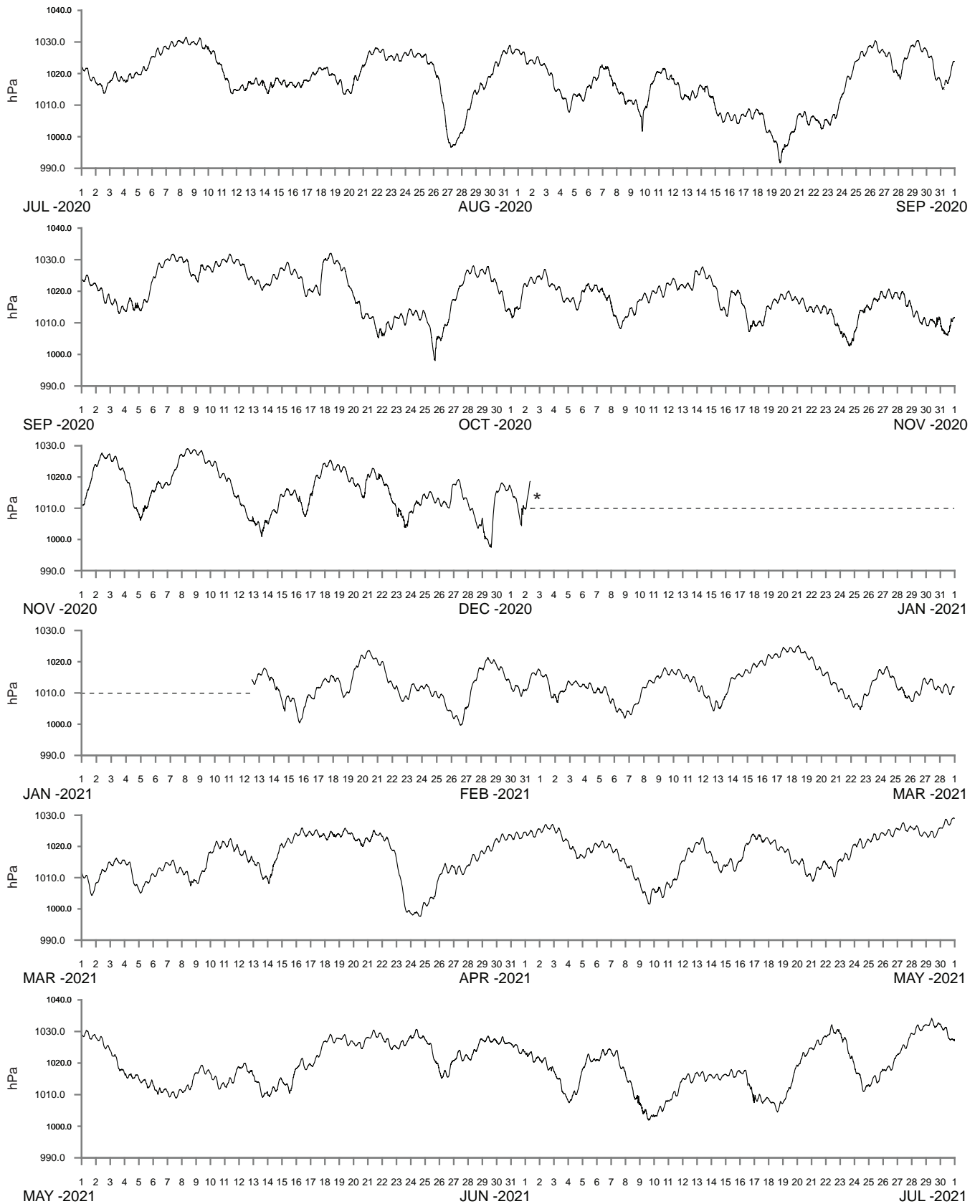
STOCKTON BRIDGE DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
B4

DRAWING 2856-B4.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS

\*Data loss due to loose connection wire between barometer and logger.



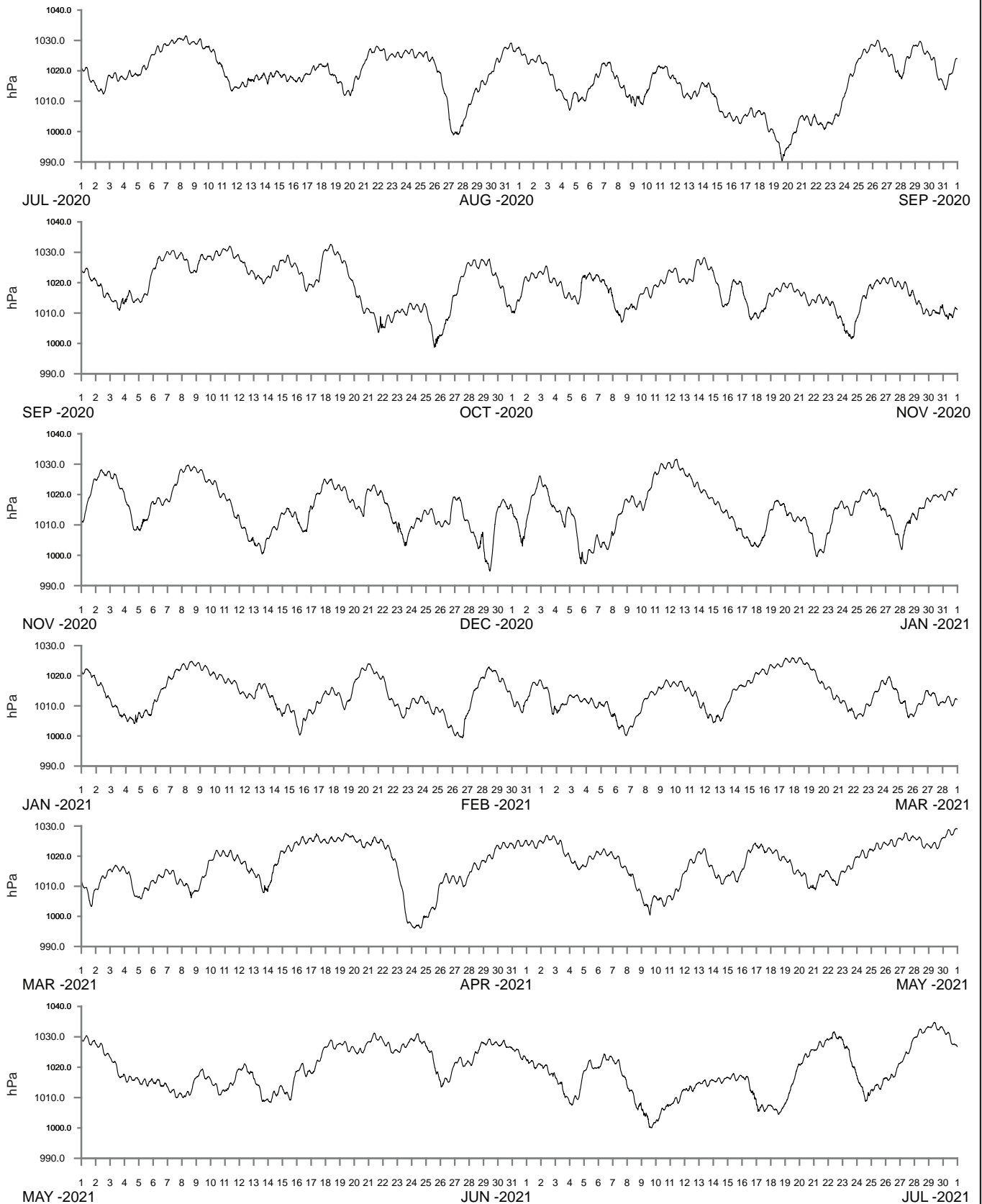
NARRABEEN BRIDGE DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
B5

DRAWING 2856-B5.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



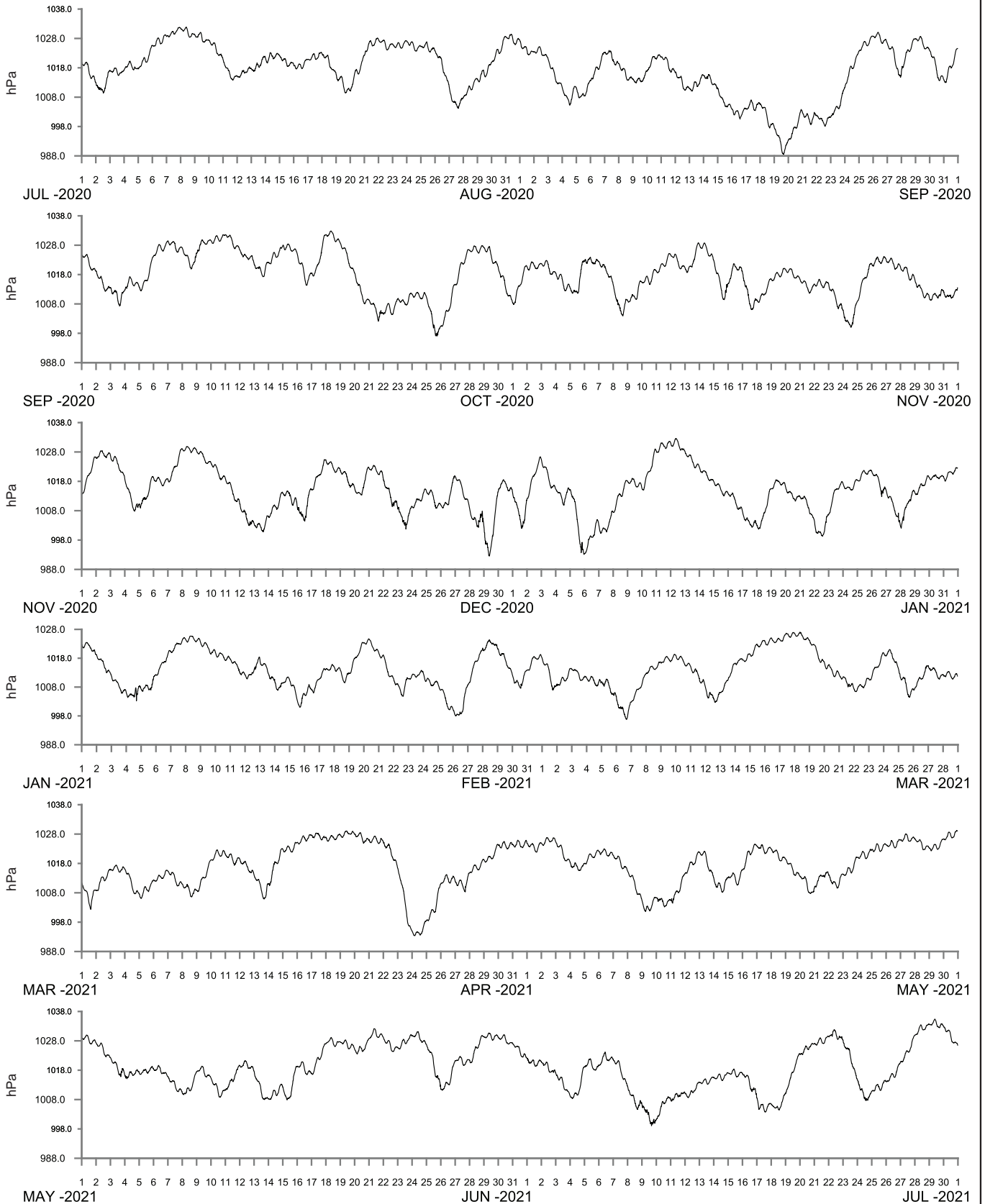
CURRARONG CREEK DATA SUMMARY  
2020–2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
B6

DRAWING 2856-B6.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



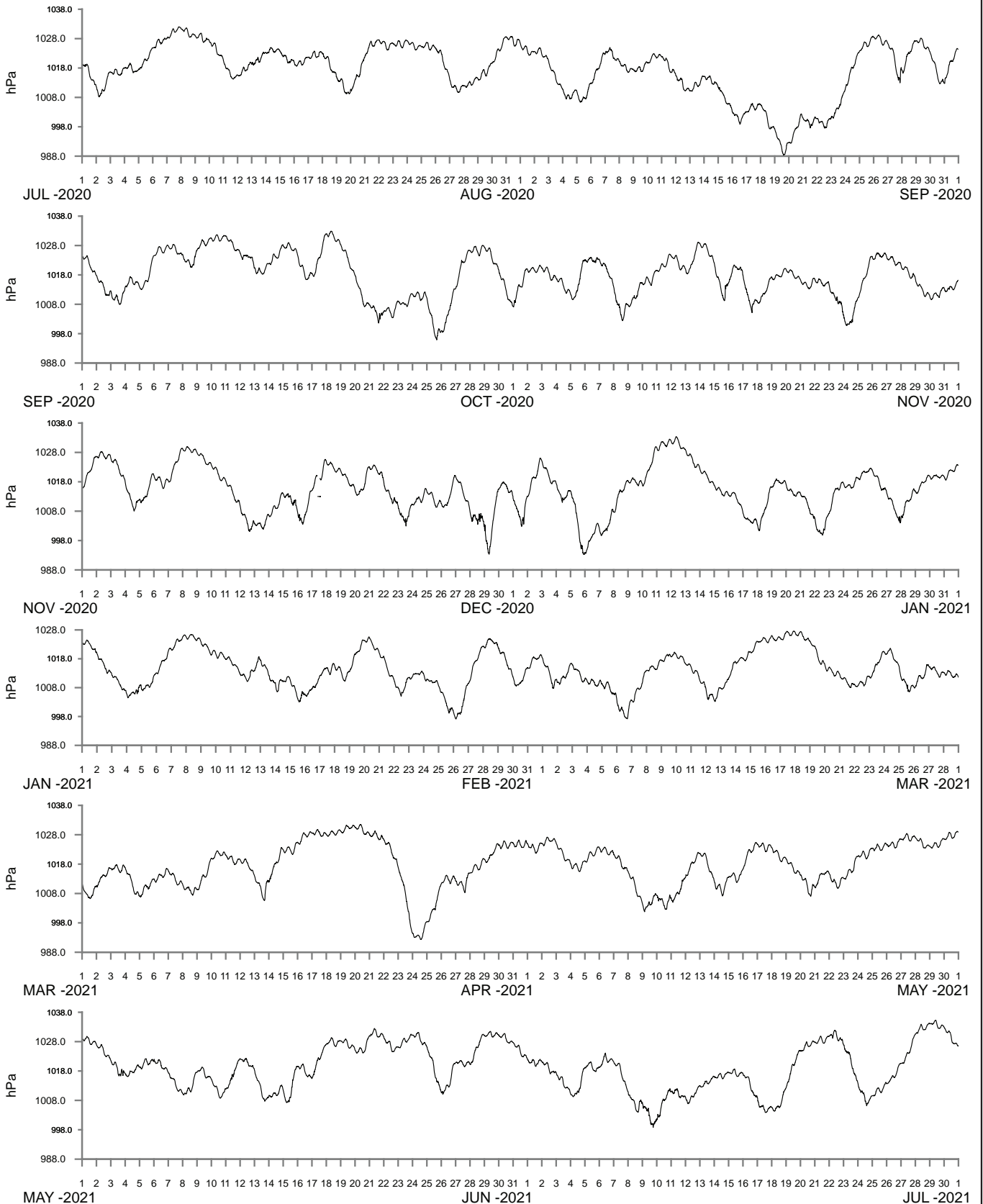
TUROSS HEAD DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
B7

DRAWING 2856-B7.cdr



BAROMETRIC PRESSURE REFERENCED TO MEAN SEA LEVEL

----- DATA LOSS



WONBOYN LAKE DATA SUMMARY  
2020-2021

Manly  
Hydraulics  
Laboratory

Report MHL2856

Figure  
B8

DRAWING 2856-B8.cdr

## Appendix C Current tidal station data

**Table C1 Current station digital data**

NSW coastal region	Catchment, river or port	Station name	Location	Period of data
North	Tweed River	Tweed Entrance South	South Breakwater	May 2014–ongoing
North	Tasman Sea	Tweed Offshore <sup>1</sup>	Offshore	Dec 1982–ongoing
North	Brunswick River	Brunswick Heads	South Breakwater	Mar 1986–ongoing
North	Richmond River	Ballina Breakwall	South Breakwater	Dec 2008–ongoing
North	Clarence River	Yamba	South Breakwater	Jul 1986–ongoing
North	Coffs Harbour	Coffs Harbour <sup>1</sup>	Inner Harbour Pumpout Jetty	Aug 1996–ongoing
Mid North	Hastings River	Port Macquarie	South Breakwater	Mar 1986–ongoing
Mid North	Tasman Sea	Port Macquarie Offshore <sup>1</sup>	Offshore	Dec 1984–ongoing
Mid North	Crowdy Head Harbour	Crowdy Head <sup>1</sup>	Fishermans Wharf	Jul 1986–ongoing
Mid North	Wallis Lake	Forster	North Breakwater	Jul 1986–ongoing
Central	Port Stephens	Shoal Bay	Public Wharf	Apr 2014–ongoing
Central	Hawkesbury River	Patonga	Public Wharf	Jun 1992–ongoing
Central	Sydney Port Jackson	Sydney	HMAS Penguin Wharf	Sep 1987–ongoing
Central	Sydney Port Jackson	Sydney Backup	HMAS Penguin Wharf	Aug 2010 - ongoing
Central	Port Hacking	Bundeena	Public Wharf	Dec 2014-ongoing
Central	Crookhaven River	Crookhaven Heads	Upstream of Entrance	Mar 1992–ongoing
Central	Tasman Sea	Shoalhaven Offshore	Offshore	Sep 2005–ongoing
Central	Jervis Bay	Jervis Bay	HMAS Creswell	Sep 1989–ongoing
South	Ulladulla Harbour	Ulladulla	Wharf in Harbour	Dec 2007–ongoing
South	Clyde River	Princess Jetty	Public Wharf	Dec 1985–ongoing
South	Tasman Sea	Batemans Bay Offshore	Snapper Island	Sep 2000–ongoing
South	Bermagui River	Bermagui	Inner Harbour	Mar 1987–ongoing
South	Twofold Bay	Eden	Working Jetty	Sep 1986–ongoing
North Tasman Sea	Tasman Sea	Lord Howe Island	Main Wharf	Aug 1994–ongoing

<sup>1</sup> Station has changed location during data period

## Appendix D Historical tide data

**Table D1 Historical tide data**

Station Name	Location	Period of record	Location
Tweed Regional	North Breakwater	Feb 1987–Apr 2015	On line
Tweed Regional	Breakwater 201470	1978–1980	On line
Richmond River	Breakwater 202471	1889–1912	HiLos on line
Richmond River	Ballina	1959–1963	Microfiche MHL
Ballina 202470	Half Tide Breakwater	Apr 1986–May 2011	On line
Clarence River	Yamba	1900–1924	HiLos on line
Yamba Offshore	Yamba 204450	Jun 1987–Sep 2009	On line
Clarence River	Iluka 204437	1956–1961	On line
Clarence River	Breakwater	1957–1958	HiLos State Archives
Coffs Harbour	Main harbour	1966–68 and 1969–72	Microfiche MHL
Coffs Harbour	Main harbour	1972–1973	Microfiche MHL
Coffs Harbour	Main harbour	1951–52, 1961–64	HiLos State Archives
Coffs Harbour	Outer harbour 205470	1951–1996	On line
Coffs Harbour	Outer harbour	1953–56, 1957–60	Microfiche MHL
Coffs Harbour	Water Police Jetty Inner Harbour 205470	1990–1996	On line
Macleay River	Entrance 206477	1901–1913	HiLos on line
Crowdy Head	CSIRO 208470	1985–1986	On line
Tomaree	Hospital Jetty 209471	Oct 1985–Apr 2014	On line
Tomaree	Hospital Jetty	1967–1969	HiLos State Archives
Newcastle	Boat harbour 210461	1899–1921	HiLos on line
Newcastle	Breakwater	1946–1961	HiLos State Archives
Port Hacking	Hungry Point	Nov 1987–Feb2015	On line
Port Jackson	Fort Denison 60370	1914–2021	On line
Port Kembla	Harbour	1957–1965	Microfiche State Archives
Port Kembla	Harbour 214480	1987–1992	On line
Jervis Bay	HMAS Creswell 216471	1914–1919	HiLos on line
Jervis Bay	Huskisson 216472	1987–1993	On line
Batemans Bay Offshore	Snapper Island 216451	1986–1990	On line
Batemans Bay Offshore	Offshore 216452	1987–1988	On line (MHL556)
Moruya River	Moruya Heads 217403	1951–1952	HiLos State Archives
Moruya River	Entrance	1951–52, 1987–88	On line
Eden	Snug Cove 220470	1978–1990	On line
Eden	Snug Cove	1954–1956	Microfiche State Archives
Norfolk Island	Kingston Jetty	1994-2015	On line

Fort Denison data courtesy of Sydney Ports Corporation and BoM National Tidal Unit.

Data for Norfolk Island since 2015 provided by Bureau of Meteorology's National Tidal Unit (NTU).

## Appendix E Glossary of terms

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Amplitude (H)	One half of the difference in height between consecutive high water and low water, hence half the tide range.
Australian Height Datum (AHD)	Is a geodetic datum for altitude measurement in Australia. According to Geoscience Australia, in 1971 the mean sea level for 1966-1968 was assigned a value of zero on the Australian Height Datum for 30 tide gauges around the coast of the Australian continent. The resulting datum surface has been termed the Australian Height Datum (AHD) and was adopted by the National Mapping Council as the datum to which all vertical control for mapping is to be referred.
Automatic tide gauge	An instrument that automatically registers the rise and fall of the tide. In some instruments, the registration is accomplished by recording the heights at regular time intervals in digital format.
Benchmark (BM)	A fixed physical object or mark used as reference for a vertical datum. A tidal benchmark is one near a tide station to which the tide staff and tidal datums are referred. A primary benchmark is the principal (or only) mark of a group of tidal benchmarks to which the tide staff and tidal datums are referred.
Chart datum	Chart datum taken to correspond to a low-water elevation, and its depression below mean sea level is represented by the symbol Z.
Coastal boundary	The mean high water line (MHWL) or mean higher high water line (MHHWL) when tidal lines are used as the coastal boundary. Also, lines used as boundaries inland of and measured from (or points thereon) the MHWL or MHHWL.
Constituent	One of the harmonic elements in a mathematical expression for the tide-producing force and in corresponding formulas for the tide or tidal current. Each constituent represents a periodic change or variation in the relative positions of the earth, moon and sun. A single constituent is usually written in the form $y = A \cos (at + \acute{a})$ , in which $y$ is a function of time as expressed by the symbol $t$ and is reckoned from a specific origin. The coefficient $A$ is called the amplitude of the constituent and is a measure of its relative importance. The angle $(at + \acute{a})$ changes uniformly and its value at any time is called the phase of the constituent. The speed of the constituent is the rate of change in its phase and is represented by the symbol $a$ in the formula. The quantity $a$ is the phase of the constituent at the initial instant from which the time is reckoned. The period of the constituent is the time required for the phase to change through $360^\circ$ and is the cycle of the astronomical condition represented by the constituent.
Digital Recorder (or logger)	An electronic recorder system which stores the information in accessible form, for example, on tape or solid state memory.

Digitise	To translate analog information into digital form i.e. a series of numeric data readable by, and stored within, a digital computer.
Diurnal	Having a period or cycle of approximately one tidal day. Thus, the tide is said to be diurnal when only one high water and one low water occur during a tidal day, and the tidal current is said to be diurnal when there is a single flood and a single ebb period of a reversing current in the tidal day. A rotary current is diurnal if it changes its direction through all points of the compass once each tidal day. A diurnal constituent is one which has a single period in the constituent day. The symbol for such a constituent is the subscript 1.
East Coast Low (ECL)	East Coast Lows (ECL) are intense low-pressure systems which occur on average several times each year off the eastern coast of Australia, in particular southern Queensland, NSW and eastern Victoria. Although they can occur at any time of the year, they are more common during autumn and winter with a maximum frequency in June. East Coast Lows will often intensify rapidly overnight making them one of the more dangerous weather systems to affect the NSW coast. East Coast Lows are also observed off the coast of Africa and America and are sometimes known as east coast cyclones.
Ellipsoid	An idealised model representing the mean sea level of the earth and is used as a computational reference for global position fixing
Encoder	A device that translates tidal movement into computer readable data.
Estuary	An embayment of the coast in which fresh river water entering at its head mixes with the relatively saline ocean water. When tidal action is the dominant mixing agent it is usually termed a tidal estuary. Also, the lower reaches and mouth of a river emptying directly into the sea where tidal mixing takes place. The latter is sometimes called a river estuary.
Extreme high water	The highest elevation reached by the sea as recorded by a tide gauge during a given period.
Extreme low water	The lowest elevation reached by the sea as recorded by a tide gauge during a given period.
Floatwell	A stilling well in which the float of a float-actuated gauge operates. Also known as a stilling well.
Gas purged pressure gauge	A type of analog tide gauge in which gas, usually nitrogen, is emitted from a submerged tube at a constant rate. Fluctuations in hydrostatic pressure due to changes in tidal height modify the emission rate for recording.
Harmonic analysis	Process of measuring or calculating the relative amplitudes and frequencies of all the significant harmonic components present in a given wave form.

Harmonic prediction	Method of predicting tides by combining the harmonic constituents into a single tidal curve. The work is usually performed by electronic digital computer.
Head	The difference in water level at either end of a strait, channel, inlet, etc.
High water (HW)	The maximum height reached by a rising tide. The high water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions. For tidal datum computational purposes, the maximum height is not considered a high water unless it contains a tidal high water.
High water mark	A line or mark left upon tide flats, beach, or alongshore objects indicating the elevation of the intrusion of high water. The mark may be a line of oil or scum on alongshore objects, or a more or less continuous deposit of fine shell or debris on the foreshore or berm. This mark is physical evidence of the general height reached by wave runup at recent high waters. It should not be confused with the mean high water line or mean higher high water line.
Higher high water (HHW)	The highest of the high waters (or single high water) of any specified tidal day due to the declination $A_1$ effects of the moon and sun.
Higher low water (HLW)	The highest of the low waters of any specified tidal day due to the declination $A_1$ effects of the moon and sun.
Highest Astronomical Tide (HAT)	The highest level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; this level may not be reached every year. HAT is not the extreme level which can be reached as storm surges may cause considerably higher levels to occur.
Hydrographic datum	A datum used for referencing depths of water and the heights of predicted tides or water level observations. Same as chart datum. See datum.
Indian spring low water	A datum originated by Professor G. H. Darwin when investigating the tides of India. It is an elevation depressed below mean sea level by an amount equal to the sum of the amplitudes of the harmonic constituents $M_2$ , $S_2$ , $K_1$ , and $O_1$ .
Inverse barometer effect	The inverse response of sea level to changes in atmospheric pressure. A static reduction of 1.005 mb in atmospheric pressure will cause a stationary rise of 1 cm in sea level.
$K_1$	Lunisolar diurnal constituent. This constituent, with $O_1$ , expresses the effect of the moon's declination. They account for diurnal inequality and, at extremes, diurnal tides. With $P_1$ , it expresses the effect of the sun's declination. Speed = $T + h = 15.041,068,6^\circ$ per solar hour.

King Tide	A non-scientific term used to describe especially high tide events occurring twice a year around early January and early July. They occur when the earth, sun and moon are in alignment and when the sun is closest and furthest from the earth (perihelion and aphelion respectively).
Lambda	Smaller lunar evectional constituent. This constituent, with $V_2$ , $U_2$ , and $(S_2)$ , modulates the amplitude and frequency of $M_2$ for the effects of variation in solar attraction of the moon. This attraction results in a slight pear-shaped lunar ellipse and a difference in lunar orbital speed between motion toward and away from the sun. Although $(S_2)$ has the same speed as $S_2$ , its amplitude is extremely small. Speed = $2T - s + p = 29.455,625,3^\circ$ per solar hour.
Low water (LW)	The minimum height reached by a falling tide. The low water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions. For tidal datum computational purposes, the minimum height is not considered a low water unless it contains a tidal low water.
Lower high water (LHW)	The lowest of the high waters of any specified tidal day due to the declination $A_1$ effects of the moon and sun.
Lower low water (LLW)	The lowest of the low waters (or single low water) of any specified tidal day due to the declination $A_1$ effects of the moon and sun.
Lowest Astronomical Tide (LAT)	The lowest level which can be predicted to occur under average meteorological conditions and under any combination of astronomical conditions; this level will not be reached every year. LAT is not the extreme level which can be reached as storm surges may cause considerably lower levels to occur.
Lunar tide	That part of the tide on the earth due solely to the moon as distinguished from that part due to the sun.
$M_2$	Principal lunar semi-diurnal constituent. This constituent represents the rotation of the Earth with respect to the Moon. Speed = $2T - 2s + 2h = 28.984,104,2^\circ$ per solar hour.
Mean high water (MHW)	A tidal datum. The average of all the high water heights observed over the National Tidal Datum Epoch. For stations with shorter series, simultaneous observational comparisons are made with a control tide station in order to derive the equivalent datum.
Mean low water springs (MLWS)	A tidal datum. Frequently abbreviated spring low water. The arithmetic mean of the low water heights occurring at the time of spring tides observed over the National Tidal Datum Epoch. It is usually derived by taking an elevation depressed below the half-tide level by an amount equal to one-half the spring range of tide, necessary corrections being applied to reduce the result to a mean value.

Mean Sea Level (MSL)	The arithmetic mean of the water level heights at the tidal station observed over a period of time (preferably 19 years).
Modem	A device allowing a computer to be accessed over a telephone line.
Neap tides	Tides of decreased range or tidal currents of decreased speed occurring semi-monthly as the result of the moon being in quadrature. The neap range ( $N_p$ ) of the tide is the average range occurring at the time of neap tides and is most conveniently computed from the harmonic constants. It is smaller than the mean range where the type of tide is either semi-diurnal or mixed and is of no practical significance where the type of tide is predominantly diurnal. The average height of the high waters of the neap tide is called neap high water or high water neaps (MHWN) and the average height of the corresponding low waters is called neap low water or low water neaps (MLWN).
$O_1$	Lunar diurnal constituent. See $K_1$ . Speed = $T - 2s + h = 13.943,035,6^\circ$ per solar hour.
Phase	<ol style="list-style-type: none"> <li>1. Any recurring aspect of a periodic phenomenon, such as new moon, high water, flood strength, etc.</li> <li>2. A particular instant of a periodic function expressed in angular measure and reckoned from the time of its maximum value, the entire period of the function being taken as <math>360^\circ</math>. The maximum and minimum of a harmonic constituent have phase values of <math>0^\circ</math> and <math>180^\circ</math>, respectively.</li> </ol>
Pressure Sensor	A pressure transducer sensing device for water level measurement. A relative transducer is vented to the atmosphere and pressure readings are made relative to atmospheric pressure. An absolute transducer measures the pressure at its location. The readings are then corrected for barometric pressure taken at the surface.
Range of tide	The difference in height between consecutive high and low waters. The mean range is the difference in height between mean high water and mean low water. The great diurnal range or diurnal range is the difference in height between mean higher high water and mean lower low water. For other ranges see spring, neap, perigean, apogean, and tropic tides; and tropic ranges.
Relative mean sea level change	A local change in mean sea level relative to a network of benchmarks established in the most stable and permanent material available (bedrock, if possible) on the land adjacent to the tide station location. A change in relative mean sea level may be composed of both an absolute mean sea level change component and a vertical land movement change component, together.
$S_2$	Principal solar semi-diurnal constituent. This constituent represents the rotation of the Earth with respect to the Sun. Speed = $2T = 30.000,000,0^\circ$ per solar hour.

Seiche	A stationary wave usually caused by strong winds and/or changes in barometric pressure. It is found in lakes, semi-enclosed bodies of water, and in areas of the open ocean. The period of a seiche in an enclosed rectangular body of water is usually represented by the formula: $\text{Period (T)} = 2L / \text{square root (gd)}$ in which L is the length, d the average depth of the body of water, and g the acceleration of gravity.
Semi-diurnal	Having a period or cycle of approximately one-half of a tidal day. The predominant type of tide throughout the world is semi-diurnal, with two high waters and two low waters each tidal day. The tidal current is said to be semi-diurnal when there are two flood and two ebb periods each day. A semi-diurnal constituent has two maxima and two minima each constituent day, and its symbol is the subscript 2.
Shallow water constituent	A short-period harmonic term introduced into the formula of tidal (or tidal current) constituents to take account of the change in the form of a tide wave resulting from shallow water conditions. Shallow water constituents include the overtides and compound tides.
Slack water (slack)	The state of a tidal current when its speed is near zero, especially the moment when a reversing current changes direction and its speed is zero. The term also is applied to the entire period of low speed near the time of turning of the current when it is too weak to be of any practical importance in navigation. The relation of the time of slack water to the tidal phases varies in different localities. For a perfect standing tidal wave, slack water occurs at the time of high and of low water, while for a perfect progressive tidal wave, slack occurs midway between high and low water.
Solar tide	<ol style="list-style-type: none"> <li>1. The part of the tide that is due to the tide-producing force of the sun.</li> <li>2. The observed tide in areas where the solar tide is dominant. This condition provides for phase repetition at about the same time each solar day.</li> </ol>
Solid State	An electronic device composed of components with no moving parts – in this instance, using the electronic properties of solids, as in transistors, semi-conductors and integrated circuits.
Spring high water	Same as mean high water springs (MHWS). See spring tides.
Spring low water	Same as mean low water springs (MLWS). See spring tides.
Spring tides	Tides of increased range or tidal currents of increased speed occurring semi-monthly as the result of the moon being new or full. The spring range (Sg) of tide is the average range occurring at the time of spring tides and is most conveniently computed from the harmonic constants. It is larger than the mean range where the type of tide is either semi-diurnal or mixed, and is of no practical significance where the type of tide is predominantly diurnal. The average height of the high waters of the spring tides is called spring high water or mean high water springs (MHWS) and the

average height of the corresponding low waters is called spring low water or mean low water springs (MLWS).

Storm surge	The local change in the elevation of the ocean along a shore due to a storm. The storm surge is measured by subtracting the astronomic tidal elevation from the total elevation. It typically has a duration of a few hours. Since wind generated waves ride on top of the storm surge (and are not included in the definition), the total instantaneous elevation may greatly exceed the predicted storm surge plus astronomic tide. It is potentially catastrophic, especially on low-lying coasts with gently sloping offshore topography.
Telemeter	Transmit data to a distant receiving station via a telephone line or by telegraphic means.
Tidal characteristics	Principally, those features relating to the time, range, and type of tide.
Tidal constants	Tidal relations that remain practically constant for any particular locality. Tidal constants are classified as harmonic and non-harmonic. The harmonic constants consist of the amplitudes and epochs of the harmonic constituents, and the non-harmonic constants include the ranges and intervals derived directly from the high and low water observations.
Tidal current	A horizontal movement of the water caused by gravitational interactions between the sun, moon and earth. The horizontal component of the particulate motion of a tidal wave. Part of the same general movement of the sea that is manifested in the vertical rise and fall called tide.
Tidal Epoch	Has been set in Australia as a 20-year period (based on the Lunar Cycle of 18.6 Earth years) over which all recordings of tidal variations and influences are analysed and reviewed.
Tidal Plane	A level of water (often defined by tidal constituents) from which water depths and heights of tides are referenced.
Tide	The periodic rise and fall of the water resulting from gravitational interactions between sun, moon and earth. The vertical component of the particulate motion of a tidal wave. Although the accompanying horizontal movement of the water is part of the same phenomenon, it is preferable to designate this motion as tidal current.
Tide curve	A graphic representation of the rise and fall of the tide in which time is usually represented by the abscissa and height by the ordinate. For a semi-diurnal tide with little diurnal inequality, the graphic representation approximates a cosine curve.
Tide (water level) gauge	An instrument for measuring the rise and fall of the tide (water level).

Tide Tables	Tables which give daily predictions of the times and heights of high and low waters. These predictions are usually supplemented by tidal differences and constants through which predictions can be obtained for numerous other locations.
Tsunami	A shallow water progressive wave, potentially catastrophic, caused by an underwater earthquake or volcano.
Universal time (UTC)	Same as Greenwich mean time (GMT).
Z <sub>0</sub>	Symbol recommended by the International Hydrographic Organisation to represent the elevation of mean sea level above chart datum

# Appendix F Publications of interest

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## Data Reports

MHL Annual Ocean Tide Levels Summaries available from 1986–87 to 2019–2020

MHL Report Nos. 515 (86–87), 544 (87–88), 563 (88–89), 585 (89–90), 602 (90–91), 628 (91–92), 658 (92–93), 697 (93–94), 732 (94–95), 777 (95–96), 876 (96–97), 947 (97–98), 1013 (98–99), 1069 (99–00), 1129 (00–01), 1205 (01–02), 1277 (02–03), 1347 (03–04), 1423 (04–05), 1512 (05–06), 1764 (06–07), 1848 (07–08), 1933 (08–09), 2010 (09–10), 2089 (10–11), 2158 (11–12), 2219 (12–13), 2292 (13–14), 2384 (14–15), 2475 (15–16), 2574 (16–17), 2618 (17–18), 2693 (18–19), 2770 (19–20)

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## Mean Sea Level

Couriel, E, B Modra and R Jacobs 2014, *NSW Sea Level Trends – The Ups and Downs*, 17<sup>th</sup> Australian Hydrographers Association Conference, Sydney, Australia, October 2014.

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