NSW OCEAN AND RIVER ENTRANCE TIDAL LEVELS AND AIR PRESSURE ANNUAL SUMMARY

2023-24

Report MHL3065

23 June 2025

Prepared for:

NSW Department of Climate Change, Energy, the Environment and Water – Conservation Programs, Heritage and Regulation

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Foreword

Manly Hydraulics Laboratory (MHL) is a business unit within the Water Group of the NSW Department of Climate Change, Energy, the Environment and Water. MHL operates and maintains ocean river entrance tidal and barometric recording stations along the NSW coast under a service level agreement with the NSW Department of Climate Change, Energy, the Environment and Water – Conservation Programs, Heritage and Regulation (DCCEEW CPHR).

The NSW ocean tide database developed by MHL supports a number of DCCEEW CPHR programs associated with coastal, floodplain and estuary management. Data uses 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 outputs are publicly available.

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

The monitoring program's protocols and station arrangements are guided by the *Australian Tides Manual Special Publication 9 Version 6* (2021) published by the Intergovernmental Committee on Surveying and Mapping (ICSM) and reviewed by contributing agencies to the Tides and Sea Levels Working Group (TSLWG).

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Executive summary

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 2023 to 30 June 2024. It provides a catalogue of all ocean and river entrance tidal data collected in NSW by MHL for DCCEEW CPHR.

The 2023–24 target data recovery rate of over 95% for the 15-minute ocean tide data (99.6%), 1-minute ocean tide data (97.4%), 5-minute offshore tide data (100%), and barometric data (100%) were achieved.

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 2023–24
- **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.

Contents

TABLES

FIGURES

1 Tidal network measurement program

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

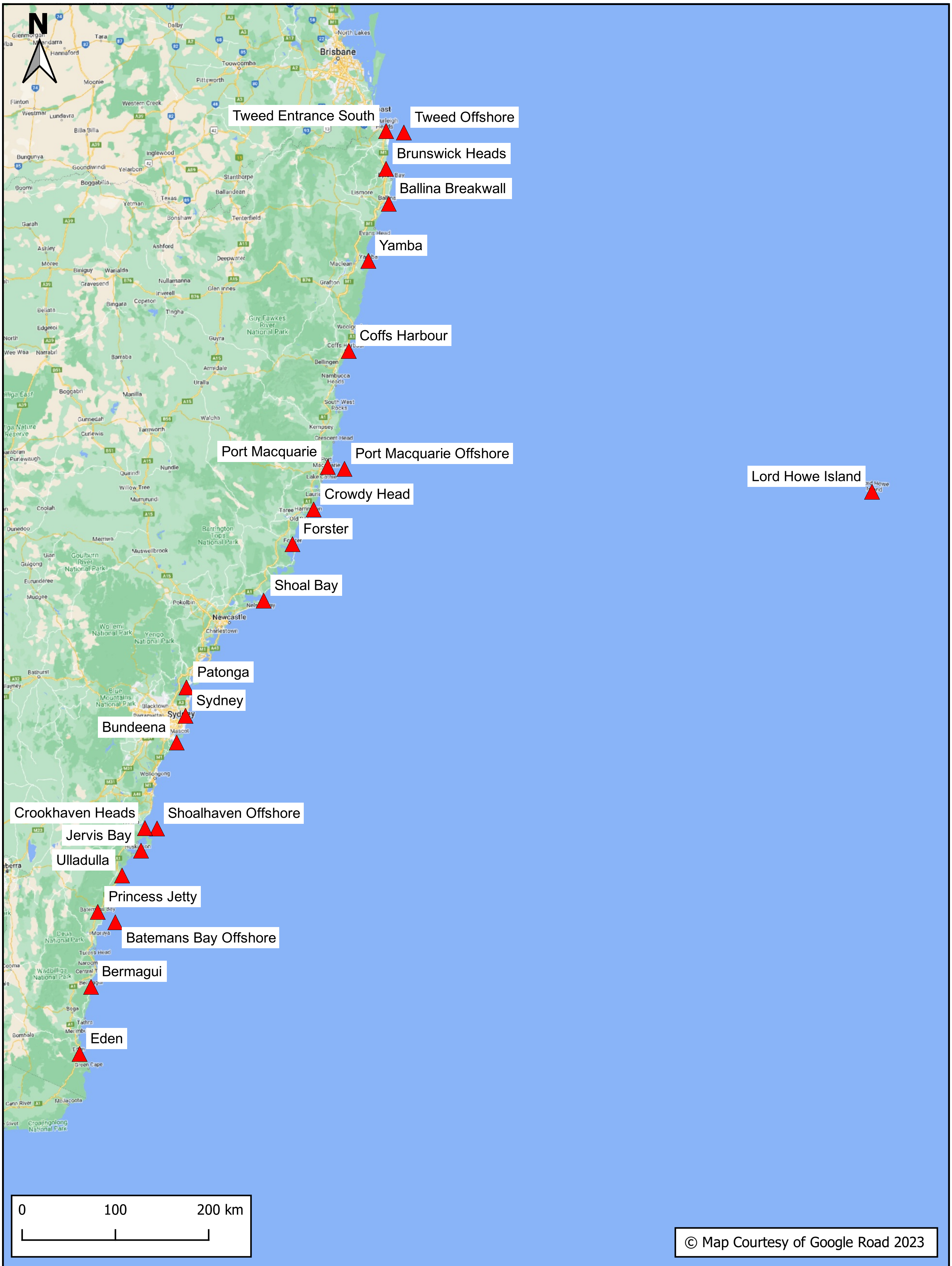
The present program is based on a network of automatic ocean tide level recording stations installed at eighteen coastal and four offshore sites, and one open ocean site located on Lord Howe Island (**Figure 1-1**). The ocean tide monitoring network features three distinctive system types for data capture: 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 www.mhl.nsw.gov.au, navigate to the individual station page and select the *STATION DETAILS* tab.

Tidal data[1] 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 are available online in tables or as plots. One-minute and some 1 second data are also available on request. 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 2906 *NSW Estuary and River Water Levels Annual Summary* (MHL 2023b).

The tidal station data summaries for 2023–24 are presented in **Appendix A**.

[1] Excluding the offshore sites which are a sensor and logger combination only without telemetry capability.



OCEAN TIDE STATION LOCATIONS

Manly Hydraulics Laboratory

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Figure
1-1

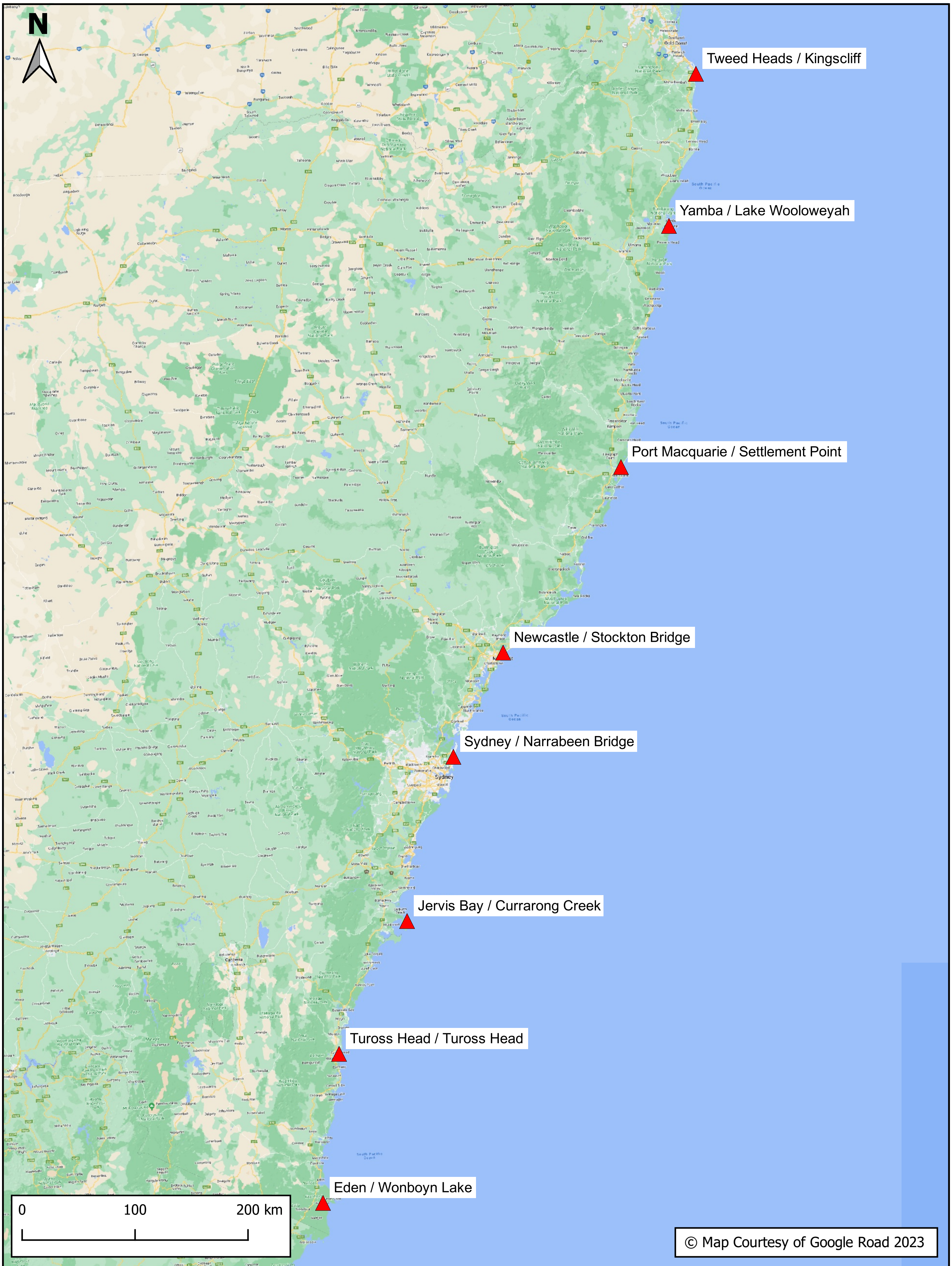
2 Air pressure program

MHL has measured air pressure along the NSW coast since 1987. This data enables the correction of water level data recorded by total pressure transducers and to provide barometric information to assist the understanding of water levels associated with ocean storms.

Barometers developed by MHL, utilising an analogue pressure transducer, were installed at six Waverider buoy receiving stations between August 1999 and February 2000 until the network was decommissioned and superseded by a more comprehensive coastal air pressure monitoring system (**Figure 2-1**).

The barometer network now utilises digital barometers that sample air pressure every 5 to 15 minutes in the range 50 hPa to 1100 hPa at ± 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. Barometric data uploads every 15 minutes with the water level data.

The barometric station data summaries for 2023–24 are presented in **Appendix B**.



BAROMETER STATION LOCATIONS

NSW GOVERNMENT

Manly Hydraulics Laboratory

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Figure
2-1

3 Tidal data access, metadata and analysis

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 2023 to 30 June 2024. 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 on the MHL web page (http://www.mhl.nsw.gov.au) with the plot of the data from that station provided in **Appendix A**. The plot confirms the availability of data for the 2023–24 financial year. For the availability of historical data which has been collected, refer to **Appendix C** and **Appendix 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 online 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 telemetered data are available online in a non-quality controlled form to aid quick access to raw data records. The online service for clients can provide access to all data catalogued in **Appendix C** and **Appendix 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, 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 **Appendix C**, 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 1971) 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 Lord Howe Island, the survey information for this station relates to the local datum.

Table 3-1 Summary of adjustments from AHD to local port datum

Station	Station datum (SD)	Adjustment (SD = AHD + Adjustment)
Tweed Entrance South	Tweed River Hydro Datum (1963)	0.893
Tweed Offshore	Mean Sea Level	N/A
Brunswick Heads	Brunswick River Flood Mitigation Datum (1962)	0.024
Ballina Breakwall	Richmond River Valley Datum (1979)	0.860
Yamba	Iluka Port Datum (1972)	0.895
Coffs Harbour	Coffs Port Datum (1974)	0.882
Port Macquarie	Australian Height Datum (1971)	0.000
Port Macquarie Offshore	Mean Sea Level	N/A
Crowdy Head	Crowdy Head Datum (1986)	0.911
Forster	Forster Hydro Datum (1978)	1.061
Shoal Bay	Port Stephens Hydro Datum (1970)	0.944
Patonga	Australian Height Datum (1972)	0.000
Sydney	Zero Fort Denison (1897)	0.925
Fort Denison (Sydney Ports)	Zero Fort Denison (1897)	0.925
Bundeena	Zero Fort Denison (1897)	0.925
Crookhaven Heads	Australian Height Datum (1971)	0.000
Shoalhaven Offshore	Mean Sea Level	N/A
Jervis Bay	Jervis Bay Port Datum (1958)	1.070
Ulladulla	Australian Height Datum (1971)	0.000
Princess Jetty	Australian Height Datum (1971)	0.000
Batemans Bay Offshore	Mean Sea Level	N/A
Bermagui	Bermagui Local Hydro Datum (1976)	0.714
Eden	Twofold Bay Hydro Datum (1985)	0.924
Lord Howe Island	Lord Howe Island Hydro Datum (1963)	Not available

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.

MHL has updated the 1990-2010 tidal planes analysis to the 2001–2020 tidal epoch in MHL Report 2786 *NSW Tidal Planes Analysis 2001-2020 Harmonic Analysis* (MHL 2023a).

HAT, LAT, mean sea level (MSL) and tidal range values are calculated in AHD shown in **Table 3-2**. The exception to these is Lord Howe Island which is in local datum as there is no reference to AHD at this location. To convert the values in **Table 3-2** to local datum, use the offsets provided in **Table 3-1**.

Table 3-2 Ocean and river entrance tide HAT and LAT values (m AHD*)

Site	Period 2001–2020			
	HAT	LAT	Range	MSL
Tweed Heads	1.09	-0.88	1.97	0.04
Brunswick Heads	1.18	-0.88	2.06	0.05
Ballina Breakwall	1.10	-0.84	1.94	-0.02
Yamba	1.11	-0.83	1.94	0.05
Coffs Harbour	1.23	-0.95	2.18	0.03
Port Macquarie	1.03	-0.74	1.77	0.02
Crowdy Head	1.19	-0.97	2.16	-0.02
Forster	0.88	-0.89	1.77	-0.03
Shoal Bay	1.16	-0.94	2.10	0.00
Patonga	1.17	-0.88	2.05	0.06
Sydney	1.15	-0.86	2.01	0.04
Bundeena	1.20	-0.82	2.02	0.08
Crookhaven Heads	1.03	-0.77	1.80	0.04
Jervis Bay	1.14	-0.88	2.02	0.06
Ulladulla	1.08	-0.88	1.96	0.04
Princess Jetty	1.06	-0.78	1.84	0.06
Bermagui	1.02	-0.87	1.89	-0.02
Eden	0.98	-1.02	2.00	-0.09
Lord Howe Island*	2.32	-0.07	2.39	1.06

*Results for Lord Howe Island are presented in local datum, as AHD is unavailable.

4 Significant tidal events 2023-24

The data recovery statistics and comments on data losses are provided in **Table 4-1**.

Table 4-1 Data recovery from July 2023 to June 2024

Data stream	Data recovery (%)	Comments
15-minute ocean tide data	99.6	Small percentage data loss occurred at: Crookhaven Heads (orifice siltation), Bermagui (loss of spring low tides due to pressure sensor height setting) and Eden (power supply disruption)
1-minute ocean tide data	97.4	
5-minute offshore tide data	100.0	Full data recovery

The 2023–24 target data recovery rate of over 95% for the 15-minute ocean tide data (99.6%), 1-minute ocean tide data (97.4%), and 5-minute offshore tide data (99.9%) were achieved.

The *2025 NSW Tide 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 ±0.25 m difference between recorded and forecast data, are identified on **Figure 4-2** and documented in more detail in **Figure 4-3** and **Figure 4-4**. Most are driven by low pressure systems or ECLs. **Figure 4-5** to **Figure 4-8** show the tidal anomalies recorded at each ocean tide station during the reporting period. **Figure 4-9** shows the anomalies for the four offshore tide stations.

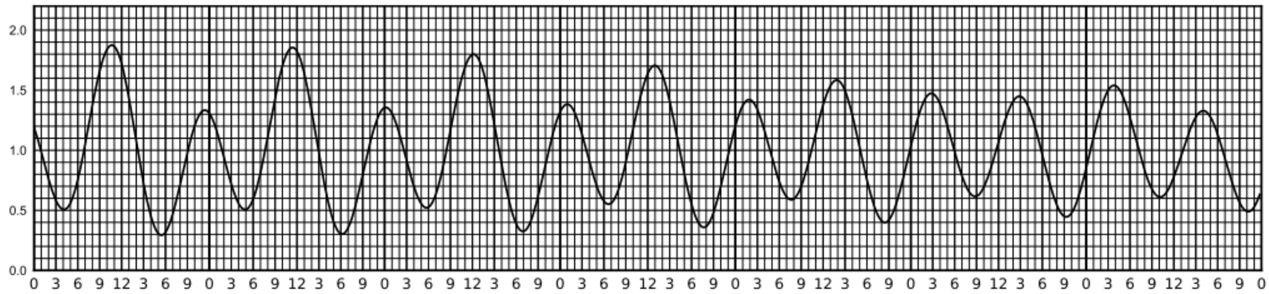
The Bureau of Meteorology (BoM) recorded two Severe Tropical Cyclones in Queensland during the 2023–24 reporting period.

- 2–17 December 2023, Severe Tropical Cyclone Jasper started as a tropical low in the east of Solomon Islands on 2 December. It moved westward and then southward, peaking to a category 5 cyclone on 8 December. Jasper started to weaken in the evening of 8 December and moved westward. It passed through the south of Willis Island as a category 1 cyclone on 11 December. It continued to move westward and then intensified, crossing the north Queensland coast near the community of Wujal Wujal as a category 2 cyclone on 13 December. After crossing the coast, Jasper quickly weakened into below tropical cyclone intensity on 13 December. It remained over land for several days and then dissipated on 17 December.
- 17 January – 5 February 2024, Severe Tropical Cyclone Kirrily started as a tropical low which formed along the monsoon trough in the Coral Sea on 17 January. It moved eastward and then south-westward, developing into a category 1 cyclone on 24 January. Its peak intensity was a category 3 cyclone on 25 January. Kirrily then began to quickly weaken, crossing the north Queensland coast in Balgal Beach, Rollingstone as a category 1 cyclone on 25 January. It further weakened as it moved inland, decreasing to below tropical cyclone intensity on 25 January. Ex-Tropical Cyclone Kirrily continued to move over land, passing through central, western and southwestern Queensland from 26 January to 5 February.

January 2025

Daylight Saving Time — 1st Quarter 7 Jan

2 Thursday	3 Friday	4 Saturday	5 Sunday	6 Monday	7 Tuesday	8 Wednesday
Sunrise: 05:48AM	Sunrise: 05:49AM	Sunrise: 05:50AM	Sunrise: 05:50AM	Sunrise: 05:51AM	Sunrise: 05:52AM	Sunrise: 05:53AM
Sunset: 08:09PM	Sunset: 08:09PM	Sunset: 08:09PM	Sunset: 08:09PM	Sunset: 08:09PM	Sunset: 08:09PM	Sunset: 08:09PM



2 Thursday	3 Friday	4 Saturday	5 Sunday	6 Monday	7 Tuesday	8 Wednesday
4:05am 0.52m 1ft 8in	4:54am 0.51m 1ft 8in	**12:10am 1.36m 4ft 6in**	**12:59am 1.39m 4ft 7in**	**1:52am 1.43m 4ft 8in**	**2:49am 1.49m 4ft 10in**	**3:47am 1.55m 5ft 1in**
10:38am 1.89m 6ft 2in	**11:22am 1.86m 6ft 1in**	5:43am 0.53m 1ft 9in	6:37am 0.56m 1ft 10in	7:37am 0.60m 1ft 12in	8:48am 0.63m 2ft 1in	10:07am 0.62m 2ft 1in
5:25pm 0.30m 0ft 12in	6:11pm 0.31m 1ft 0in	**12:10pm 1.81m 5ft 11in**	**12:58pm 1.72m 5ft 8in**	**1:50pm 1.60m 5ft 3in**	**2:50pm 1.46m 4ft 10in**	**4:01pm 1.34m 4ft 5in**
11:22pm 1.34m 4ft 5in		6:54pm 0.33m 1ft 1in	7:40pm 0.37m 1ft 2in	8:27pm 0.41m 1ft 4in	9:17pm 0.46m 1ft 6in	10:09pm 0.50m 1ft 8in

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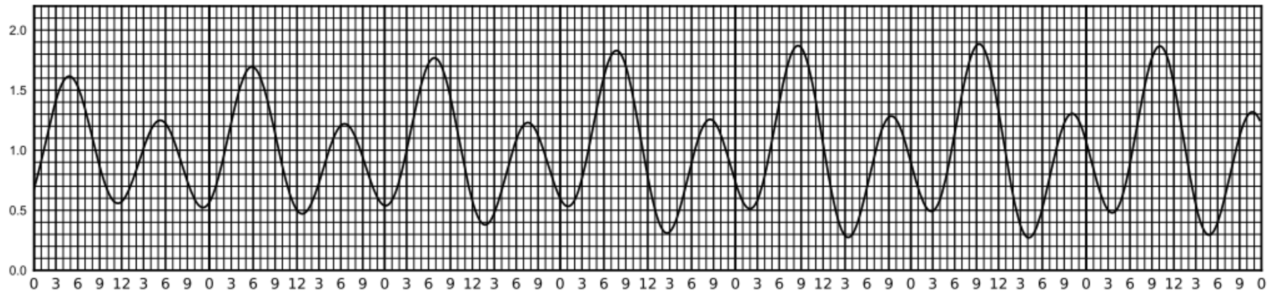
January 2025

Daylight Saving Time — Full Moon 14 Jan

9 Thursday	10 Friday	11 Saturday	12 Sunday	13 Monday	14 Tuesday	15 Wednesday
Sunrise: 05:54AM	Sunrise: 05:55AM	Sunrise: 05:56AM	Sunrise: 05:57AM	Sunrise: 05:57AM	Sunrise: 05:58AM	Sunrise: 05:59AM
Sunset: 08:09PM	Sunset: 08:09PM	Sunset: 08:09PM	Sunset: 08:09PM	Sunset: 08:08PM	Sunset: 08:08PM	Sunset: 08:08PM



9 Thursday	10 Friday	11 Saturday	12 Sunday	13 Monday	14 Tuesday	15 Wednesday
4:50am 1.63m 5ft 4in	**5:50am 1.71m 5ft 7in**	12:07am 0.55m 1ft 10in	1:06am 0.55m 1ft 9in	1:59am 0.52m 1ft 9in	2:49am 0.50m 1ft 8in	3:34am 0.49m 1ft 7in
11:28am 0.57m 1ft 11in	12:41pm 0.49m 1ft 7in	**6:49am 1.78m 5ft 10in**	**7:43am 1.84m 6ft 1in**	**8:34am 1.88m 6ft 2in**	**9:21am 1.90m 6ft 3in**	**10:04am 1.88m 6ft 2in**
5:15pm 1.26m 4ft 2in	**6:31pm 1.24m 4ft 1in**	1:44pm 0.40m 1ft 4in	2:39pm 0.33m 1ft 1in	3:27pm 0.29m 0ft 11in	4:09pm 0.28m 0ft 11in	4:49pm 0.30m 0ft 12in
11:09pm 0.54m 1ft 9in		**7:35pm 1.25m 4ft 1in**	**8:32pm 1.27m 4ft 2in**	**9:20pm 1.30m 4ft 3in**	**10:04pm 1.32m 4ft 4in**	**10:44pm 1.33m 4ft 4in**

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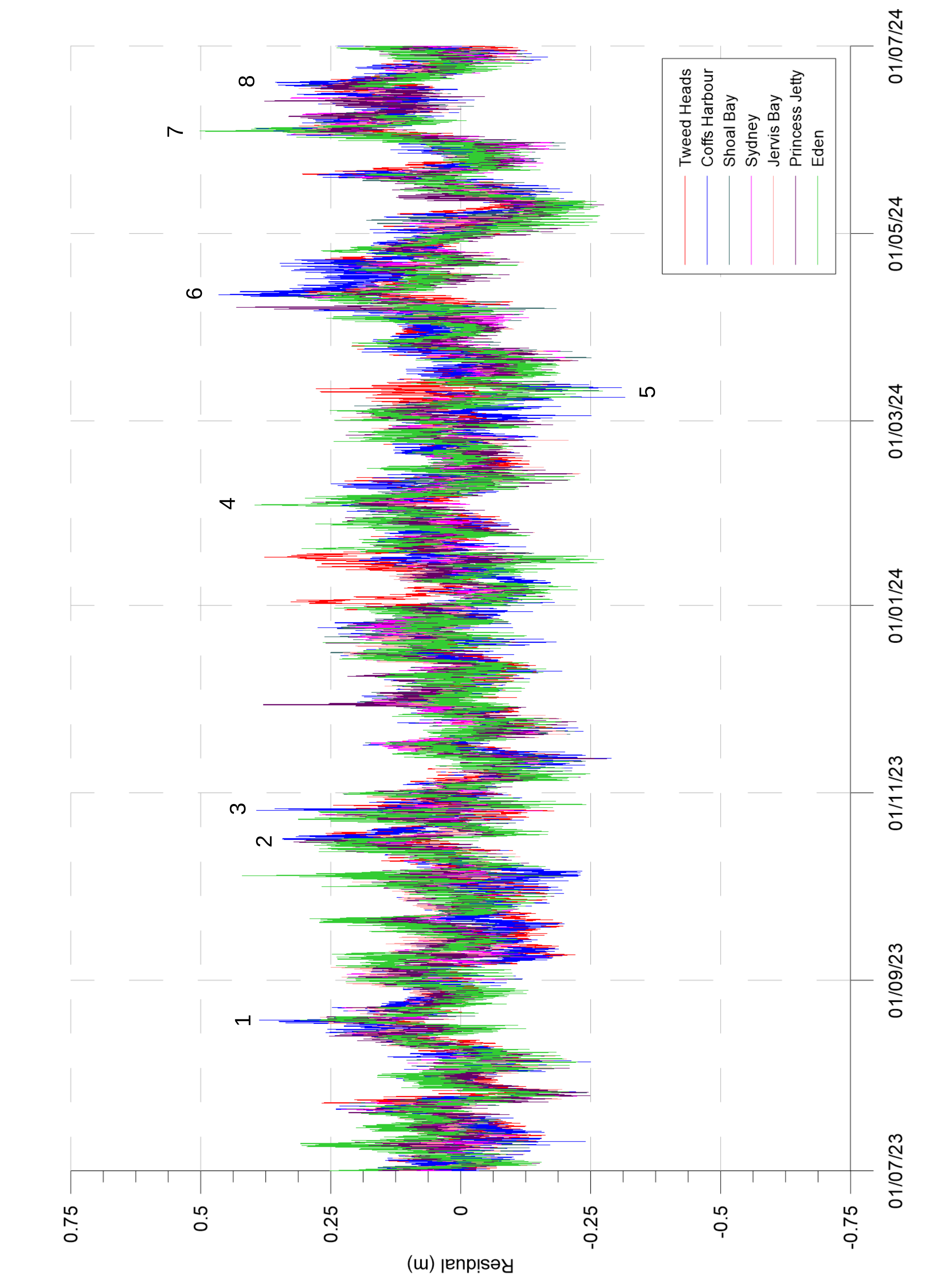
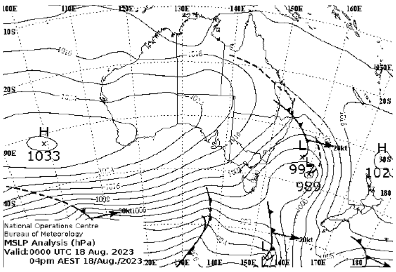
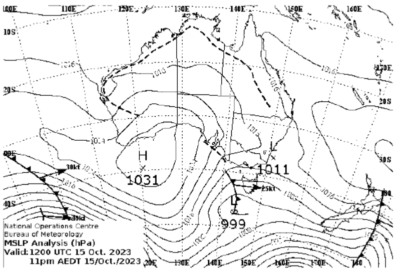
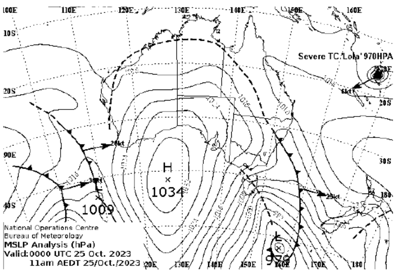
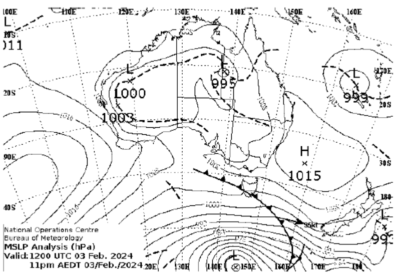
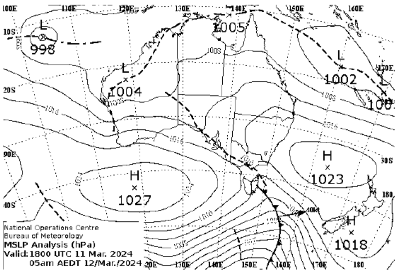
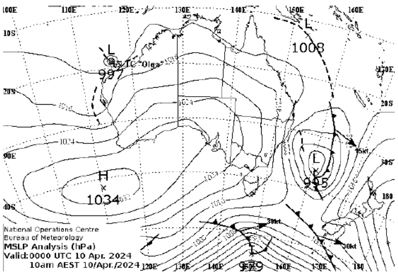
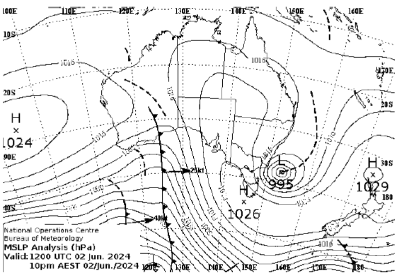
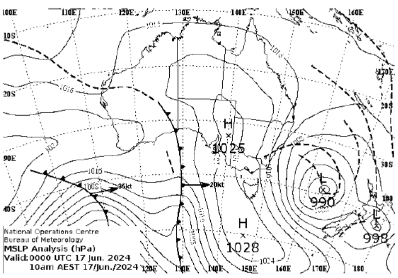
NSW Tide Chart 2025

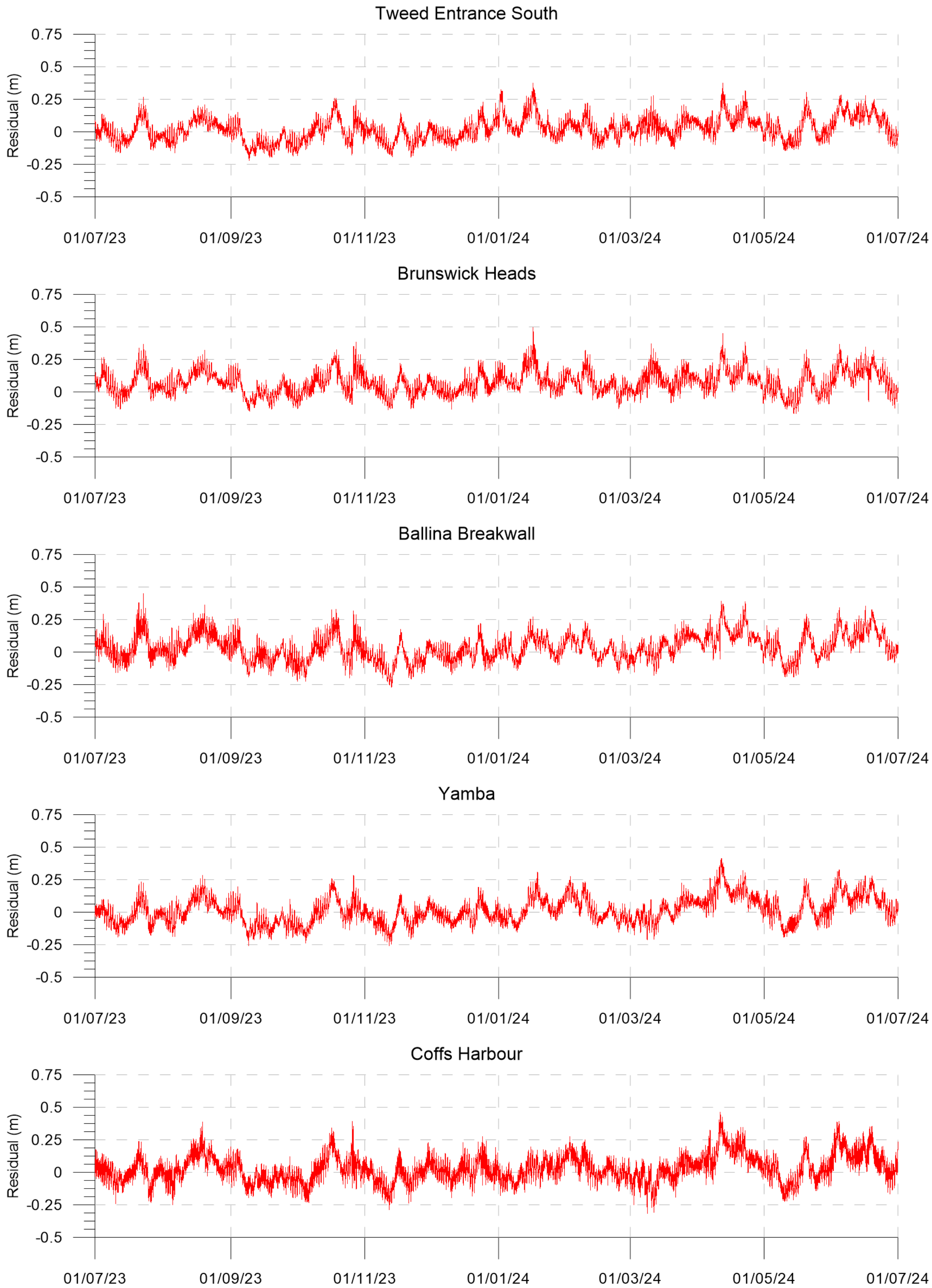


Numbered anomalies described in detail in Figure 4-3 and Figure 4-4.

NSW GOVERNMENT	NSW TIDAL ANOMALIES PLOT 2023–24	Manly Hydraulics Laboratory Report MHL3065 Figure 4-2

Event No (See Figure 4-2)	Event period	BoM weather map*	Peak anomaly	Stations where anomaly > ± 0.25m
1	17-20 August 2023	 Multiple low pressure systems	Station: Coffs Harbour Date: 18/08/2023 Time: 2330 Peak value: 0.387	Brunswick Heads, Ballina Breakwall, Yamba, Coffs Harbour, Crowdy Head, Forster, Shoal Bay, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden
2	15-17 October 2023	 Low pressure system	Station: Ulladulla Date: 15/10/2023 Time: 2230 Peak value: 0.357	Brunswick Heads, Ballina Breakwall, Yamba, Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden
3	24-26 October 2023	 Southerly low pressure cold front; trough; seich wave	Station: Coffs Harbour Date: 26/10/2023 Time: 0645 Peak value: 0.393	Brunswick Heads, Ballina Breakwall, Yamba, Coffs Harbour, Crowdy Head, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Eden
4	2-3 February 2023	 Antarctic low pressure system	Station: Eden Date: 2/02/2024 Time: 1530 Peak value: 0.396	Yamba, Coffs Harbour, Crowdy Head, Ulladulla, Princess Jetty, Bermagui, Eden

Event No (See Figure 4-2)	**Event period**	**BoM weather map***	**Peak anomaly**	**Stations where anomaly > ± 0.25m**
5	8-11 March 2024	 Multiple blocking high pressure systems	Station Coffs Harbour Date 8/03/2024 Time 1745 Peak value -0.317	Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Ulladulla, Eden
6	10-13 April 2024	 East Coast Low	Station Crowdy Head Date 10/04/2024 Time 1130 Peak value 0.505	Tweed Heads, Brunswick Heads, Ballina Breakwall, Yamba, Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Eden
7	2-8 June 2024	 Low pressure system	Station Eden Date 3/06/2024 Time 0830 Peak value 0.502	Tweed Heads, Brunswick Heads, Ballina Breakwall, Yamba, Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui, Eden
8	17-19 June 2024	 East Coast Low	Station Crowdy Head Date 18/06/2024 Time 0530 Peak value 0.372	Brunswick Heads, Ballina Breakwall, Yamba, Coffs Harbour, Port Macquarie, Crowdy Head, Forster, Shoal Bay, Patonga, Sydney, Bundeena, Crookhaven Heads, Jervis Bay, Ulladulla, Princess Jetty, Bermagui

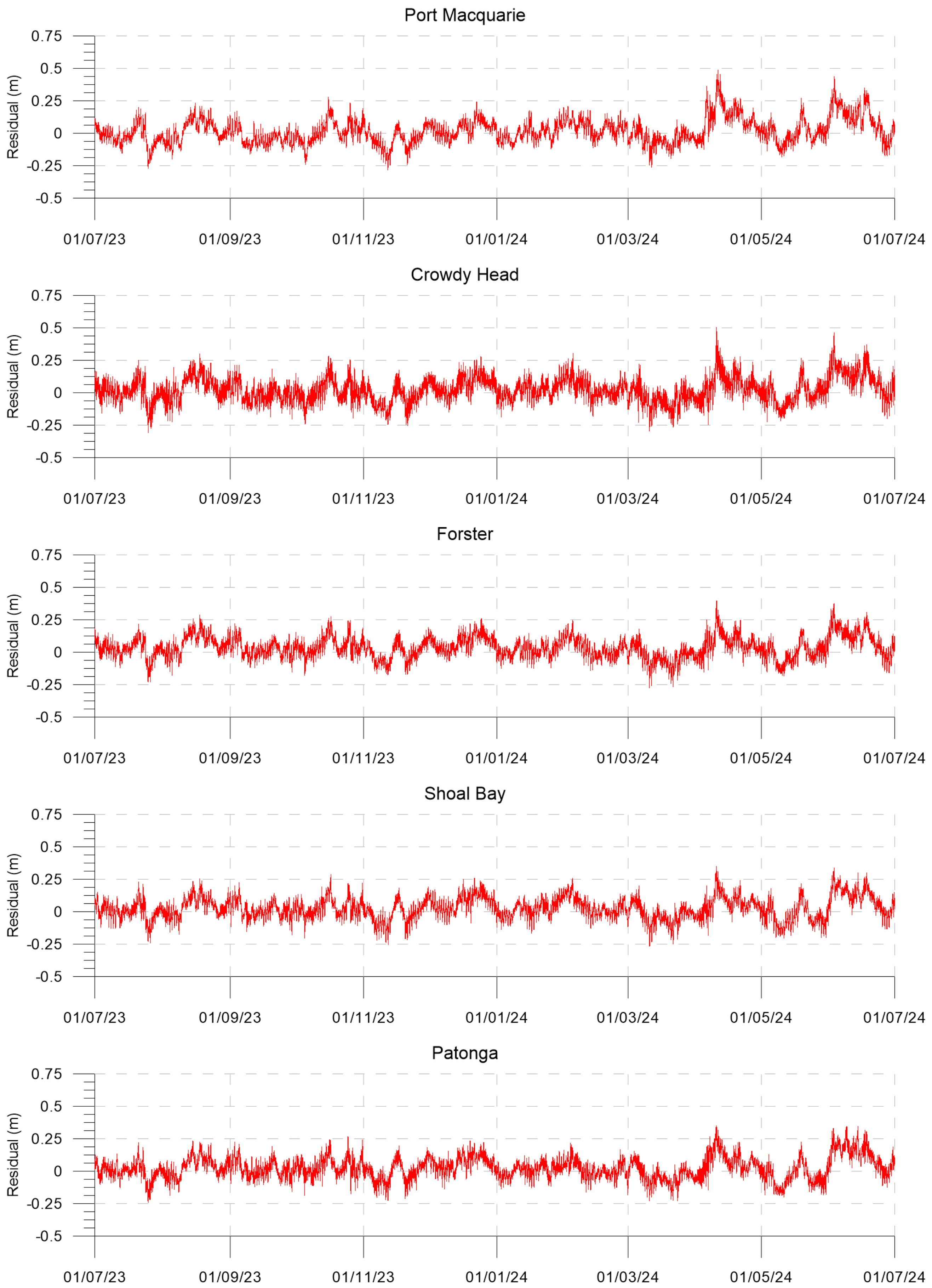


NSW GOVERNMENT

TIDAL ANOMALIES
2023–24
TWEED ENTRANCE SOUTH TO COFFS HARBOUR

Manly Hydraulics Laboratory

Report MHL3065
Figure
4-5

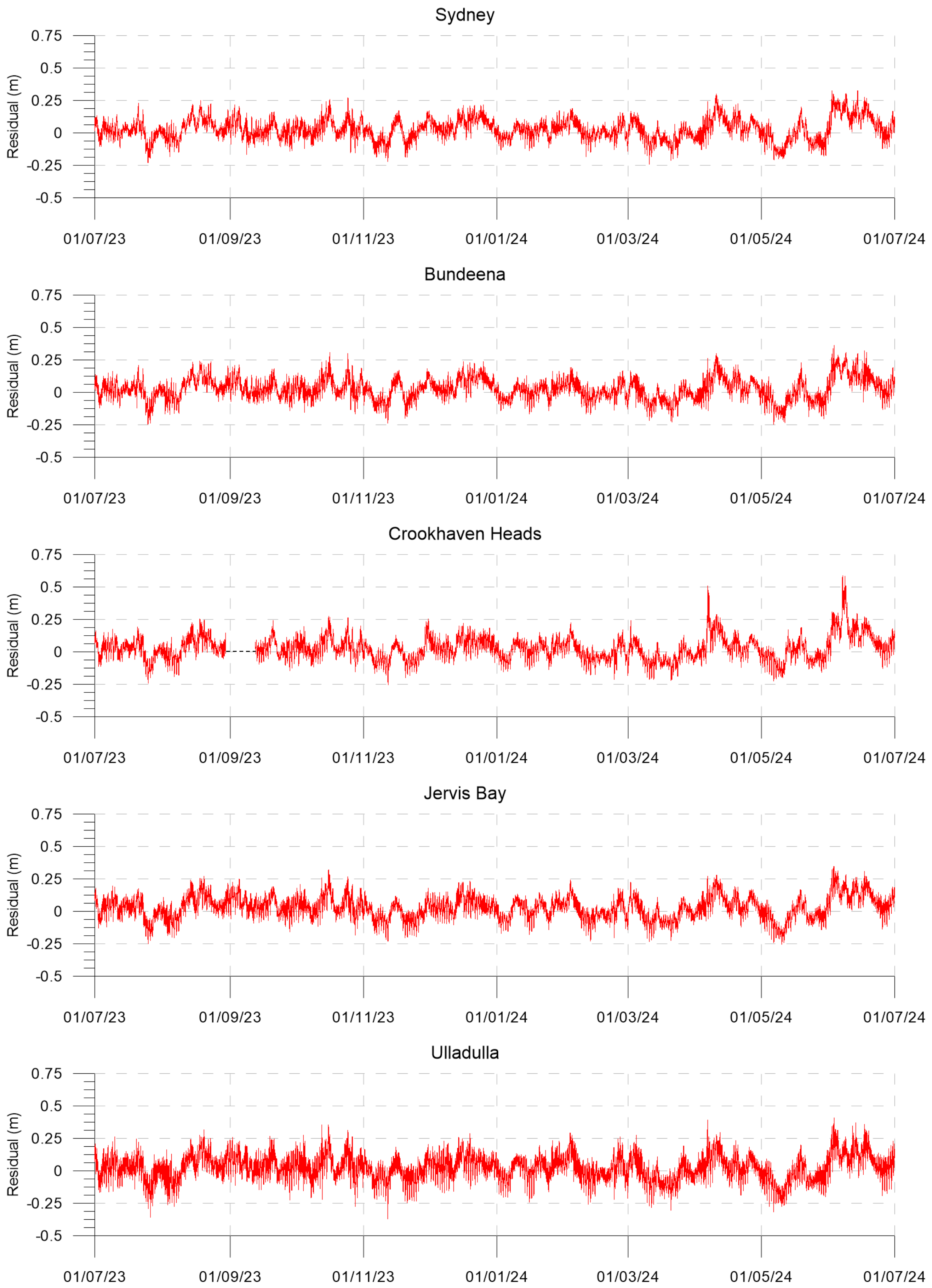


TIDAL ANOMALIES
2023–24
PORT MACQUARIE TO PATONGA

NSW GOVERNMENT

Manly Hydraulics Laboratory

Report MHL3065
Figure
4-6

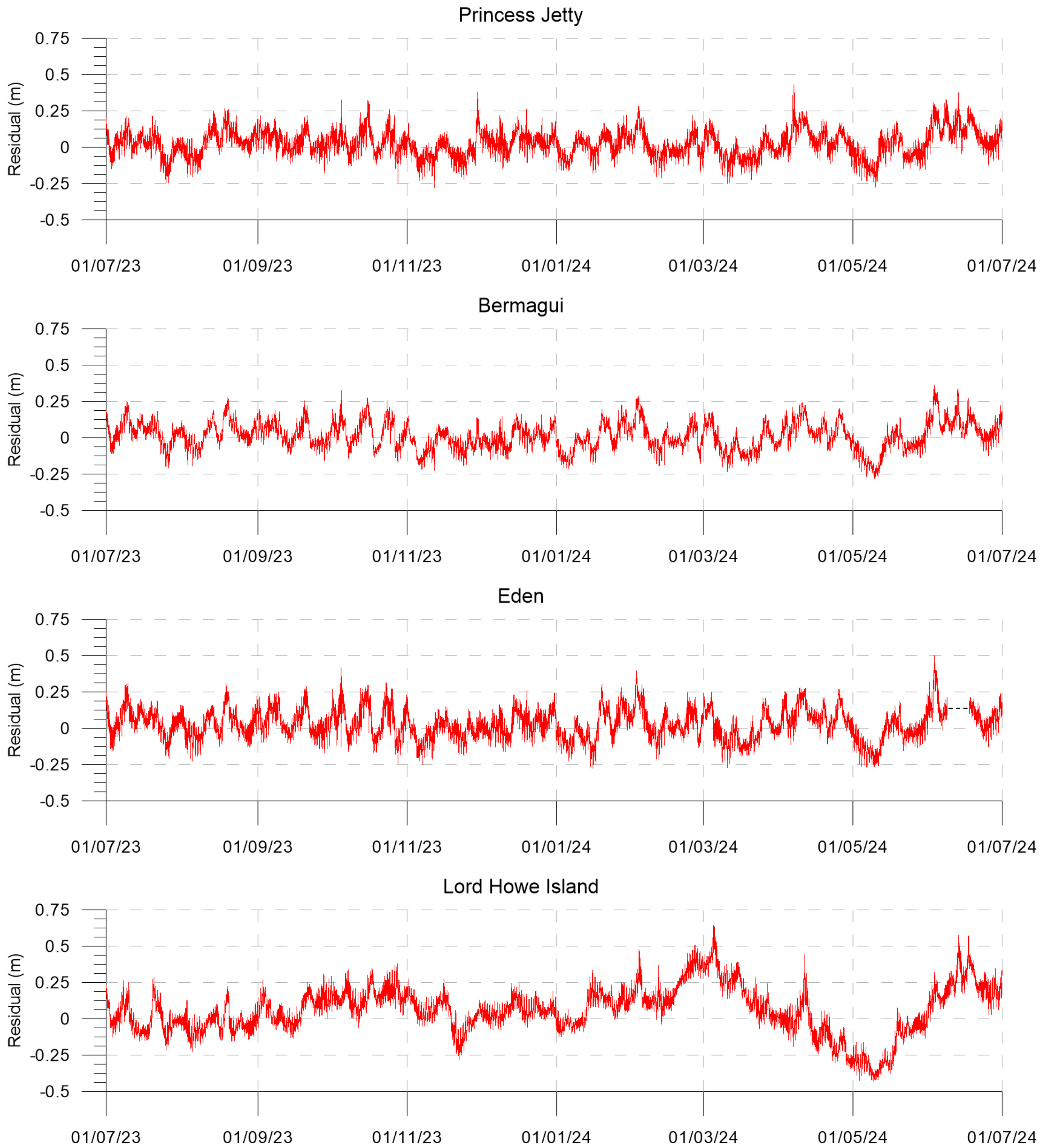


NSW GOVERNMENT

TIDAL ANOMALIES
2023–24
SYDNEY TO ULLADULLA

Manly Hydraulics Laboratory

Report MHL3065
Figure
4-7



NSW GOVERNMENT

TIDAL ANOMALIES
2023–24
PRINCESS JETTY TO LORD HOWE ISLAND

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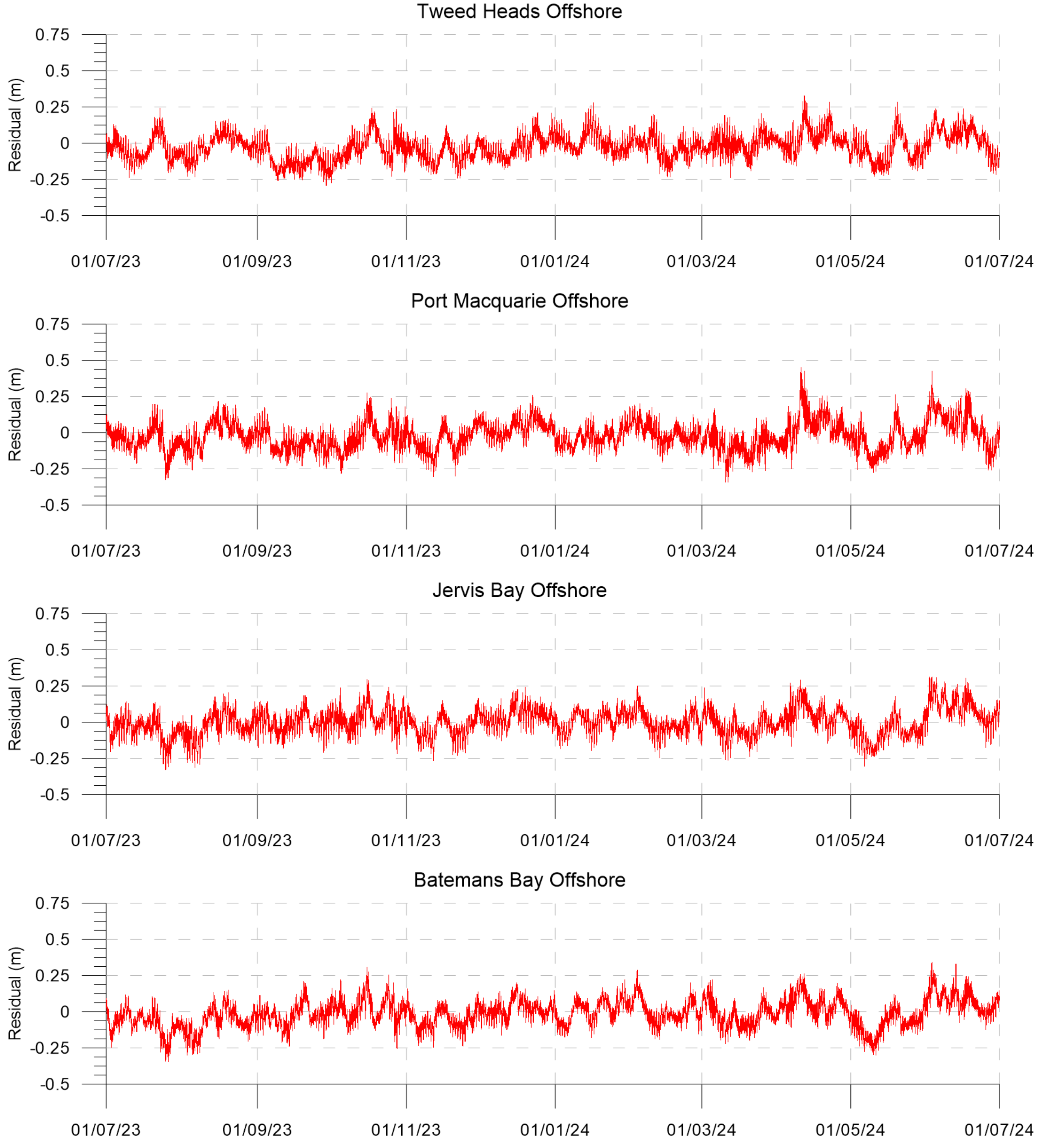
Report MHL3065
Figure
4-8



TIDAL ANOMALIES
2023–24
OFFSHORE TIDE GAUGES

NSW GOVERNMENT

Manly Hydraulics Laboratory

Report MHL3065
Figure
4-9

4.2 Tsunami events

Table 4-2 lists the earthquake events that had associated tsunami events in the Pacific region that occurred within the 2023–24 financial year. Earthquake events included in the list are those that have a moment magnitude (M_w) of greater than or equal to 6 Mw (NOAA 2023).

Table 4-2 Recorded earthquake events from July 2023 to June 2024

Date (UTC)	Event	Location	Observable on NSW tide recordings
22/11/2023	Earthquake (6.7 M_w)	Vanuatu – Vanuatu Islands	No
07/12/2023	Earthquake (7.1 M_w)	Vanuatu – Vanuatu Islands	No

Source: National Oceanic and Atmospheric Administration (NOAA) National Geophysical Data Centre / World Data Service, NCEI/WDS Global Historical Tsunami Database https://www.ngdc.noaa.gov/hazard/tsu_db.shtml

In the last quarter of 2023, there were two earthquake events that occurred at the Vanuatu Islands. These earthquakes had moment magnitude of 6.7 and 7.1, however these were not observed on NSW tide recordings.

4.3 King tide events

Over the 2023–24 financial year, the dates of predicted king tides were 4 July 2023, 2 August 2023, 13 January 2024, 8 May 2024, and 6 June 2024. The highest recorded actual water level associated with a spring tide in Sydney was 1.20 m AHD (1971) in July 2023.

The highest actual water level recorded at the Sydney gauge during the 2023–24 financial year was 1.23 m AHD (1971) on 8 June 2024. This high water level was one of the several events in 2023–24 that created a high anomaly value or residual level (difference between actual and predicted tide) above 0.25 m at the Sydney gauge. This was driven by a combination of a spring tide and a low pressure system off the coast of NSW, as highlighted in **Figure 4-4**.

4.4 Seiche wave events

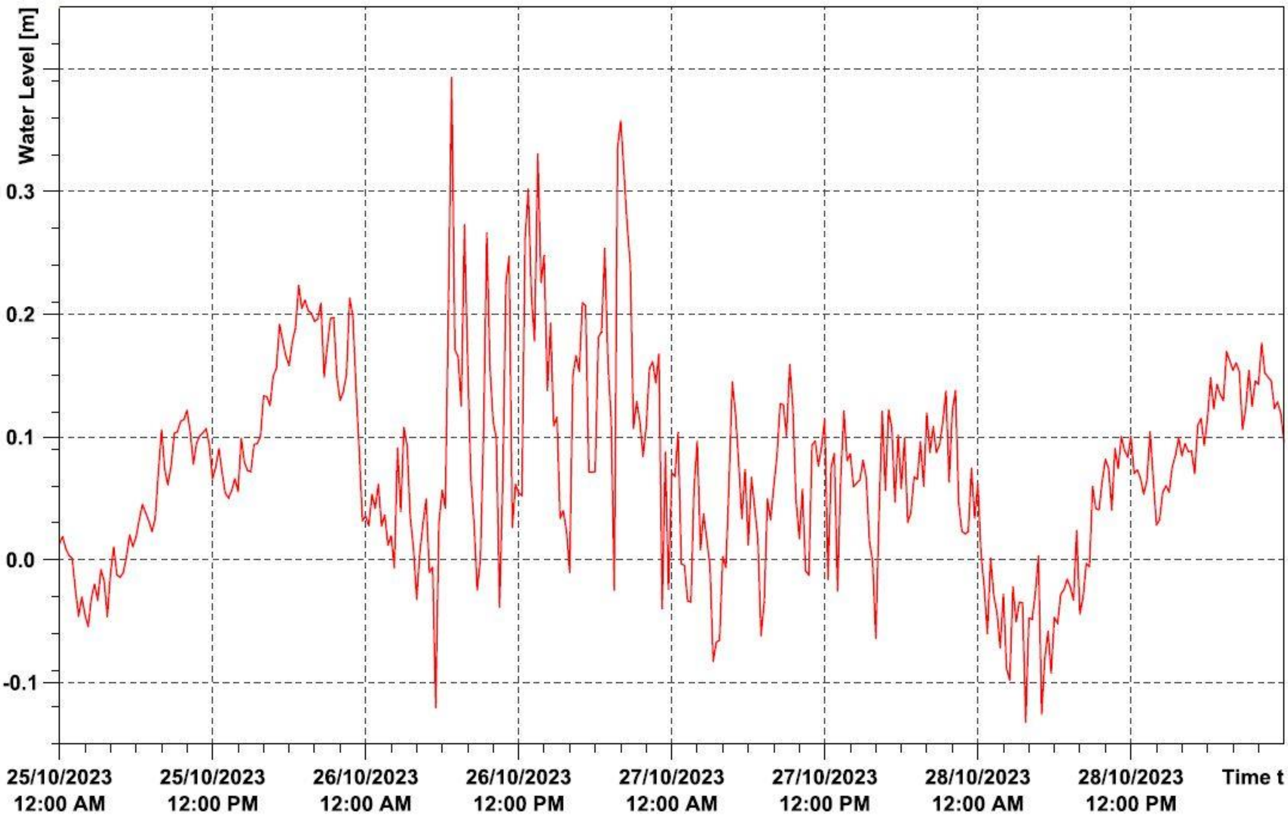
Coastal harbours are often subject to periodic surface water level and current speed oscillations (‘seiche’) in the range of 1 minute and longer. These oscillations can impede harbour operations by causing vessels to surge and sway at their berth; strain or break mooring lines; or cause other damage through overtopping or scour. Seiche waves can have multiple sources of disturbance that include storm front, tsunamis, meteo tsunamis and coastally trapped waves. At 00:00 26 October 2023 there was a sharp decrease measured in the Coffs Harbour ocean tide gauge residual followed by continued oscillations where a max residual wave over 0.5m was recorded (**Figure 4-10**). Conditions that contribute to the seiche wave event include the rapid change in swell direction from Easterly to South

Westerly recorded by the Coffs Harbour wave buoy, and the significant wave height (Hsig) building rapidly from 4m to 8m by 27 October 2023. The synoptic chart from this event confirms the strong southerly low pressure fed swell and wind conditions (**Figure 4-11**). The magnitude of the maximum residual waves were 0.50m in comparison with the 2022 Hunga Tonga–Hunga Haʻapai tsunami event (0.95m), and no known damage was reported during the event.

4.5 Lord Howe Island negative anomalies

Negative anomalies are usually generated with sustained high pressure systems which force down on water levels causing them to under range on predicted peaks. Lord Howe Island (LHI) is a unique system however, located further into the north Tasman Sea and has greater exposure to sea level variability than the NSW coastline. The variability is derived from volatility in the Eastern Australian Current (EAC). The EAC is seasonal, where sea temperature can drive current patterns, which can compound water level anomalies.

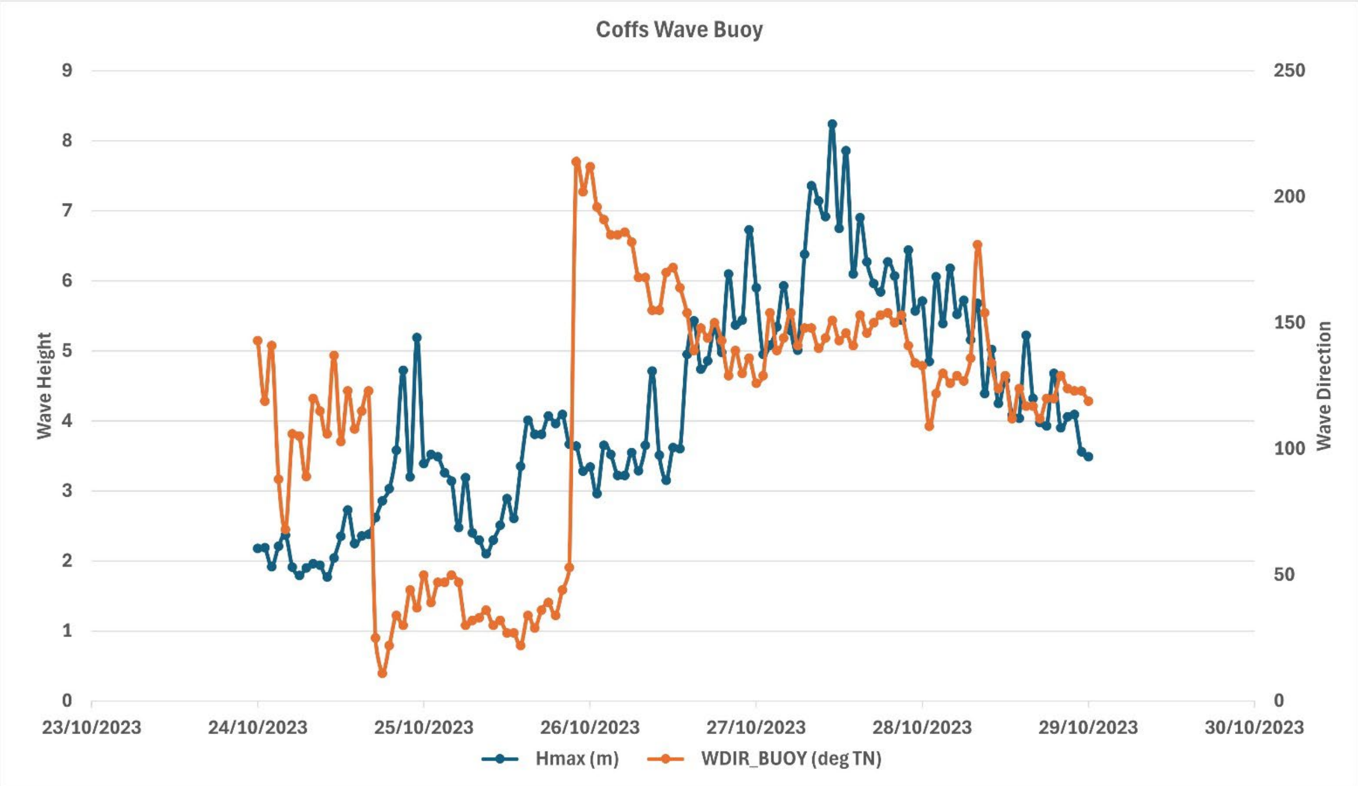
A sustained negative anomaly event occurred through April and May 2024 at LHI. This type of event has been documented by the Lord Howe Island Board (LHIB) and their private contract supplier of goods to the island. As per the LHIB notes on reasons for delayed goods in May 2024 “low tides in May 2024, which are impeding the *Island Trader’s* passage from entering and departing the LHI lagoon”. These events can prevent supplies reaching the island as there is no safe entry or exit through the reef to the main wharf where the ship anchors to deliver supplies. The recorded water level data for this event is shown in **Figure 4-12** where the recorded water level remains below the predicted through April and May 2024. The Sydney residual is overplotted for context showing a distinct difference in ocean conditions experienced on the NSW mainland to LHI.

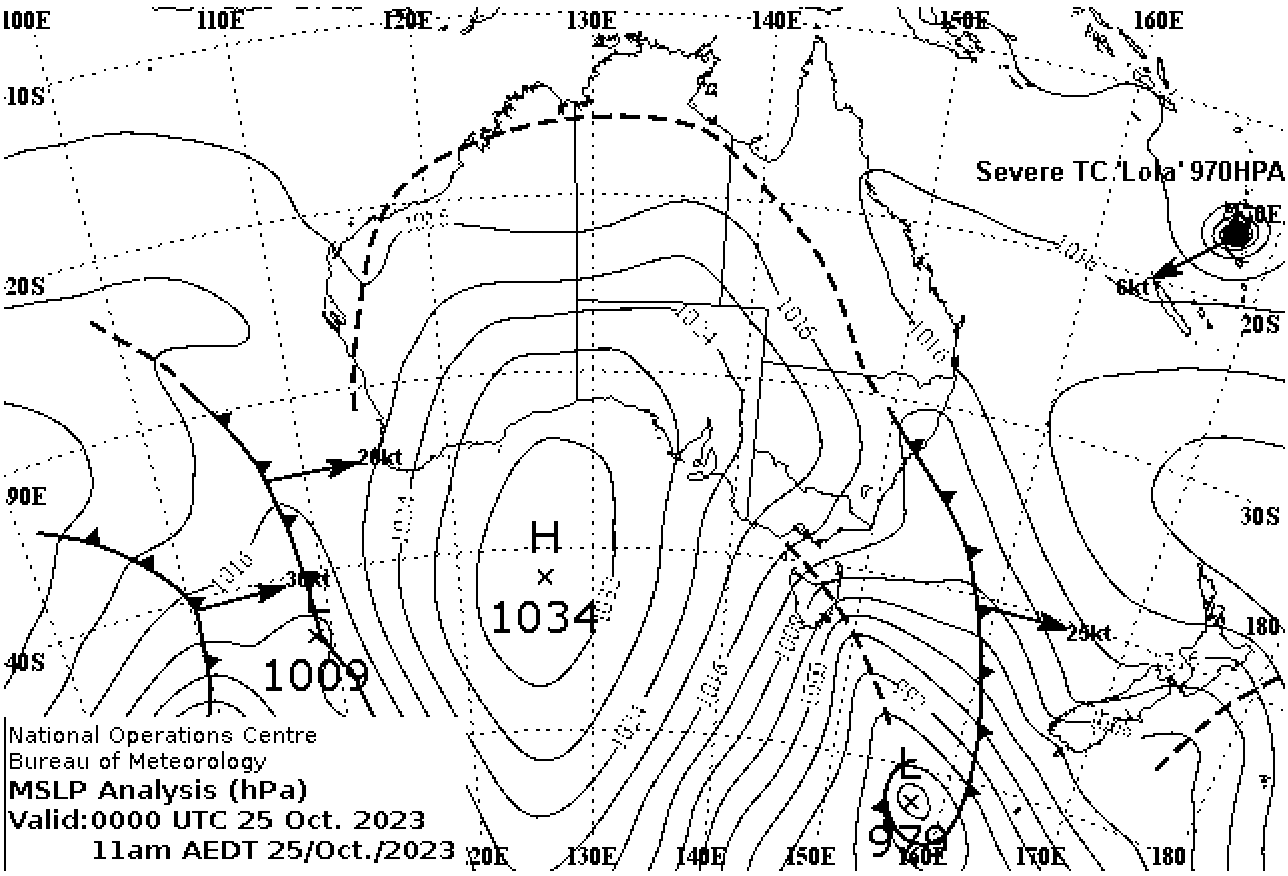


COFFS HARBOUR RESIDUAL DATA DURING 26 OCTOBER 2023 SEICHE WAVE EVENT

Manly Hydraulics Laboratory

Report MHL3065
Figure
4-10





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

NSW GOVERNMENT

COFFS HARBOUR WAVE BUOY DATA
AND SYNOPTIC CHART FOR THE
COFFS HARBOUR SEICHE WAVE EVENT

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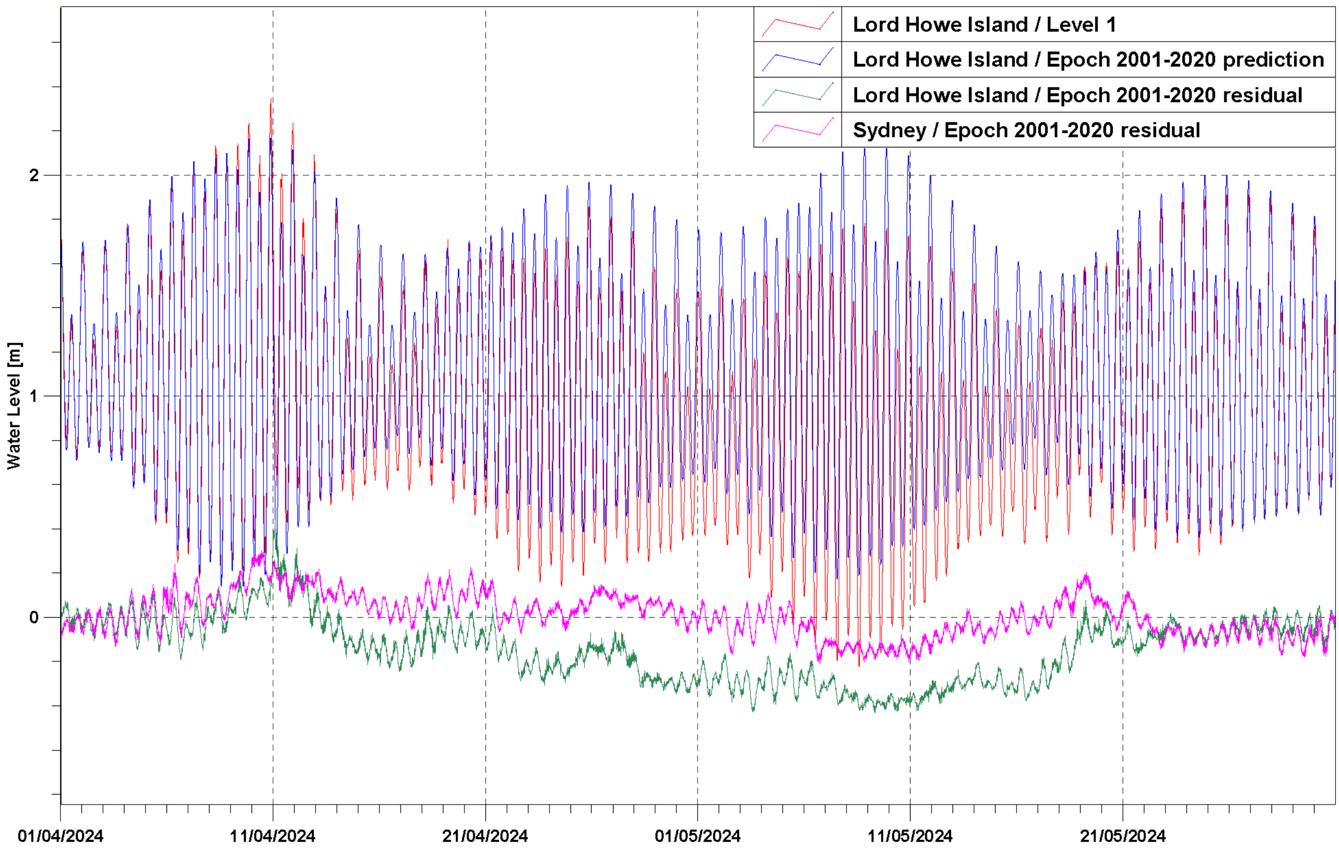
Report MHL3065
Figure
4-11



LORD HOWE ISLAND WATER LEVEL DATA
AND RESIDUAL COMPARISON WITH SYDNEY

Manly Hydraulics Laboratory

Report MHL3065
Figure
4-12

5 Air pressure program summary 2023–24

5.1 Data capture

From July 2023 to June 2024, the overall data recovery for all barometer stations was 99.5%. The small percentage of data loss is mainly contributed by Eden / Wonboyn Lake barometer station. A faulty barometer caused intermittent data loss from December 2023 to March 2024, which was resolved when the barometer was changed on 14 March 2024. This was immediately followed by a 2-week data loss starting 22 March 2024 due to a logger program bug, which was resolved on 03 April 2024. Minor data loss occurred at the Tweed Heads / Kingscliff barometer station in December 2024 due to low battery voltage.

Monthly data recovery during the 2023–24 financial year is shown in **Table 5-1**. **Appendix B** provides the plots of measured air pressure at each site.

Table 5-1 New South Wales air pressure: 2023–24 data capture

Water level / barometer 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	99.6	100	100	100	100	100	100	100
Yamba / Lake Wooloweyah	100	100	100	100	100	100	100	100	100	100	100	100	100
Port Macquarie / Settlement Point	100	100	100	100	100	100	100	100	100	100	100	100	100
Newcastle / Stockton Bridge	100	100	100	100	100	100	100	100	100	100	100	100	100
Sydney / Narrabeen Bridge	100	100	100	100	100	100	100	100	100	100	100	100	100
Jervis Bay / Currarong Creek	100	100	100	100	100	100	100	100	100	100	100	100	100
Tuross Head / Tuross Head	100	100	100	100	100	100	100	100	100	100	100	100	100
Eden / Wonboyn Lake	100	100	100	100	100	99.8	99.9	92.9	68.1	93.1	100	100	96.2

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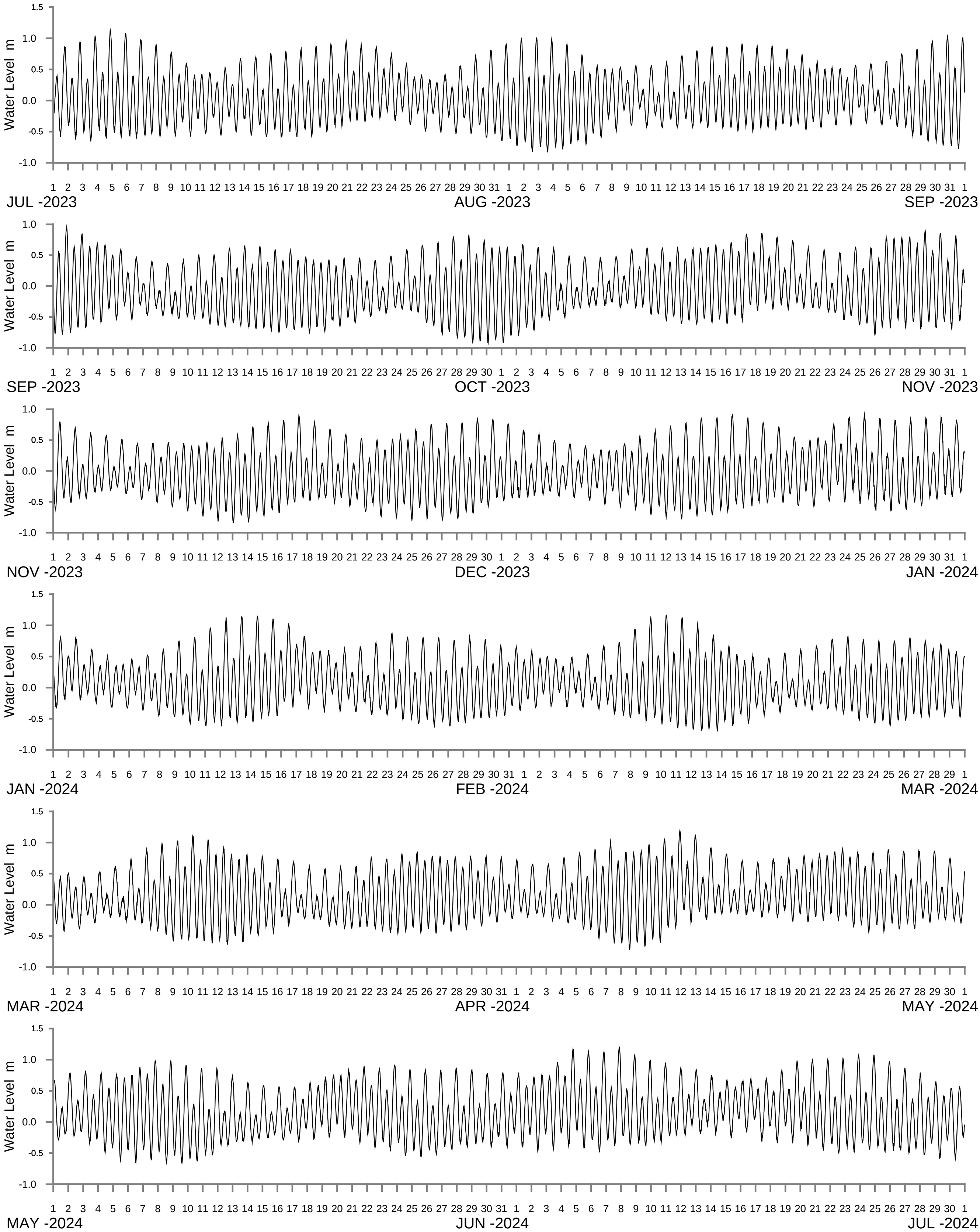
Appendix A Annual tidal station data summaries



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

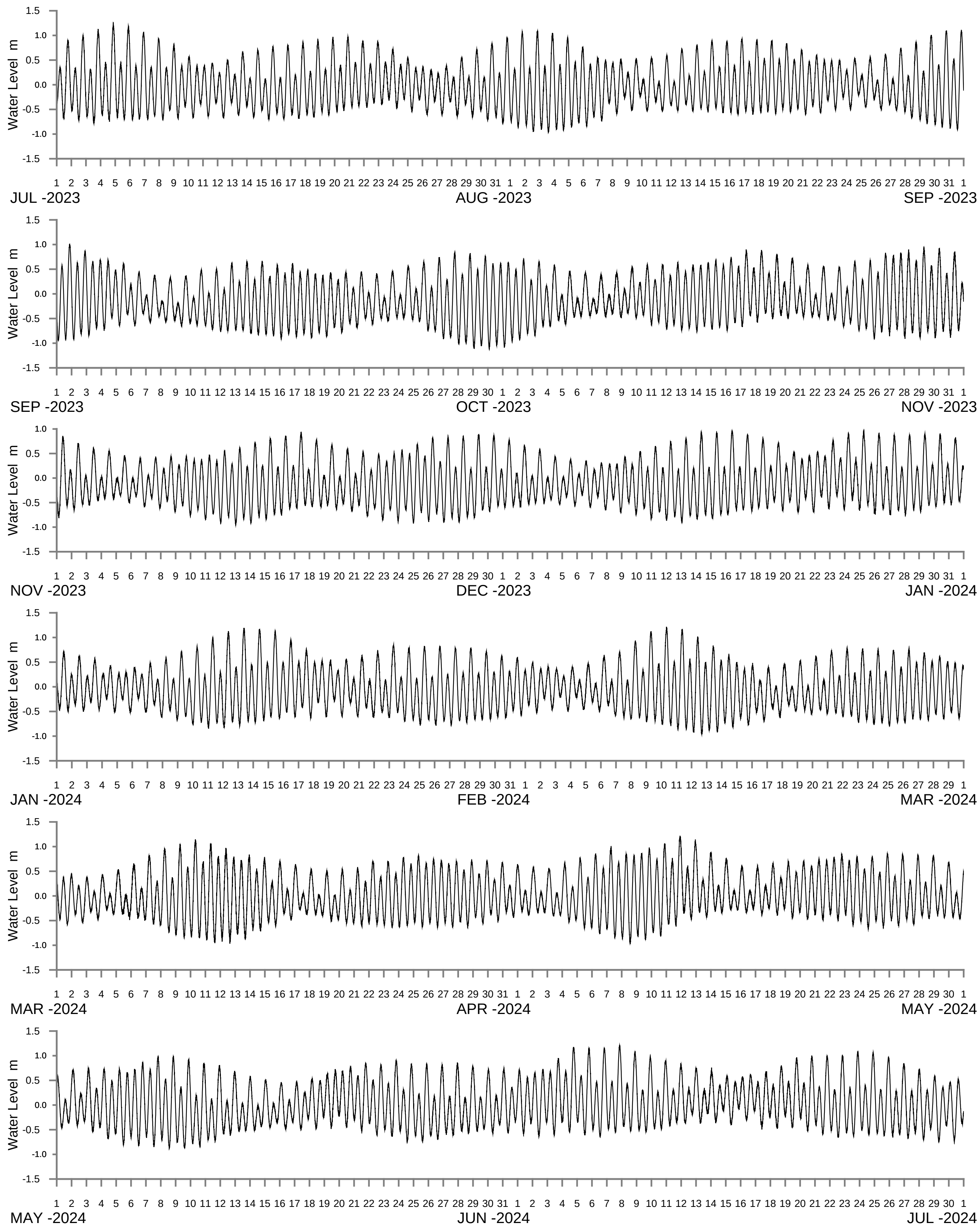
------------ DATA LOSS

NSW GOVERNMENT

TWEED RIVER AT TWEED ENTRANCE SOUTH
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A1



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

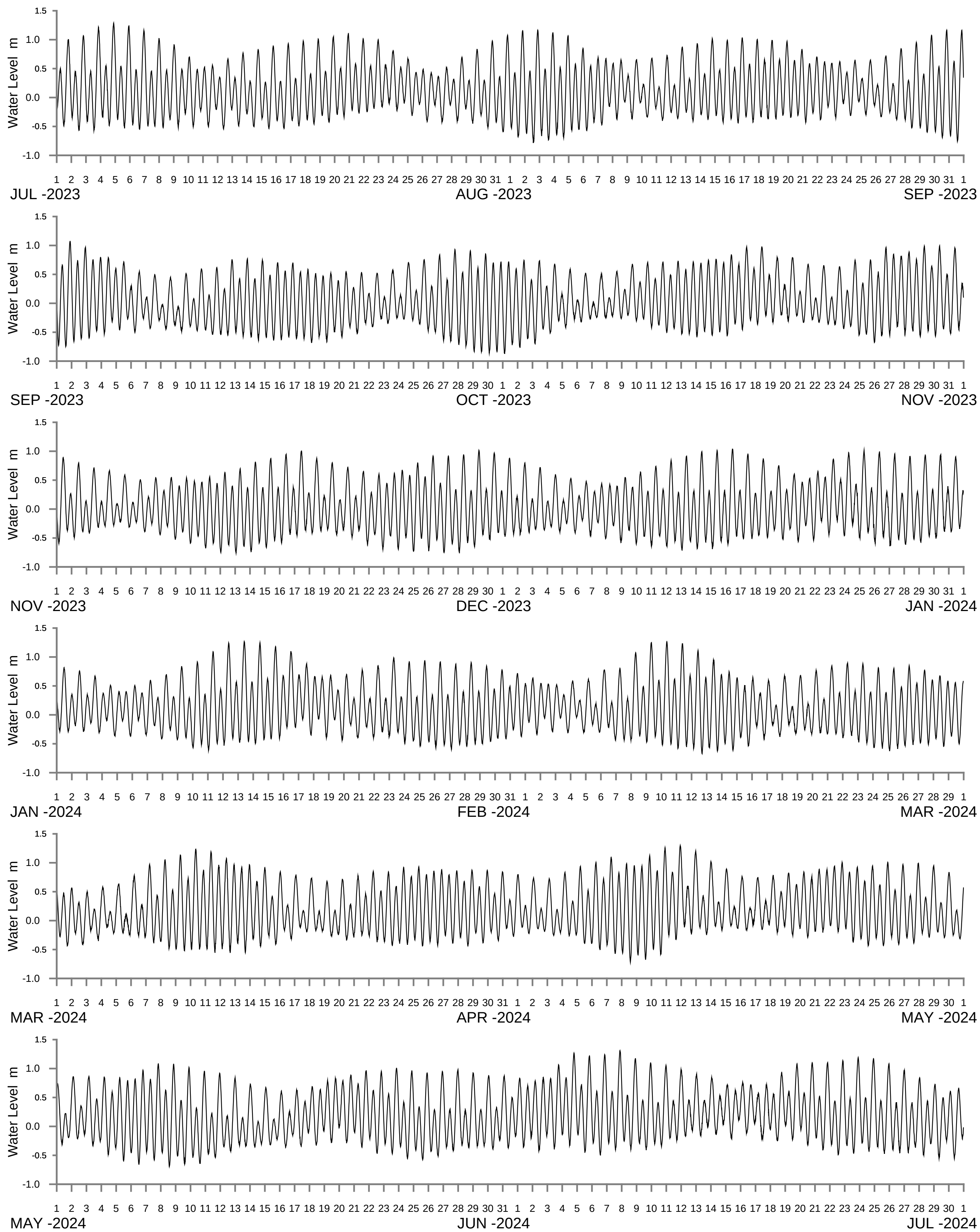
------------ DATA LOSS

NSW GOVERNMENT

TASMAN SEA AT TWEED HEADS OFFSHORE
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A2



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

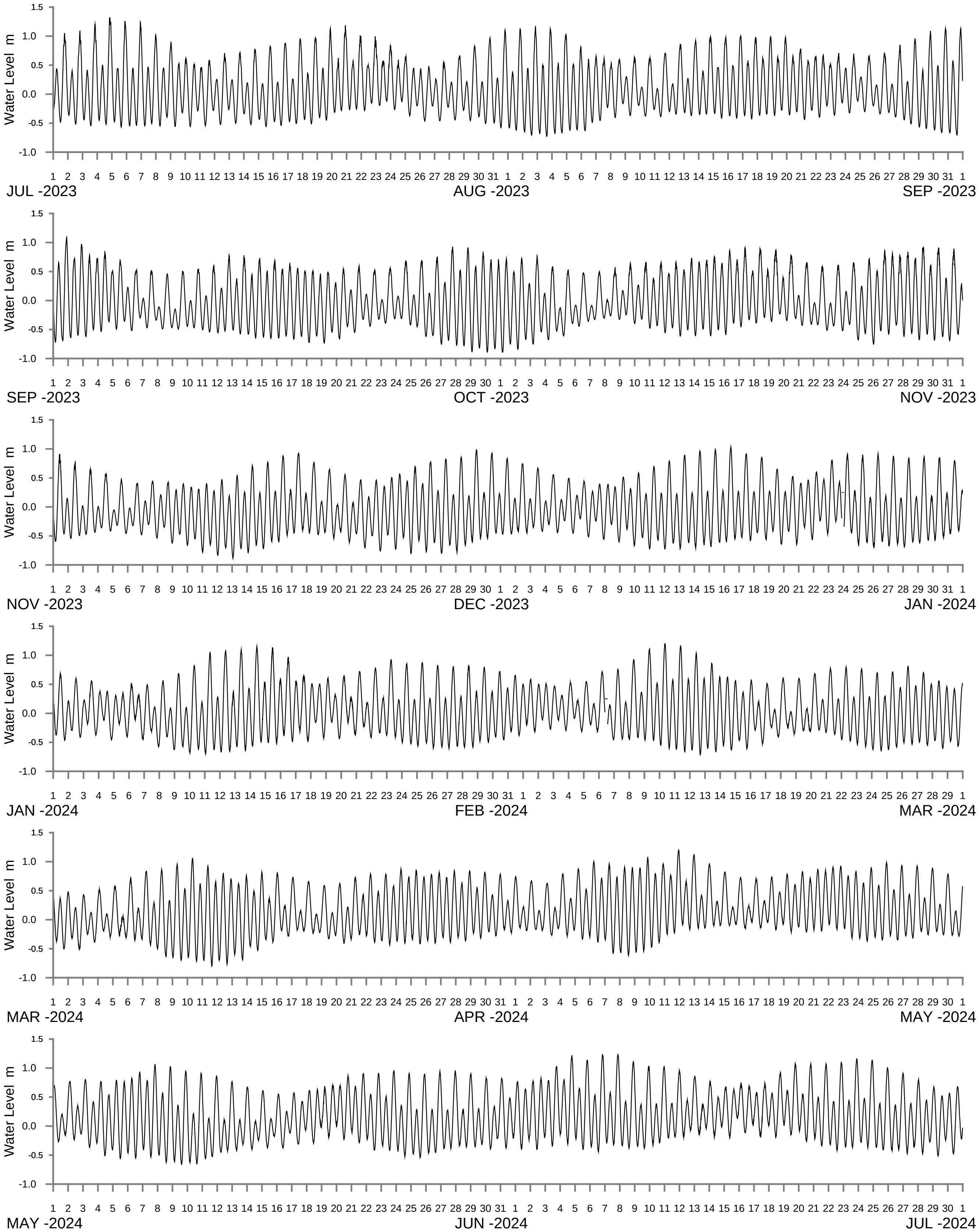
- - - - - - - - - - - - DATA LOSS

NSW GOVERNMENT

BRUNSWICK RIVER AT BRUNSWICK HEADS
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A3



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

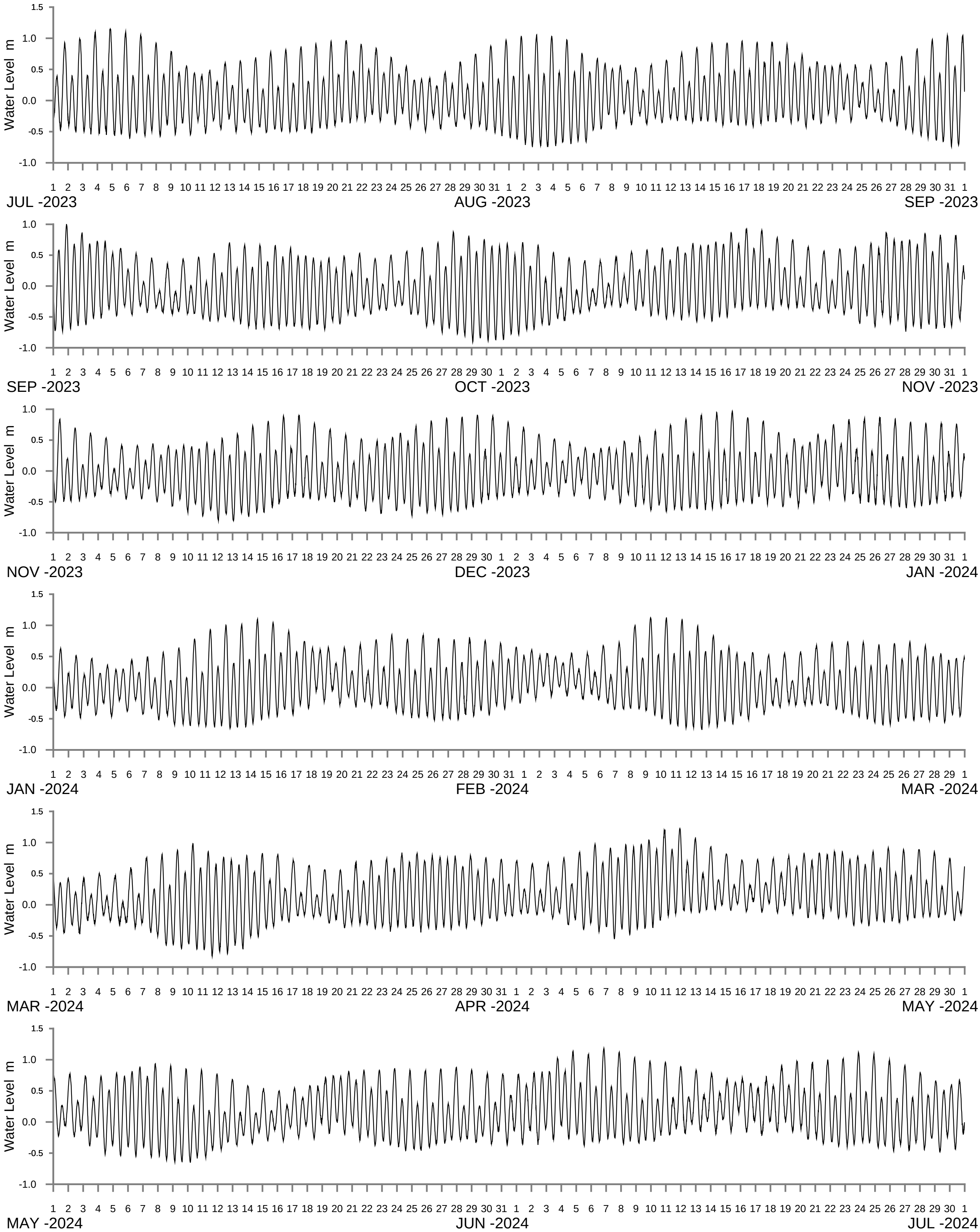
- - - - - - - - - - - - DATA LOSS

NSW GOVERNMENT

RICHMOND RIVER AT BALLINA BREAKWALL
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A4



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

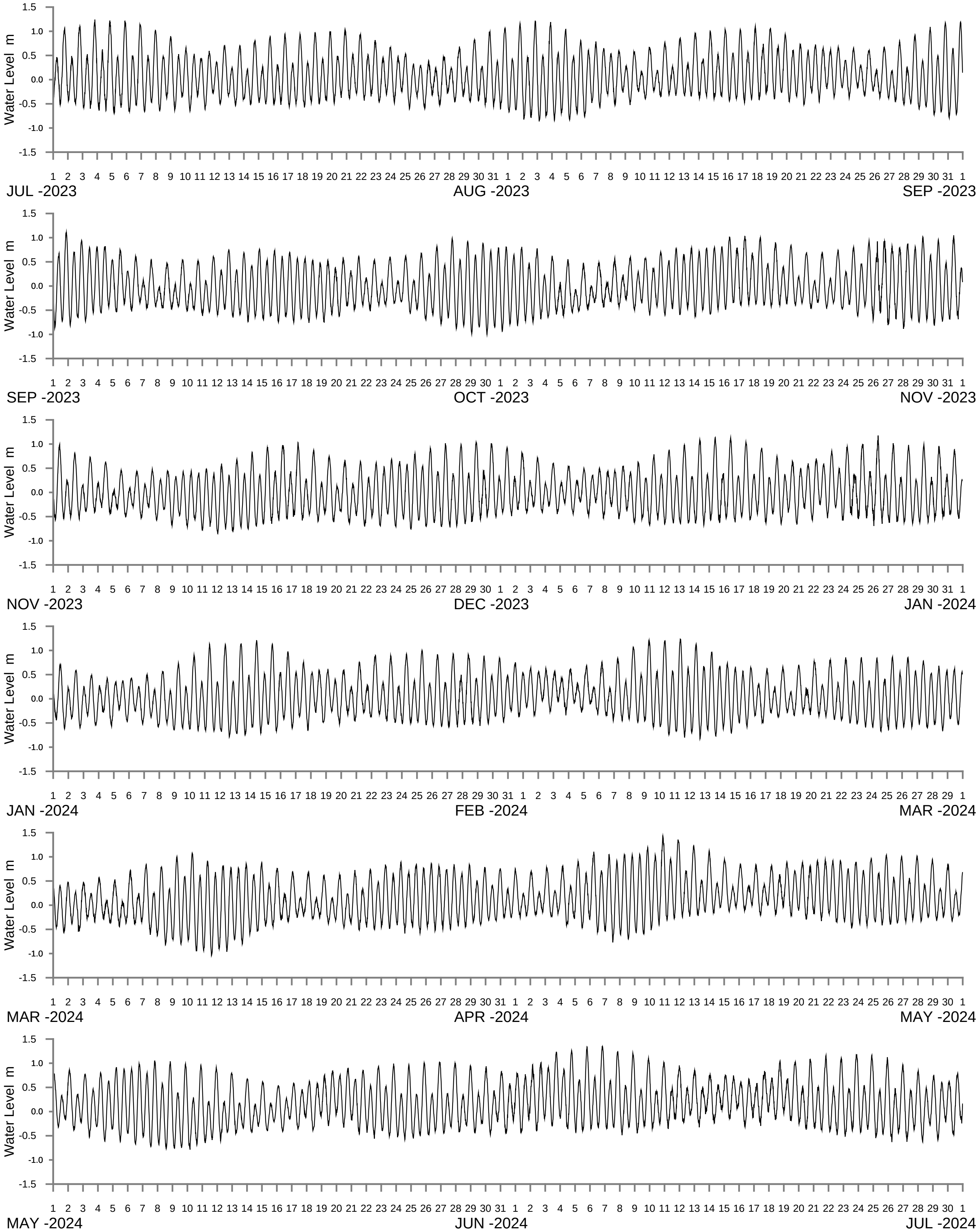
------------ DATA LOSS

NSW GOVERNMENT

CLARENCE RIVER AT YAMBA
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A5



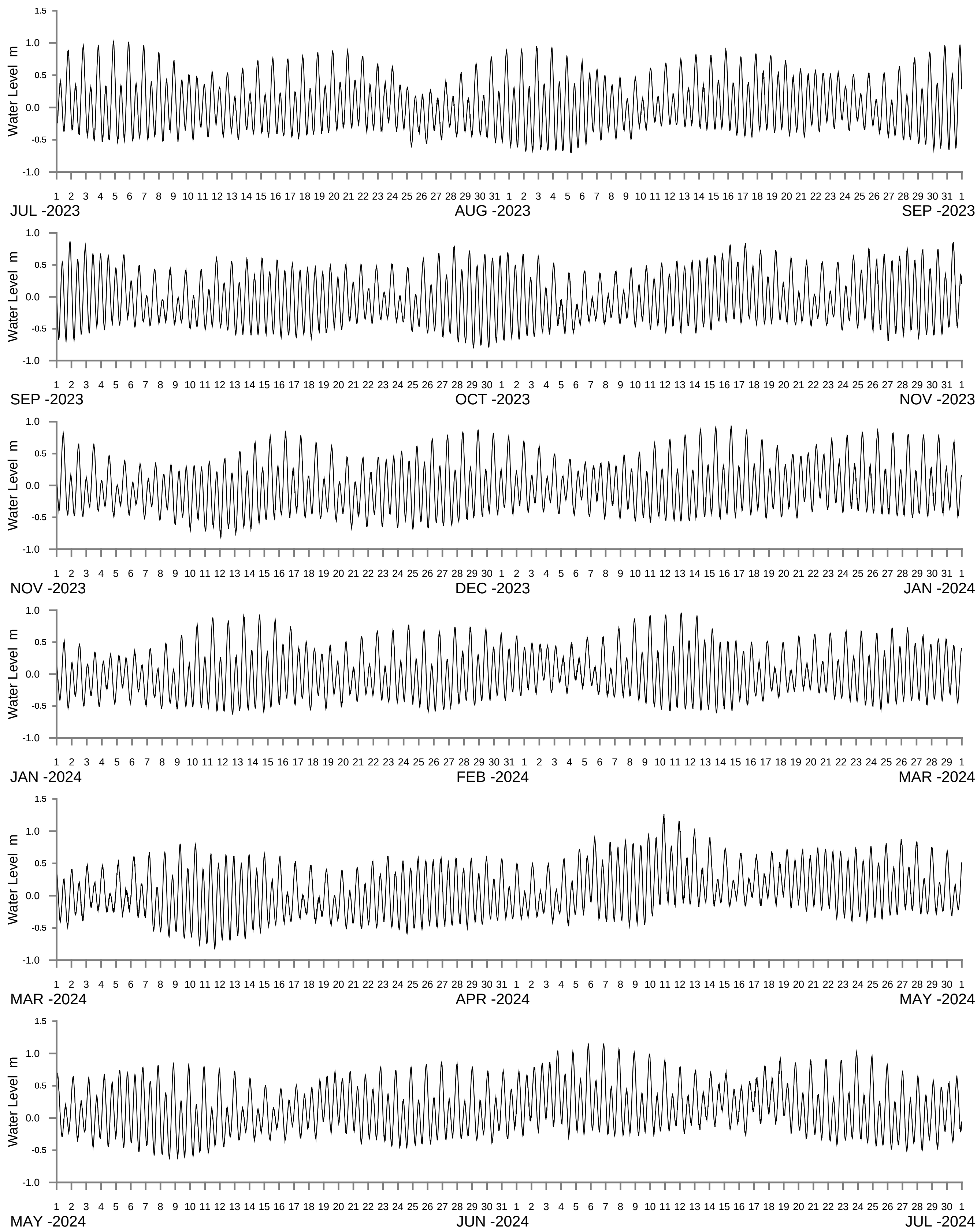
WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

- - - - - - - - - - - - DATA LOSS

COFFS HARBOUR AT COFFS HARBOUR
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A6



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

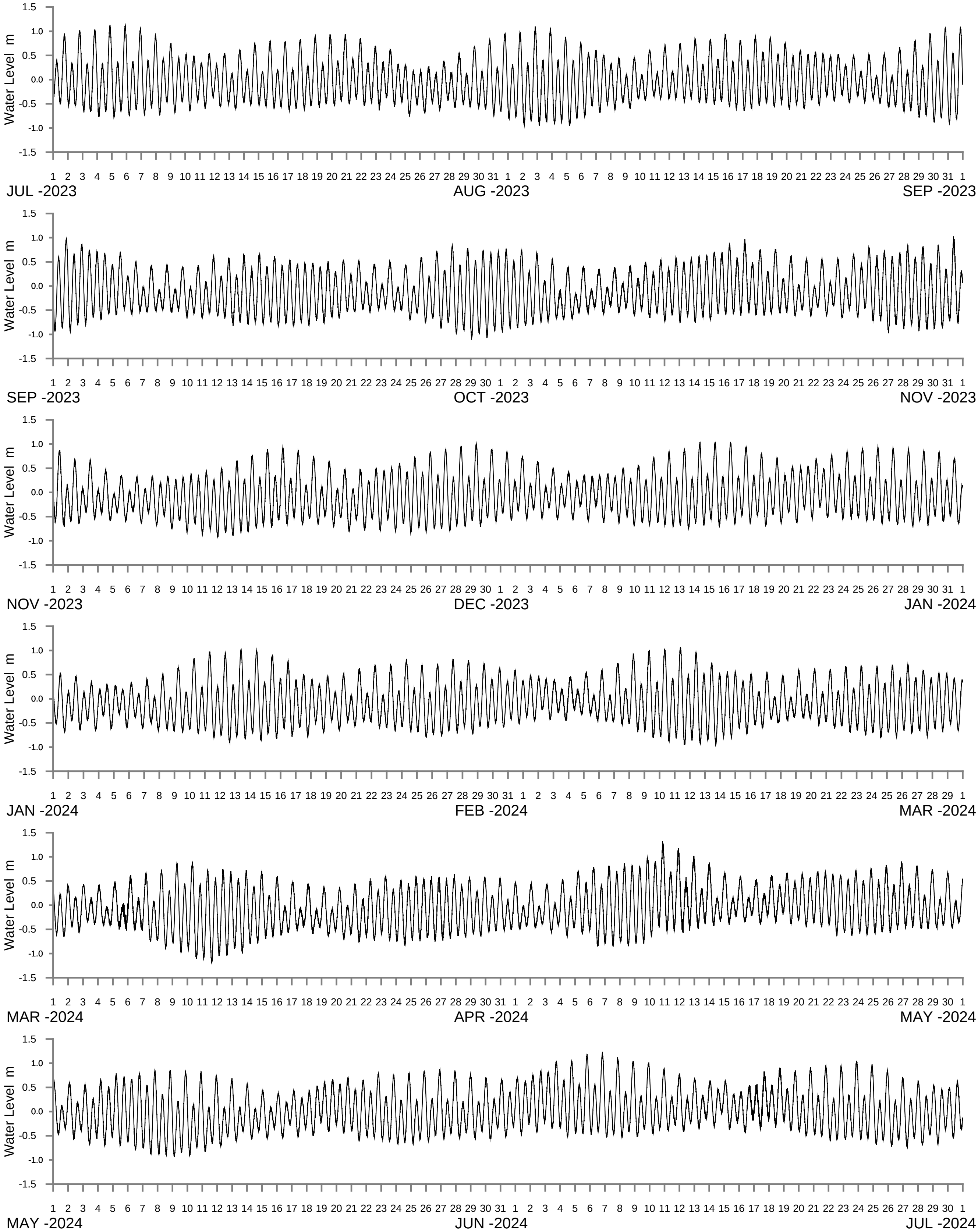
------------ DATA LOSS

NSW GOVERNMENT

HASTINGS RIVER AT PORT MACQUARIE
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A7



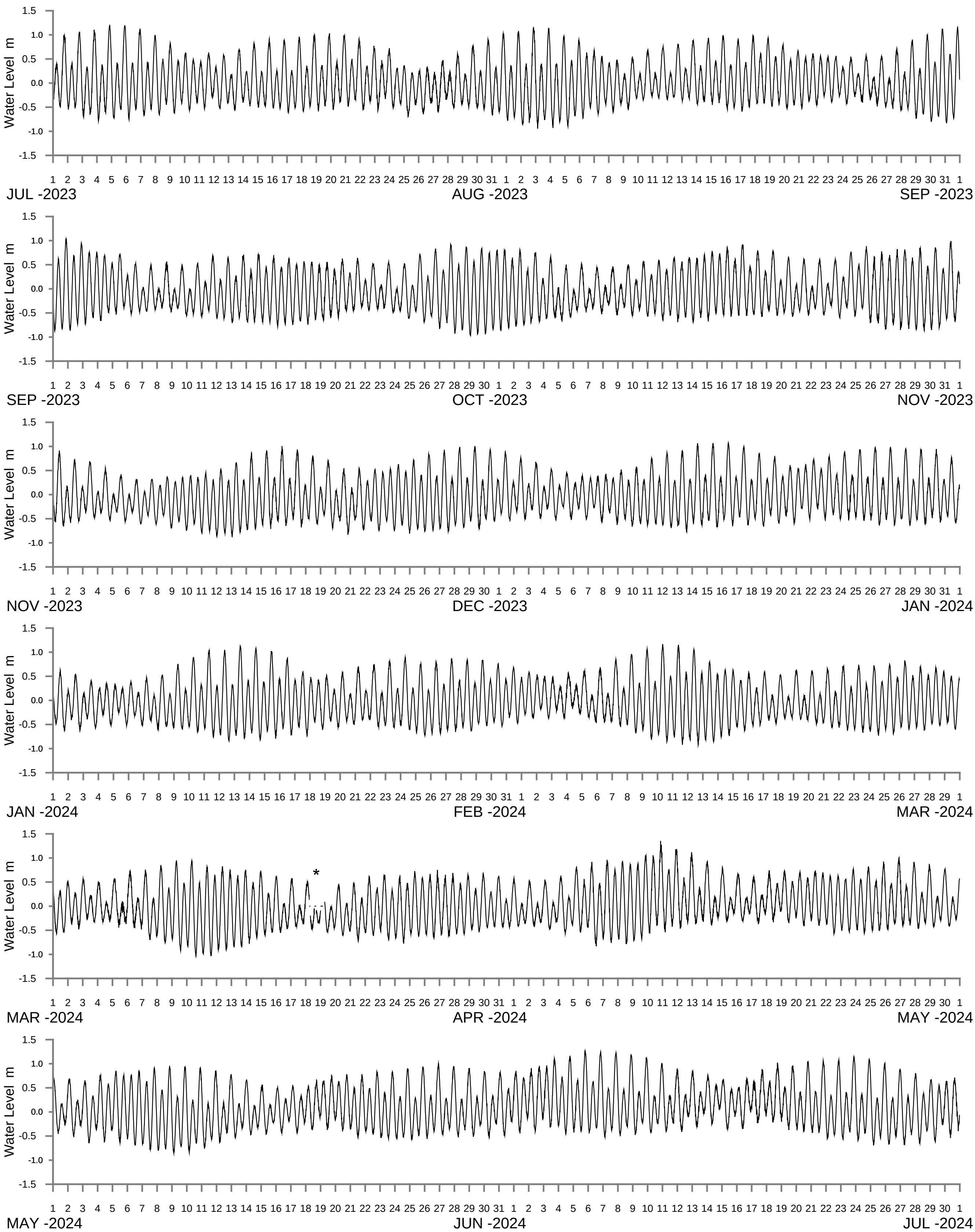
WATER LEVEL REFERENCED TO MEAN SEA LEVEL

------------ DATA LOSS

TASMAN SEA AT PORT MACQUARIE OFFSHORE
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A8



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

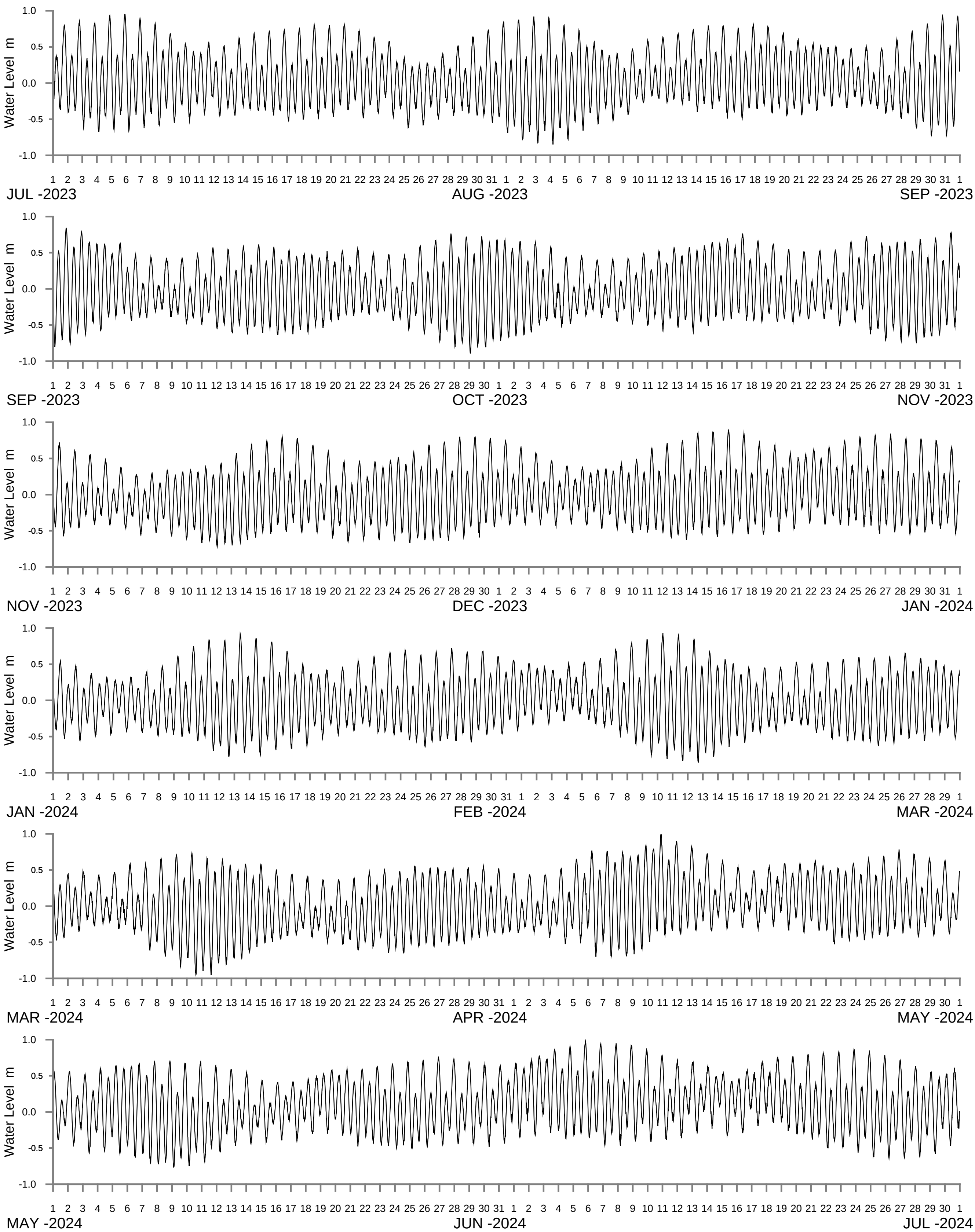
------------ DATA LOSS

*Data loss due to radar interference.

CROWDY HEAD HARBOUR AT CROWDY HEAD BOAT HARBOUR
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A9



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

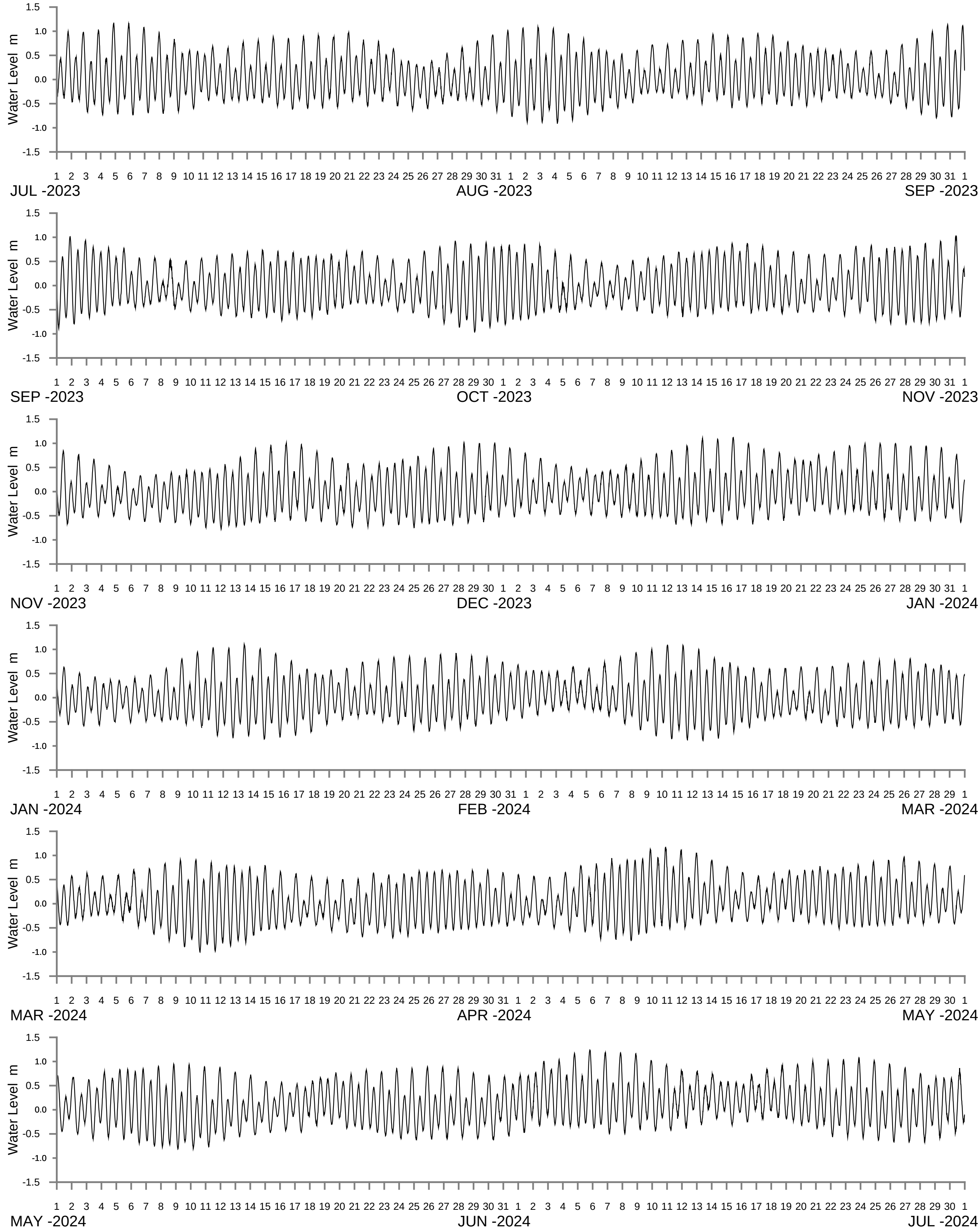
------------ DATA LOSS

NSW GOVERNMENT

WALLIS LAKE ENTRANCE AT FORSTER
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A10



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

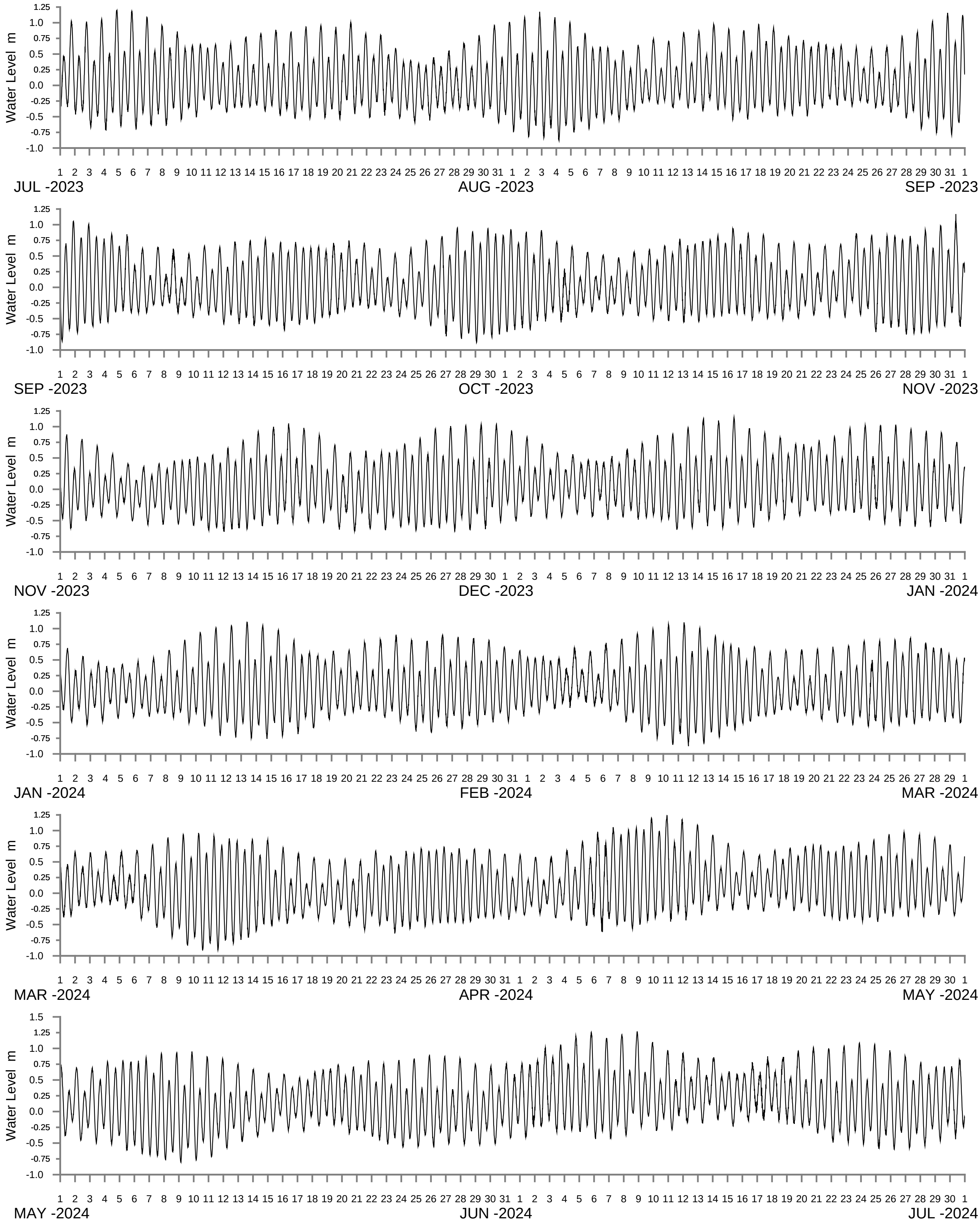
- - - - - - - - - - - - DATA LOSS

NSW GOVERNMENT

PORT STEPHENS AT SHOAL BAY
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A11



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

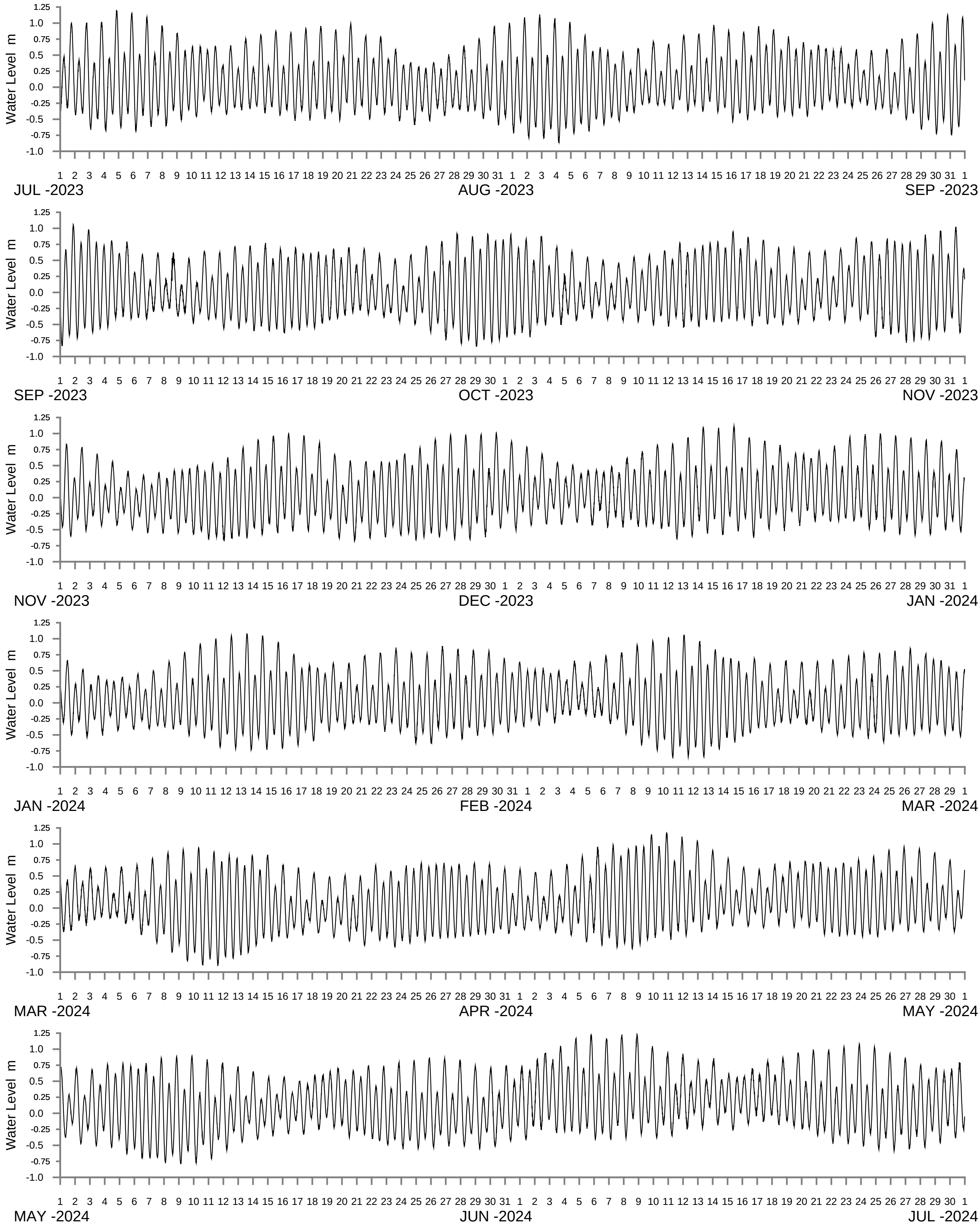
- - - - - - - - - - - - DATA LOSS

NSW GOVERNMENT

HAWKESBURY RIVER AT PATONGA
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A12



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

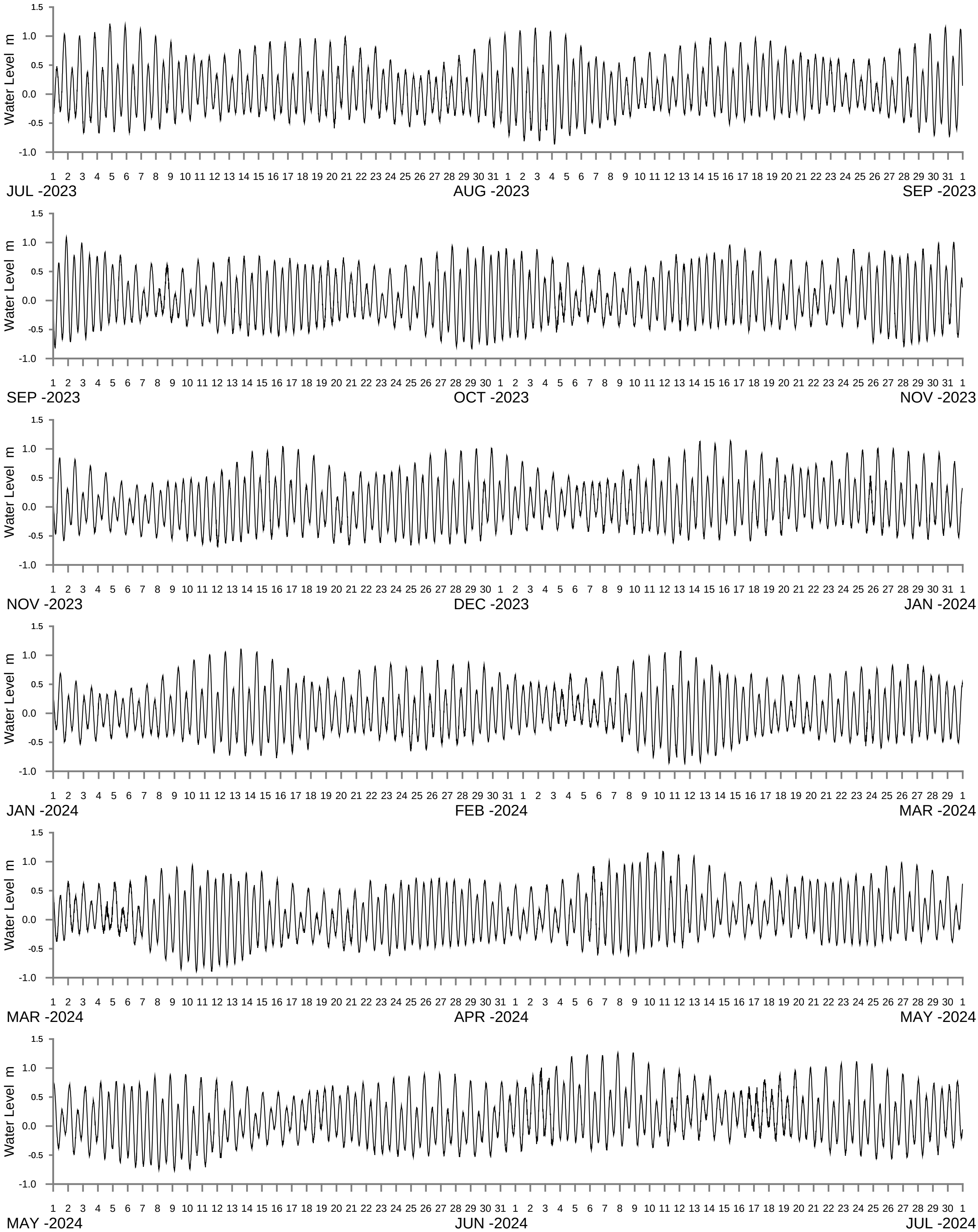
- - - - - - - - - - - - DATA LOSS

NSW GOVERNMENT

SYDNEY PORT JACKSON AT HMAS PENGUIN
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A13



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

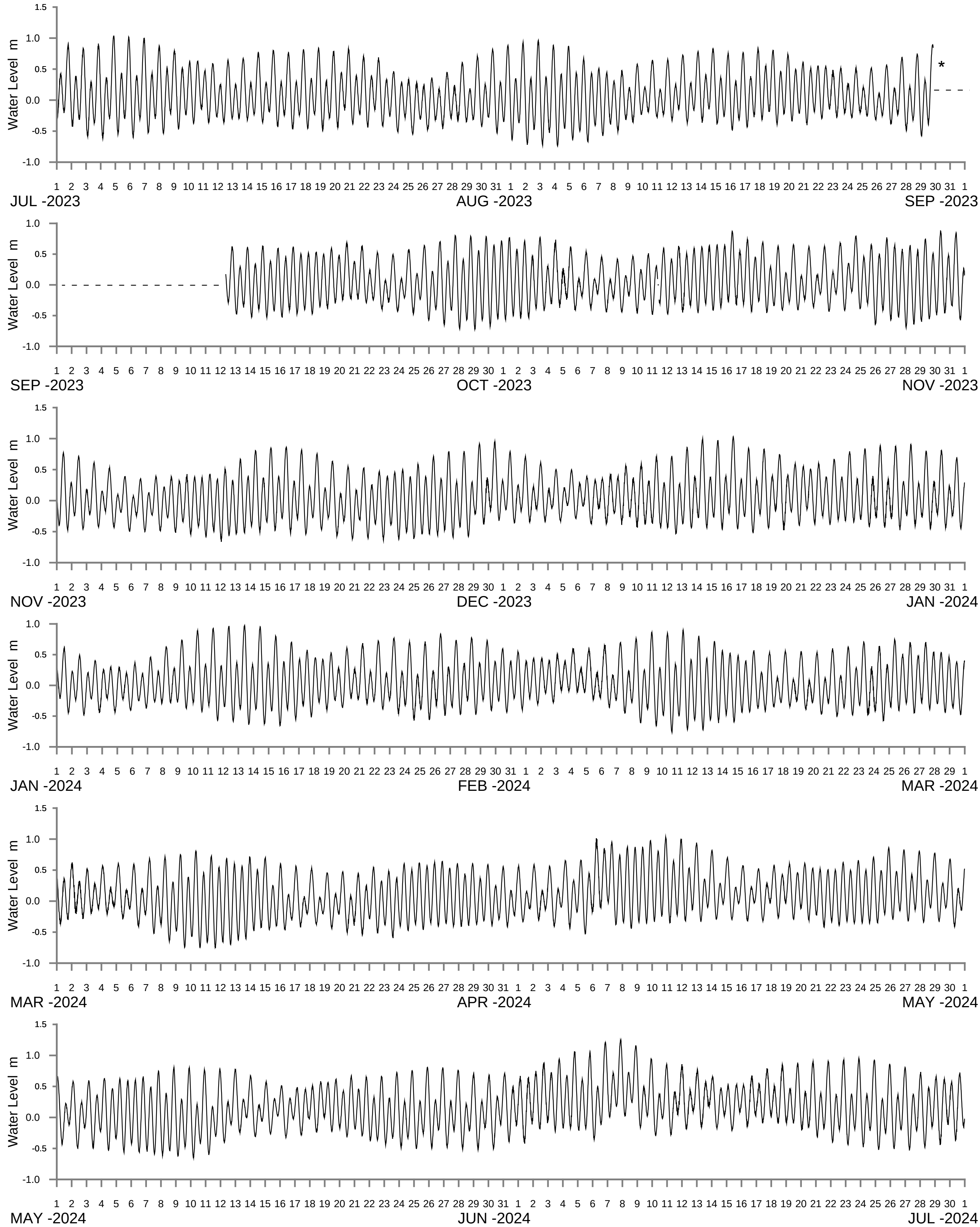
------------ DATA LOSS

NSW GOVERNMENT

PORT HACKING AT BUNDEENA
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A14



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

- - - - - - - - - - - - DATA LOSS

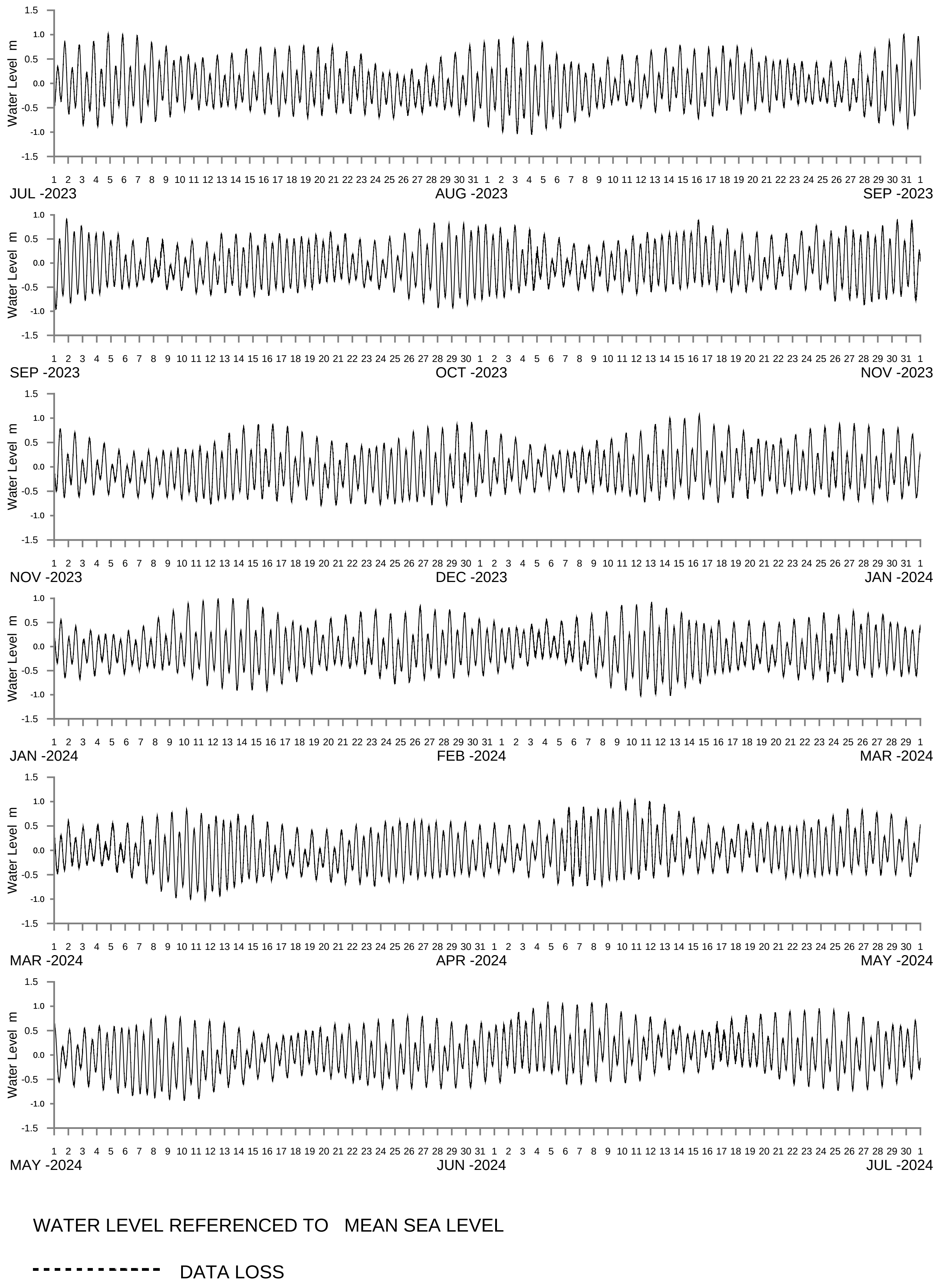
*Data loss due to orifice issue.

NSW GOVERNMENT

CROOKHAVEN RIVER AT CROOKHAVEN HEADS
2023–24

Manly Hydraulics Laboratory

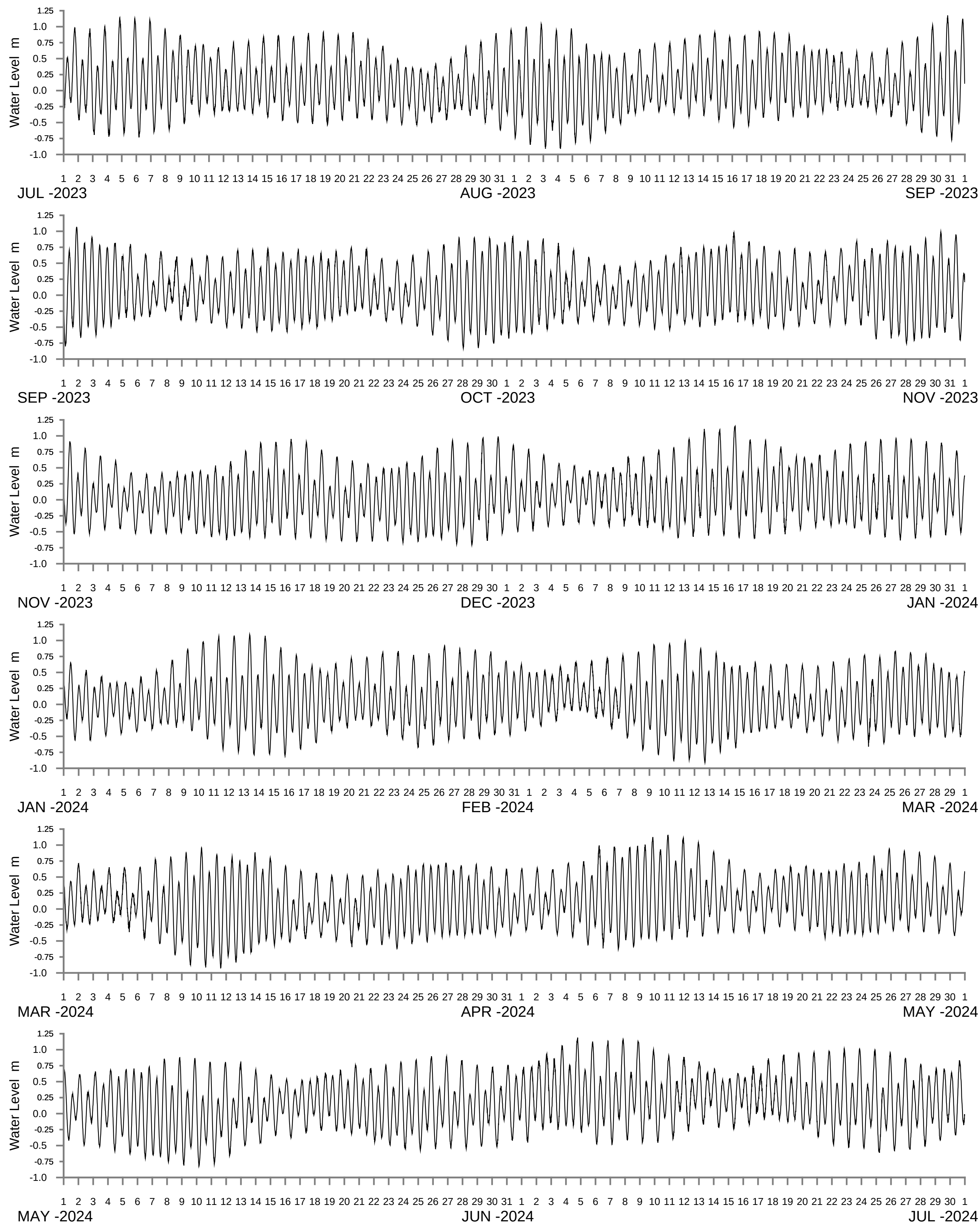
Report MHL3065
Figure
A15



TASMAN SEA AT JERVIS BAY OFFSHORE
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A16



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

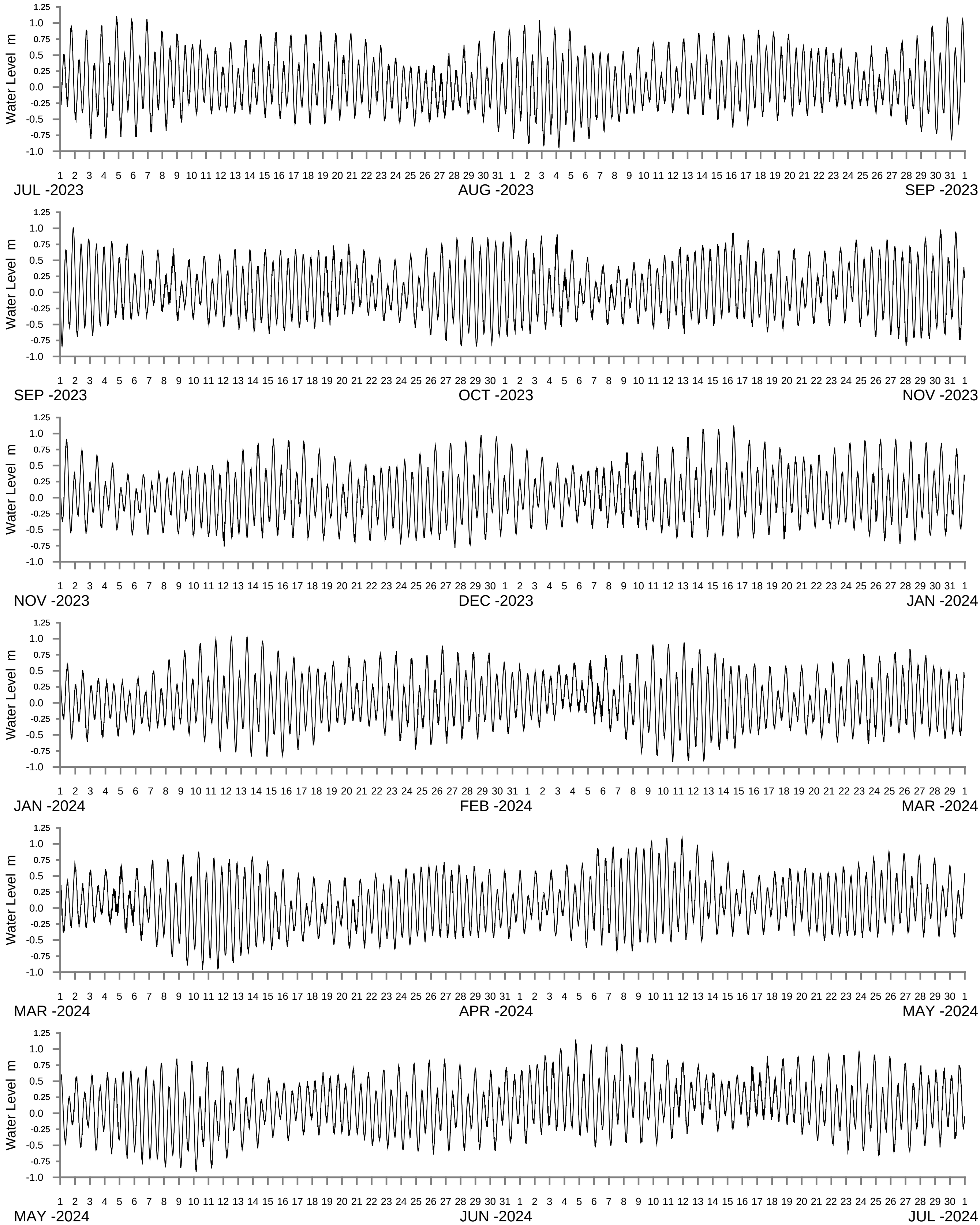
------------ DATA LOSS

NSW GOVERNMENT

JERVIS BAY AT HMAS CRESWELL
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A17



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

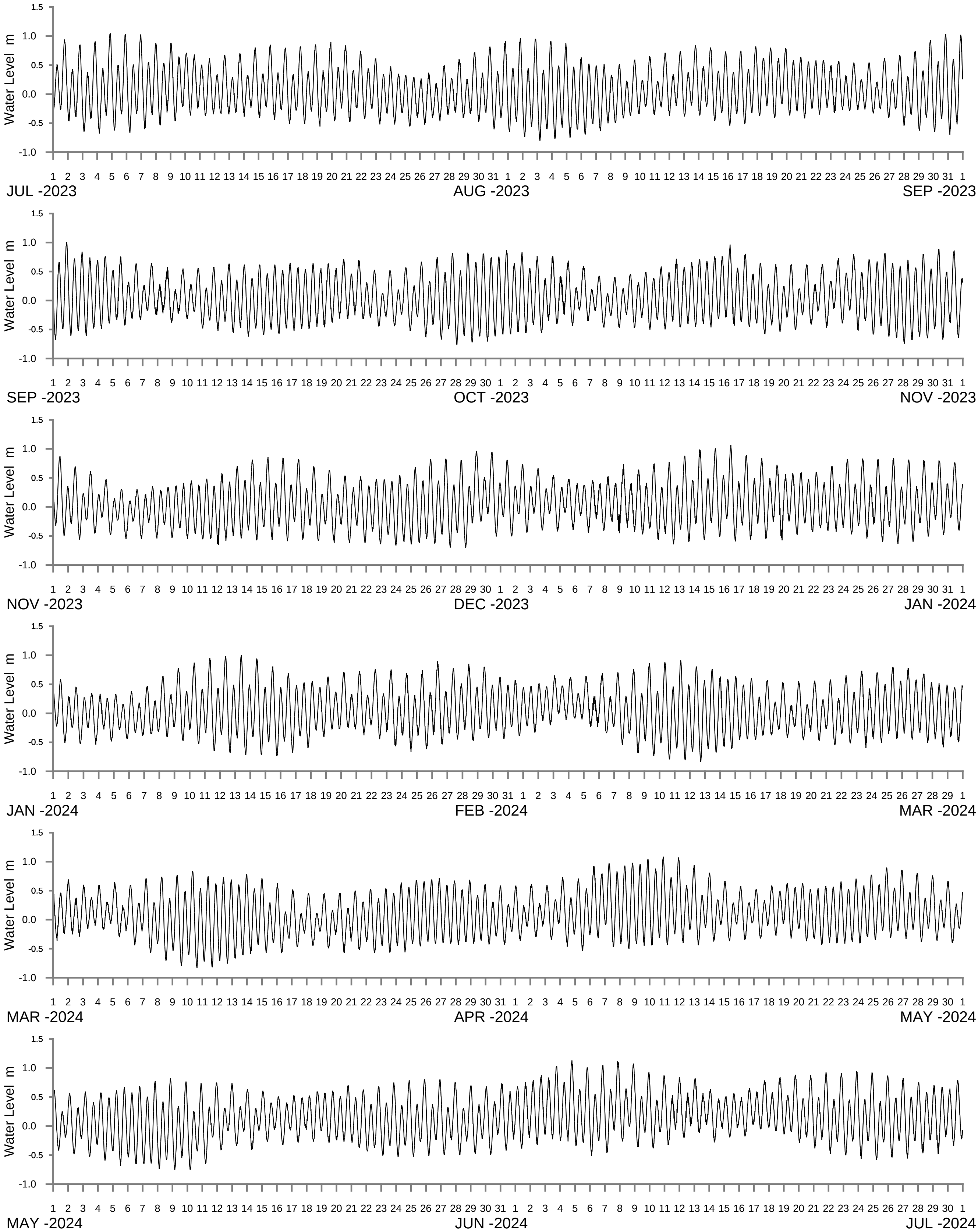
------------ DATA LOSS

NSW GOVERNMENT

ULLADULLA HARBOUR AT ULLADULLA BOAT HARBOUR
2023–24

Manly Hydraulics Laboratory

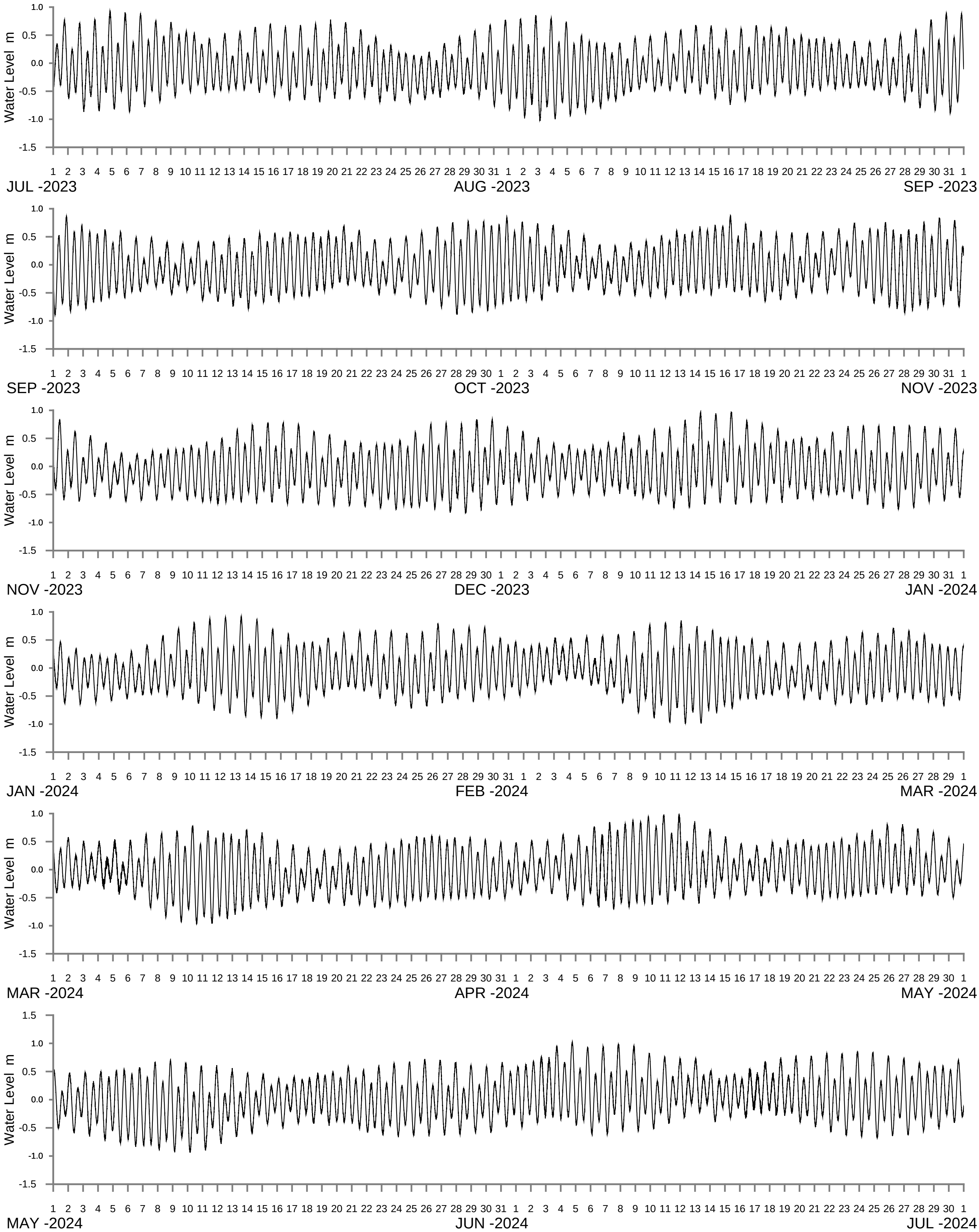
Report MHL3065
Figure
A18



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

------------ DATA LOSS

NSW GOVERNMENT	BATEMANS BAY CLYDE RIVER AT PRINCESS JETTY 2023–24	Manly Hydraulics Laboratory Report MHL3065 Figure A19



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

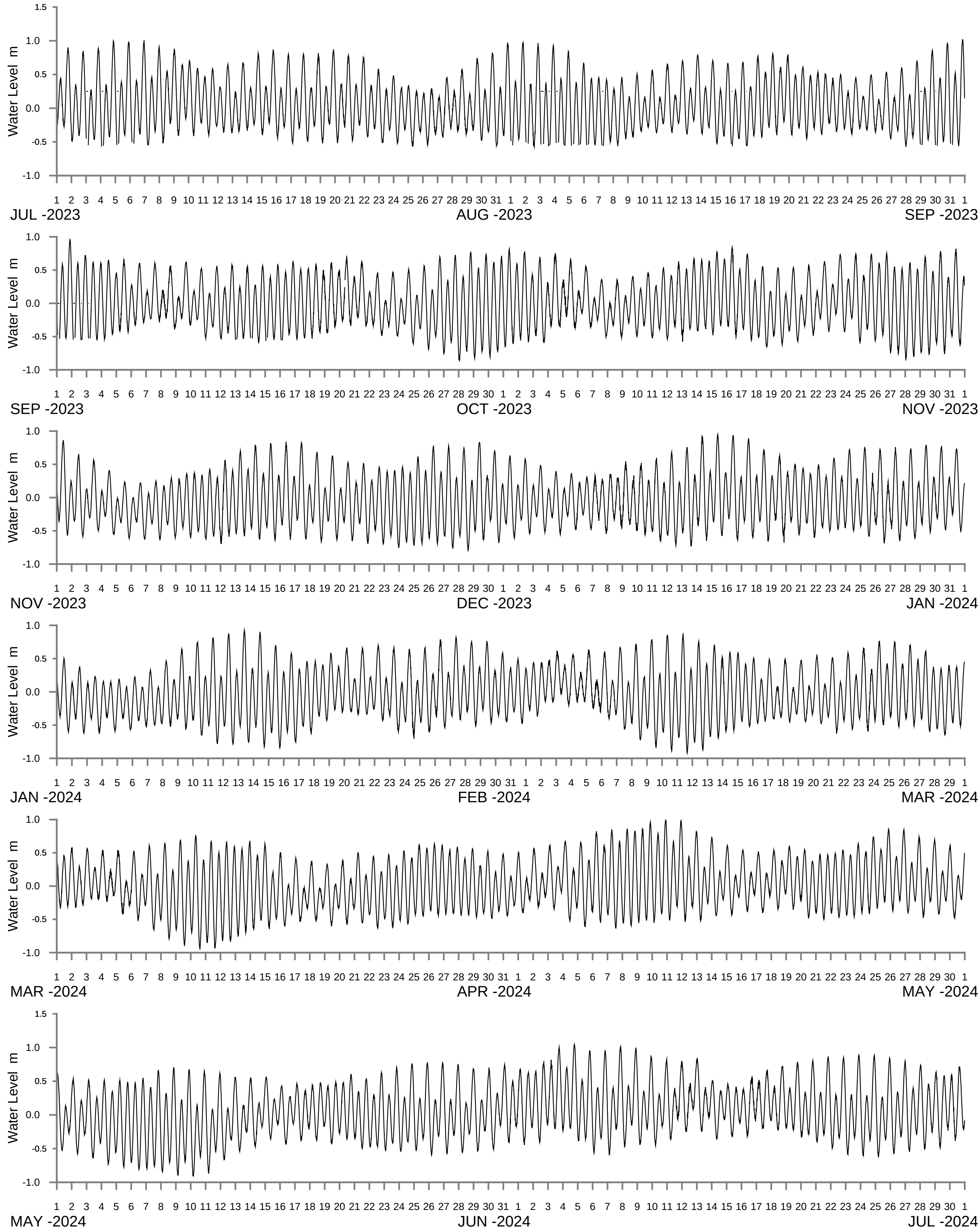
- - - - - - - - - - - - DATA LOSS

NSW GOVERNMENT

TASMAN SEA AT BATEMANS BAY OFFSHORE
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A20



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

- - - - - - - - - - - - DATA LOSS

NSW GOVERNMENT

BERMAGUI RIVER AT BERMAGUI
2023–24

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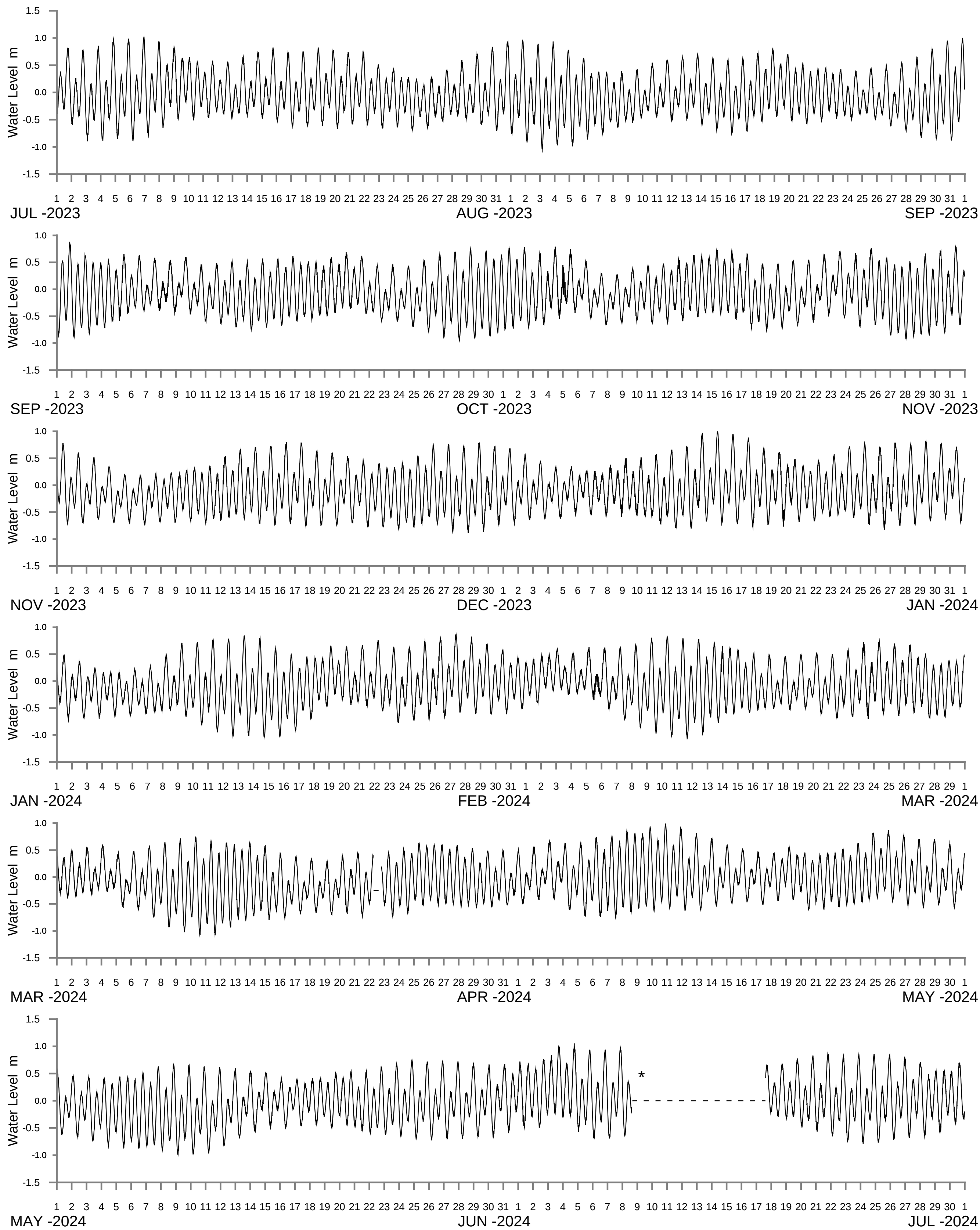
Report MHL3065
Figure
A21

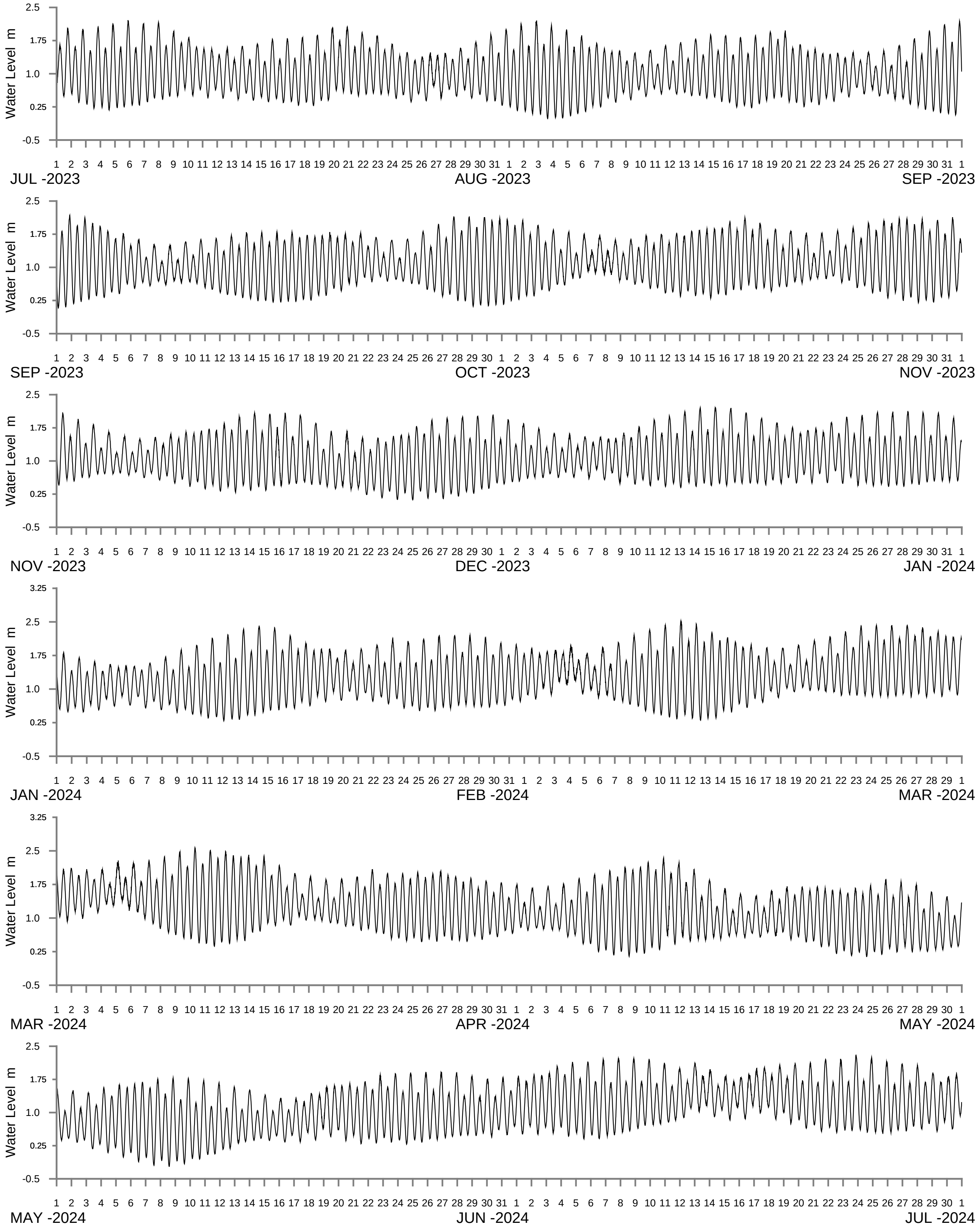


WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM (1971)

------------ DATA LOSS

*Data loss due to faulty battery charger.

NSW GOVERNMENT	TWOFOLD BAY AT EDEN BOAT HARBOUR 2023–24	Manly Hydraulics Laboratory Report MHL3065 Figure A22



WATER LEVEL REFERENCED TO LORD HOWE ISLAND TIDAL DATUM (1963)

------------ DATA LOSS

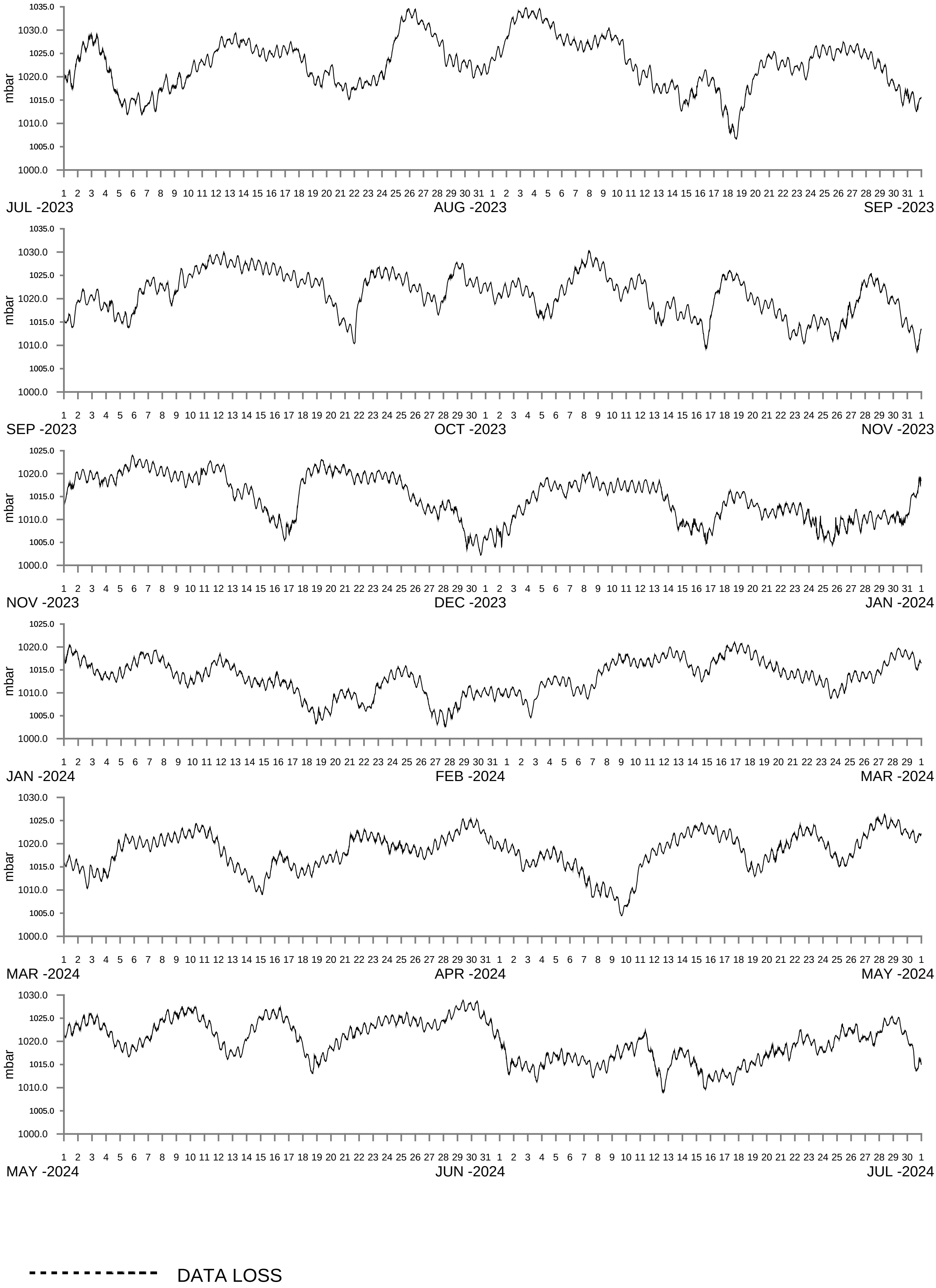
NSW GOVERNMENT

TASMAN SEA AT LORD HOWE ISLAND
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
A23

Appendix B Annual barometric station data summaries



CUDGEN CREEK AT KINGSCLIFF
2023–24

NSW GOVERNMENT

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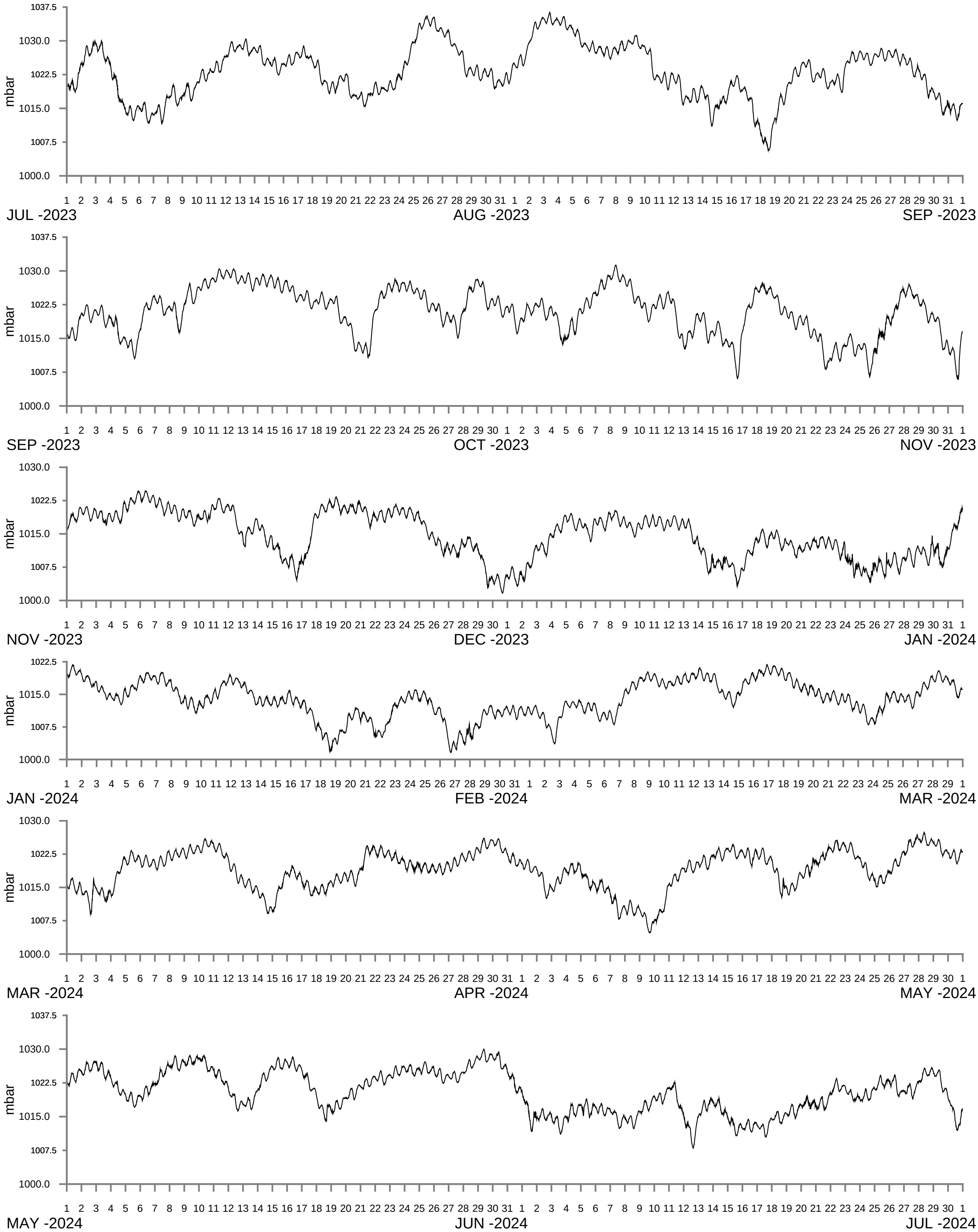
Figure
B1

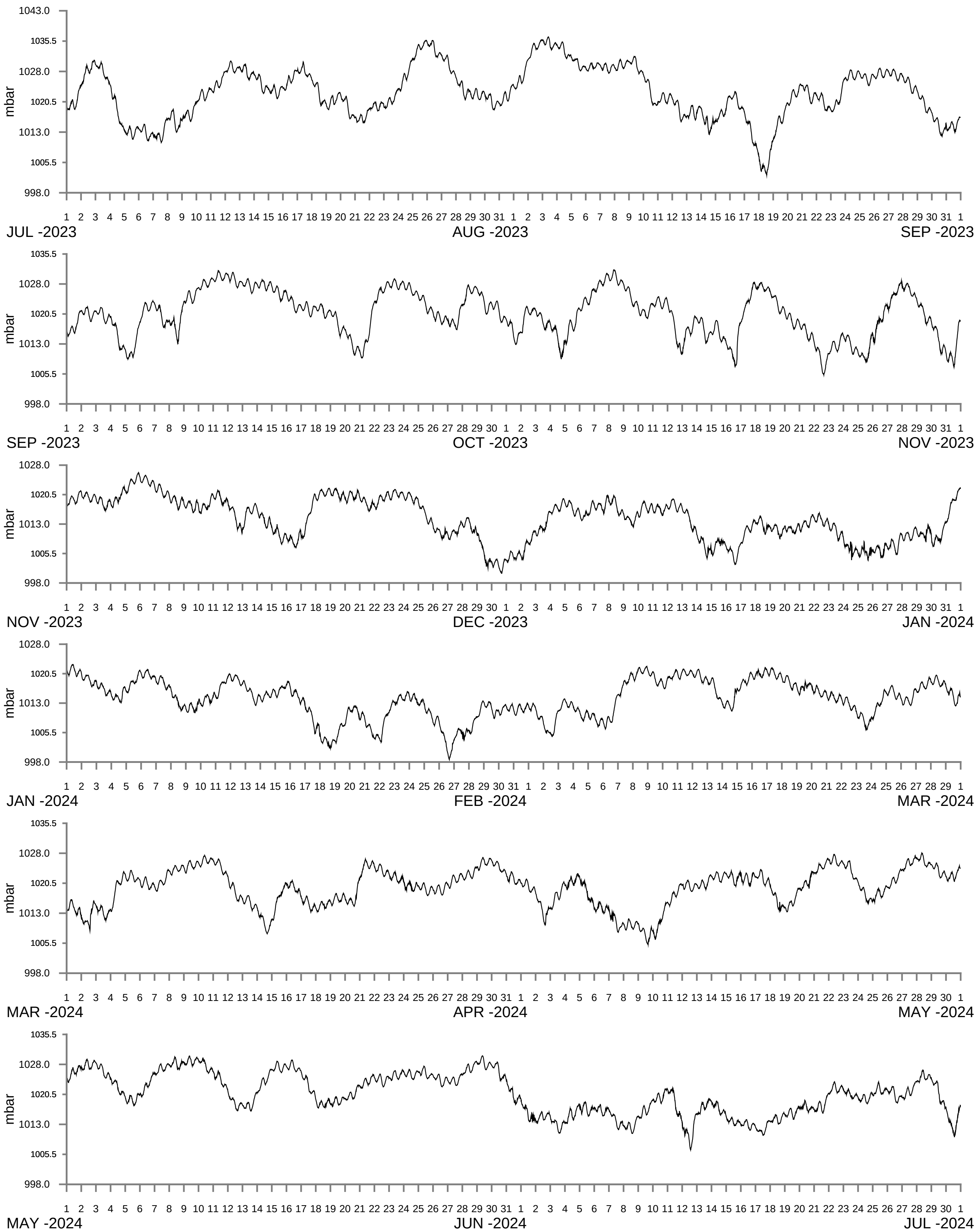


DATA LOSS

LAKE WOOLOWEYAH AT LAKE WOOLOWEYAH
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
B2



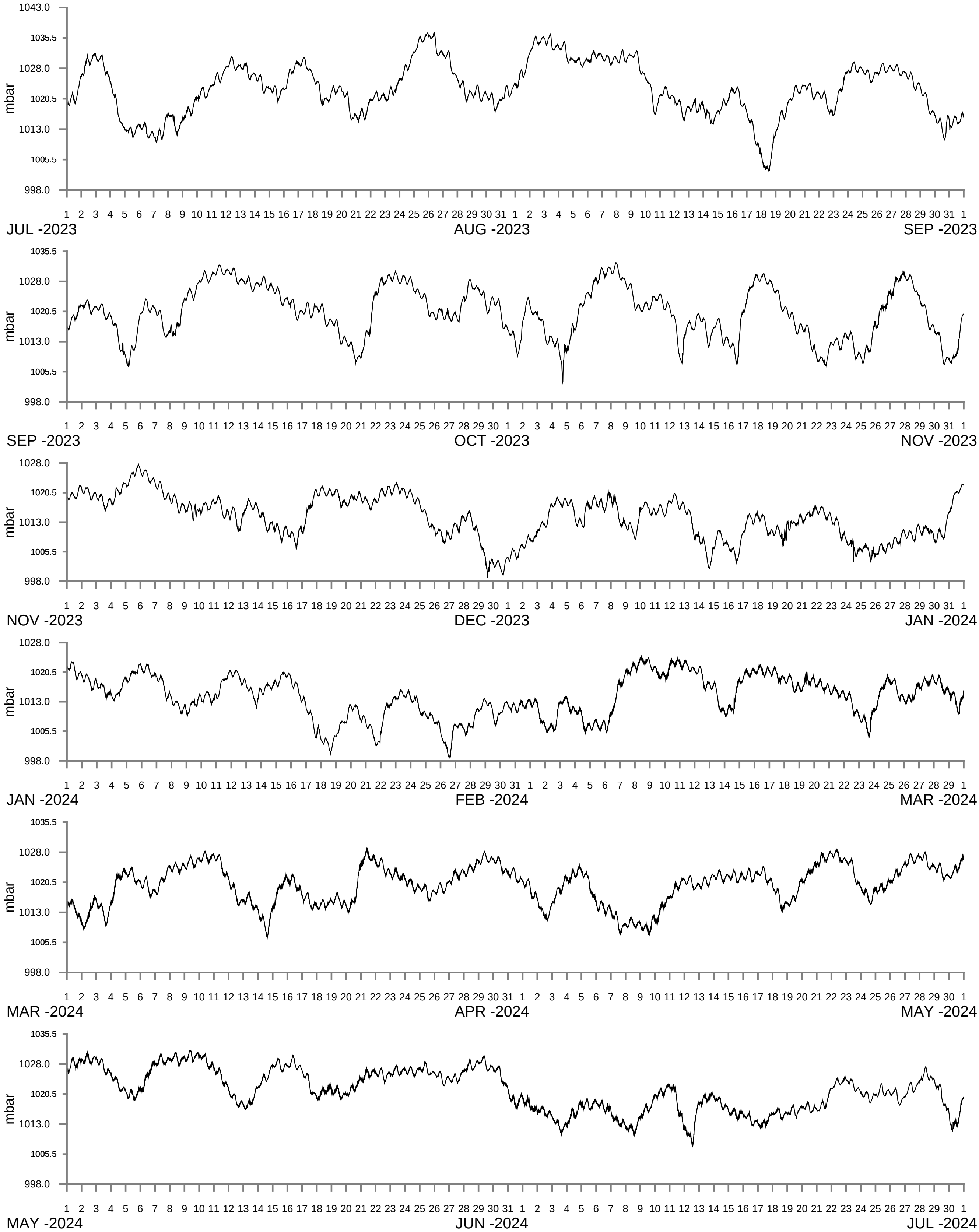
DATA LOSS

HASTINGS RIVER AT SETTLEMENT POINT
2023–24

NSW GOVERNMENT

Manly Hydraulics Laboratory

Report MHL3065
Figure
B3

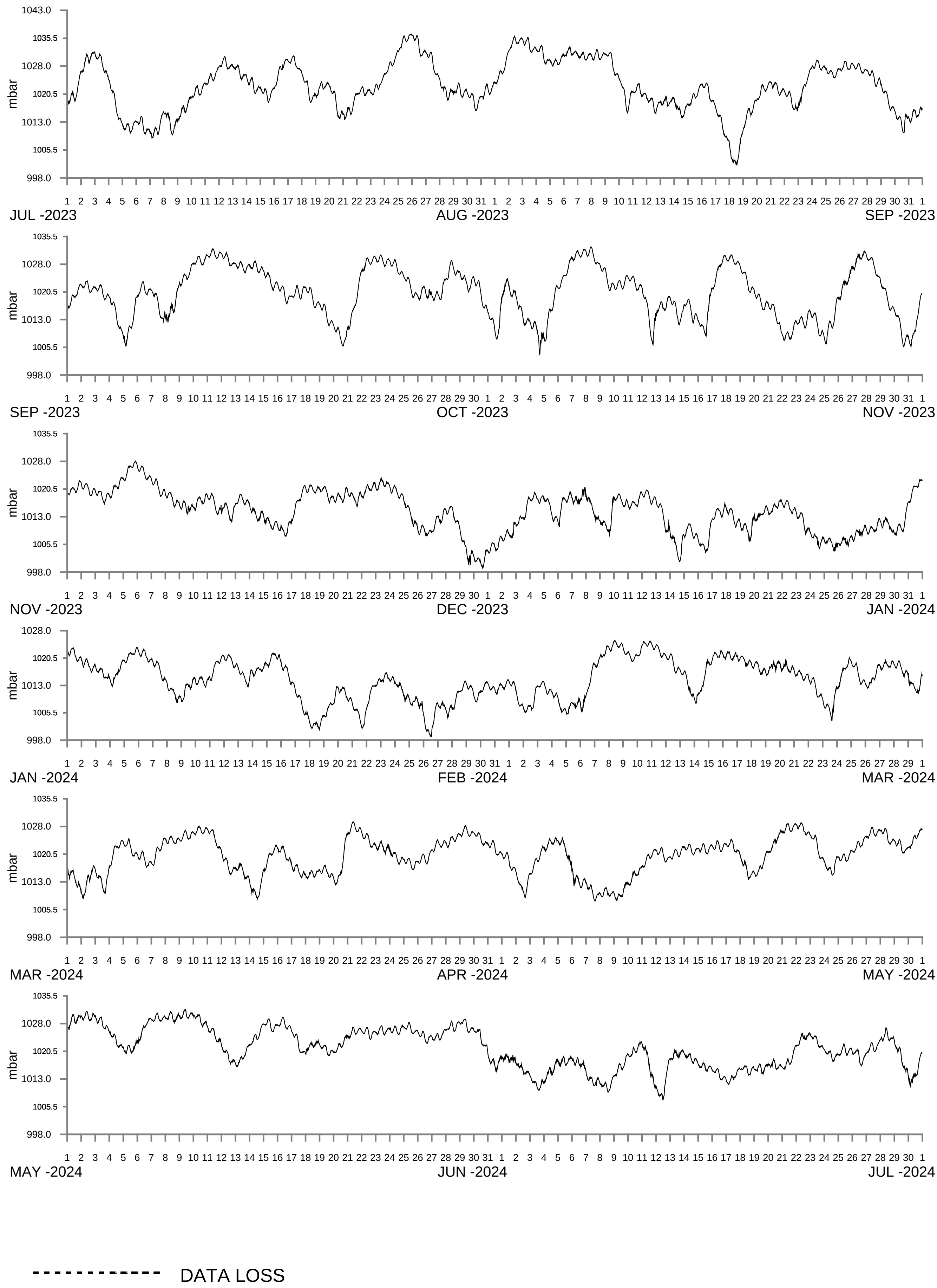


DATA LOSS

HUNTER RIVER AT STOCKTON BRIDGE
2023–24

Manly Hydraulics Laboratory

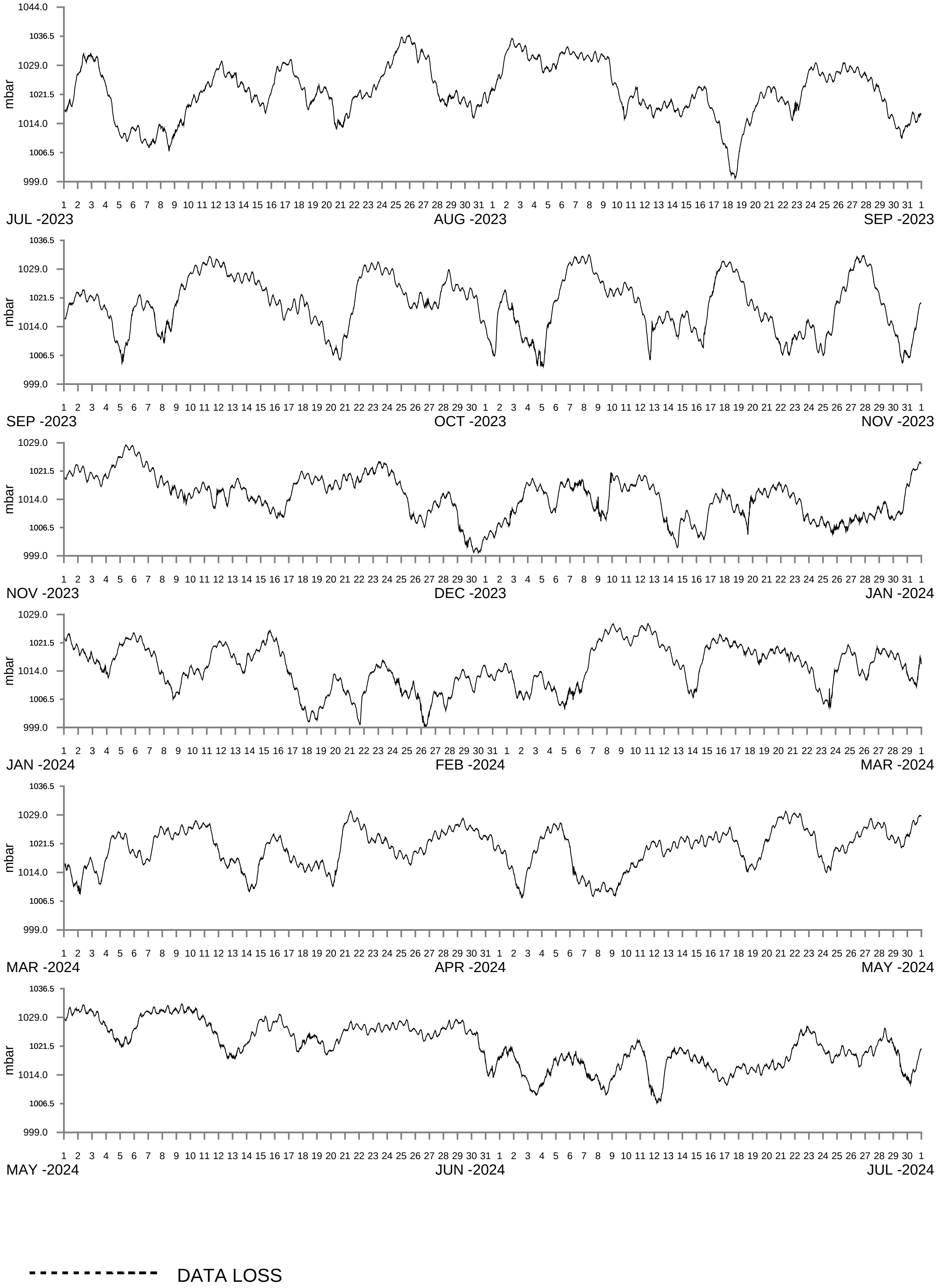
Report MHL3065
Figure
B4



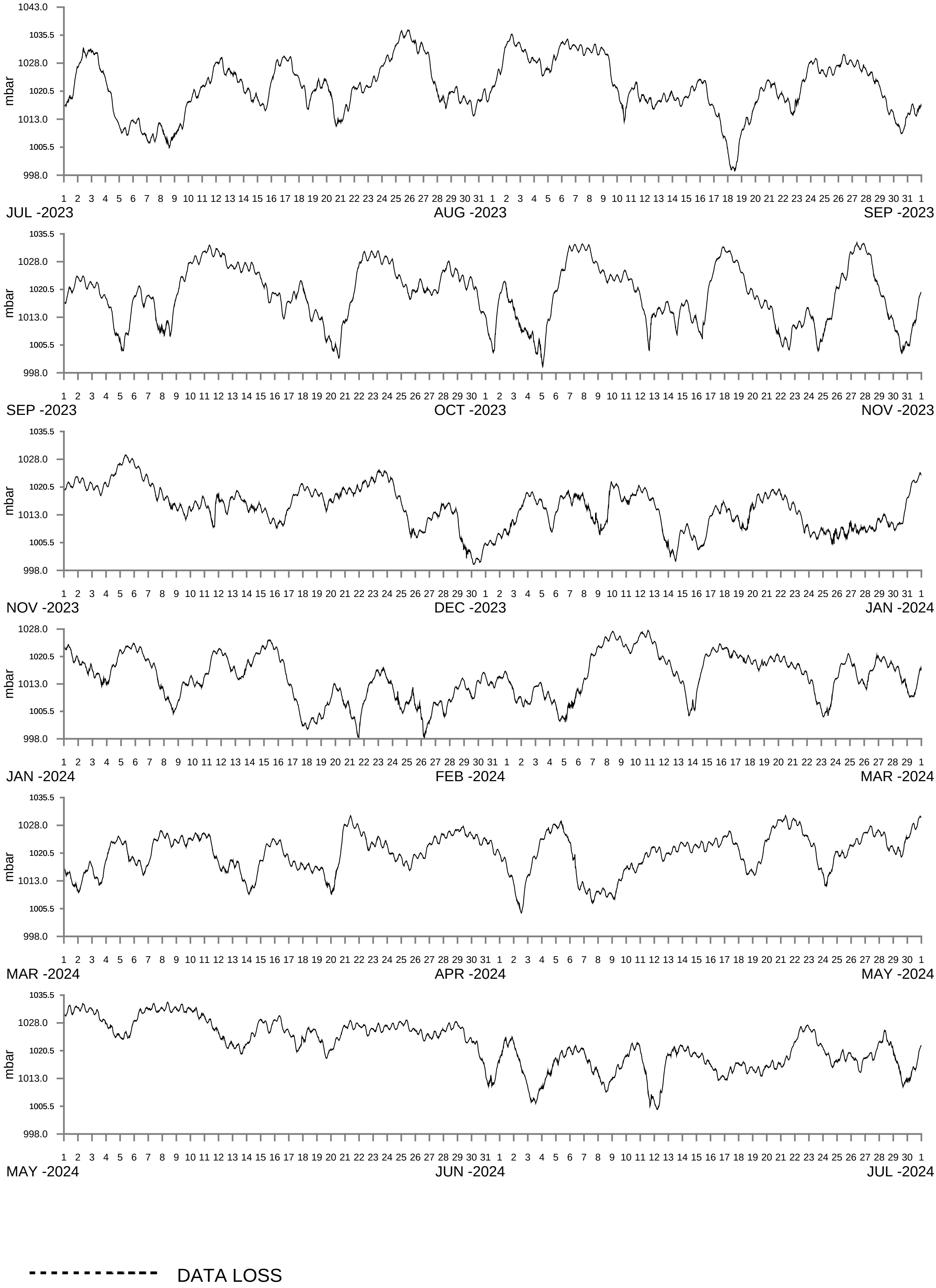
NARRABEEN LAGOON AT NARRABEEN BRIDGE
2023–24

Manly Hydraulics Laboratory

Report MHL3065
Figure
B5



NSW GOVERNMENT	CURRARONG CREEK AT CURRARONG CREEK 2023–24	Manly Hydraulics Laboratory Report MHL3065 Figure B6

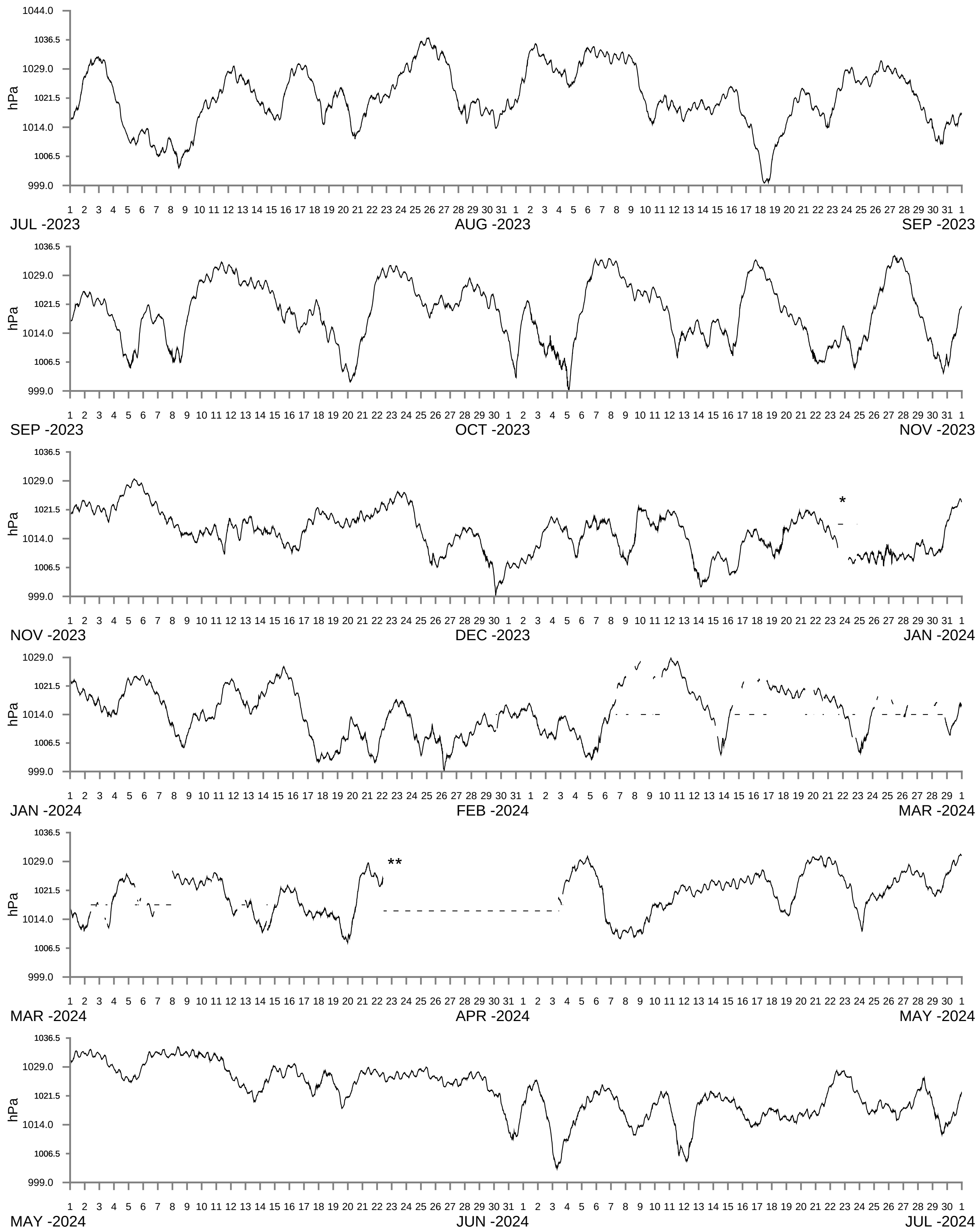


TUROSS RIVER AT TUROSS HEAD
2023–24

NSW GOVERNMENT

Manly Hydraulics Laboratory

Report MHL3065
Figure
B7



- - - - - - - - - - - - DATA LOSS

*Data loss due to faulty barometer.

**Data loss due to a bug in the logger program, triggered when accessed remotely.

NSW GOVERNMENT

WONBOYN LAKE AT WONBOYN LAKE

2023–24

Manly Hydraulics Laboratory

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Figure

B8

Appendix C Current tidal station data

Table C-1 Current station digital data

NSW coastal region	Catchment, river or port	Station name	Location	NSW coastal region
North	Tweed River	Tweed Entrance South	South Breakwater	May 2014–ongoing
North	Tasman Sea	Tweed Offshore[1]	Offshore	Dec 1982–ongoing
North	Brunswick River	Brunswick Heads	South Breakwater	Mar 1986–ongoing
North	Richmond River	Ballina Breakwall[1]	South Breakwater	Dec 2008–ongoing
North	Clarence River	Yamba	South Breakwater	Jul 1986–ongoing
North	Coffs Harbour	Coffs Harbour[1]	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[1]	Offshore	Dec 1984–ongoing
Mid North	Crowdy Head Harbour	Crowdy Head[1]	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 Jervis Bay 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

[1] Station has changed location during data period

Appendix D Historical tide data

Table D-1 Historical tide data

Station Name	Location	Period of record	Location
Tweed Regional	North Breakwater	Feb 1987–Apr 2015	Online
Tweed Regional	Breakwater 201470	1978–1980	Online
Richmond River	Breakwater 202471	1889–1912	HiLos online
Richmond River	Ballina	1959–1963	Microfiche MHL
Ballina 202470	Half Tide Breakwater	Apr 1986–May 2011	Online
Clarence River	Yamba	1900–1924	HiLos online
Yamba Offshore	Yamba 204450	Jun 1987–Sep 2009	Online
Clarence River	Iluka 204437	1956–1961	Online
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	Online
Coffs Harbour	Outer harbour	1953–56, 1957–60	Microfiche MHL
Coffs Harbour	Water Police Jetty Inner Harbour 205470	1990–1996	Online
Macleay River	Entrance 206477	1901–1913	HiLos online
Crowdy Head	CSIRO 208470	1985–1986	Online
Tomaree	Hospital Jetty 209471	Oct 1985–Apr 2014	Online
Tomaree	Hospital Jetty	1967–1969	HiLos State Archives
Newcastle	Boat harbour 210461	1899–1921	HiLos online
Newcastle	Breakwater	1946–1961	HiLos State Archives
Port Hacking	Hungry Point	Nov 1987–Feb2015	Online
Port Jackson	Fort Denison 60370	1914–October 2024	Online
Port Kembla	Harbour	1957–1965	Microfiche State Archives
Port Kembla	Harbour 214480	1987–1992	Online
Jervis Bay	HMAS Creswell 216471	1914–1919	HiLos online
Jervis Bay	Huskisson 216472	1987–1993	Online
Batemans Bay Offshore	Snapper Island 216451	1986–1990	Online
Batemans Bay Offshore	Offshore 216452	1987–1988	Online (MHL556)
Moruya River	Moruya Heads 217403	1951–1952	HiLos State Archives
Moruya River	Entrance	1951–52, 1987–88	Online
Eden	Snug Cove 220470	1978–1990	Online
Eden	Snug Cove	1954–1956	Microfiche State Archives
Norfolk Island	Kingston Jetty	1994-2015	Online

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

Data for Norfolk Island since 2015 is available from Bureau of Meteorology's National Tidal Unit (NTU).

Appendix E Glossary of terms

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 + á), 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 + á) 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° 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_l 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_l 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.

K1	Lunisolar diurnal constituent. This constituent, with O1, expresses the effect of the moon’s declination. They account for diurnal inequality and, at extremes, diurnal tides. With P1, it expresses the effect of the sun’s declination. Speed = T + h = 15.041,068,6° 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° 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_l 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_l 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° 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 (Np) 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° per solar hour.
Phase	1. Any recurring aspect of a periodic phenomenon, such as new moon, high water, flood strength, etc. 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 360°. The maximum and minimum of a harmonic constituent have phase values of 0° and 180°, respectively.
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° 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: Period (T) = 2L / 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	1. The part of the tide that is due to the tide-producing force of the sun. 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.
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 mobile network, satellite or radio transmission 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_0	Symbol recommended by the International Hydrographic Organisation to represent the elevation of mean sea level above chart datum

Appendix F Publications of interest

Data reports

MHL annual ocean tide levels summaries available from 1986–87 to 2022–2023
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), 2856 (20–21), 2907 (21-22), 2995 (22-23).

Manly Hydraulics Laboratory 1989, *Comparison of Tide Levels Between Fort Denison and Middle Harbour, Sydney Harbour,* Report No. MHL558.

Manly Hydraulics Laboratory 1998, *Tweed Heads, Yamba and Port Macquarie Offshore Tide Gauges 1982–1997,* MHL Report 722, May 1998.

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Manly Hydraulics Laboratory 2010, *Tidal Data Compilation 2010,* MHL Report 1988, June 2010.

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Manly Hydraulics Laboratory 2014, *OEH NSW Water Level Frequency Distribution Analysis*, MHL Report 2100, March 2014.

Manly Hydraulics Laboratory 2025, *NSW Water Level Frequency Distribution Analysis*, MHL Report 2971, February 2025.

Ocean tide program reports

Manly Hydraulics Laboratory 1987, *Ocean Tide Measurement Program Progress Report,* Report No. MHL471.

Manly Hydraulics Laboratory 1987, *Tide Gauge System: Yamba - Clarence River,* Report No. MHL496.

Manly Hydraulics Laboratory 1990, *NSW Ocean Tide Network Jervis Bay HMAS Creswell Tide Gauge System,* Report No. MHL580.

Manly Hydraulics Laboratory 2005, *Review of Automatic Water Level Recorder Network,* MHL Report 1419, October 2005.

Manly Hydraulics Laboratory 2005, Tide Gauge Histories Metadata for National and NSW Tide Gauges*,* MHL Report 2179, November 2012.

Manly Hydraulics Laboratory 2013, *North Coast Ocean Tide Scoping Study,* MHL Report 2072, September 2013.

Manly Hydraulics Laboratory 2019, *Review of NSW automatic water level recorder network,* MHL Report 2546, June 2020.

Harmonic analysis and tidal planes

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