Public Works
Manly Hydraulics Laboratory

NSW OCEAN AND RIVER ENTRANCE TIDAL LEVELS ANNUAL SUMMARY 2012-2013

Report MHL2219
October 2013

prepared for
Office of Environment and Heritage

A division of the Department of Finance & Services

NSW Ocean and River Entrance Tidal Levels Annual Summary 2012-2013

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Foreword

NSW Public Works' Manly Hydraulics Laboratory (MHL) operates and maintains a number of ocean and river entrance tidal recording stations along the NSW coast under contract with the Department of Premier and Cabinet, Office of Environment and Heritage (OEH). NSW Public Works is a division of the Department of Finance and Services.

The NSW ocean tide database has been developed by MHL to support a number of OEH 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 is available to local government and other organisations, both in Australia and overseas.

This annual summary presents ocean and river entrance tidal data captured by the automatic tide level recording stations along the coastline of New South Wales over the period 1 July 2012 to 30 June 2013, and catalogues all ocean and river entrance tidal data collected in NSW by MHL.

This summary has been prepared as a guide to enable ready access to MHL's ocean tide 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.

Requests for further information should be directed to:

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Acknowledgement is made of the following contributions to the delivery of the program:

- field management by Phil Clark and Colin Browne
- technical expertise, direction and analysis by Ben Modra.

Summary

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 2012-2013
- Appendix A, the annual data summaries for each site (see Figure 1.1 for site locations)
- Appendix B detailing the tidal data available on-line
- Appendix C detailing the historical tidal data available
- Appendix D which shows data output formats available from MHL
- 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

This report presents the twenty-eighth year of data collected by automatic ocean tide level recorders. The network of recorders and the associated analysis routines enable MHL to provide an efficient service in accessing tide data. In addition to this information, a significant historical database of tide levels can be made available on request.

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 each located on Norfolk Island and Lord Howe Island (Figure 1.1). The ocean tide monitoring network features distinctive systems of data capture: radar, electromagnetic tide pole, solid state Floatwell, vented pressure sensor and submersed water level pressure recorder. Each system functions as follows:

- Radar sensors: the water level is detected by RAdio Detection And Ranging technology. The water level is averaged over 60 or 120 seconds to create a 1-minute or 15-minute time series data file respectively. The data recorded is then transferred to MHL via an IP link through a modem between the data logger and MHL's data server. The system is shown in Figure 1.2.
- Electromagnetic Wave Staff (EWS): the water level is sampled continuously by the EWS. The water level is averaged over 60 or 120 seconds to create a 1-minute or 15-minute time series data file respectively. The data is downloaded every 24 to 48 hours directly from the data logger via an IP link through a modem to MHL's data server or transmitted via radio link to a shore-based receiving station where it can be transferred to MHL via a separate modem connection to the data server. The system is shown in Figure 1.3.
- Vented pressure sensors: the water level is determined by a vented pressure sensor and recorded on a data logger. The sensor is vented to atmospheric pressure and therefore requires no correction for barometric pressure changes. The data recorded is then transferred to MHL via an IP link through a modem between the data logger and MHL's data server. The system is shown in Figure 1.3.
- Solid state Floatwell: the level is sensed by a float connected to a shaft encoder which is read and stored every 15 minutes. The data recorded is then transferred to MHL via an IP link through a modem between the data logger and MHL's data server. The system is shown in Figure 1.4.
- Submersed water level recorder: the water level is determined by an absolute pressure sensor sealed in a waterproof housing and mounted on the ocean bed. The data requires post-recording correction for water density and barometric pressure changes. The data is downloaded manually from the recorder to the Laboratory's data server after recovery from the ocean bed by divers. The system is shown in Figure 1.5.

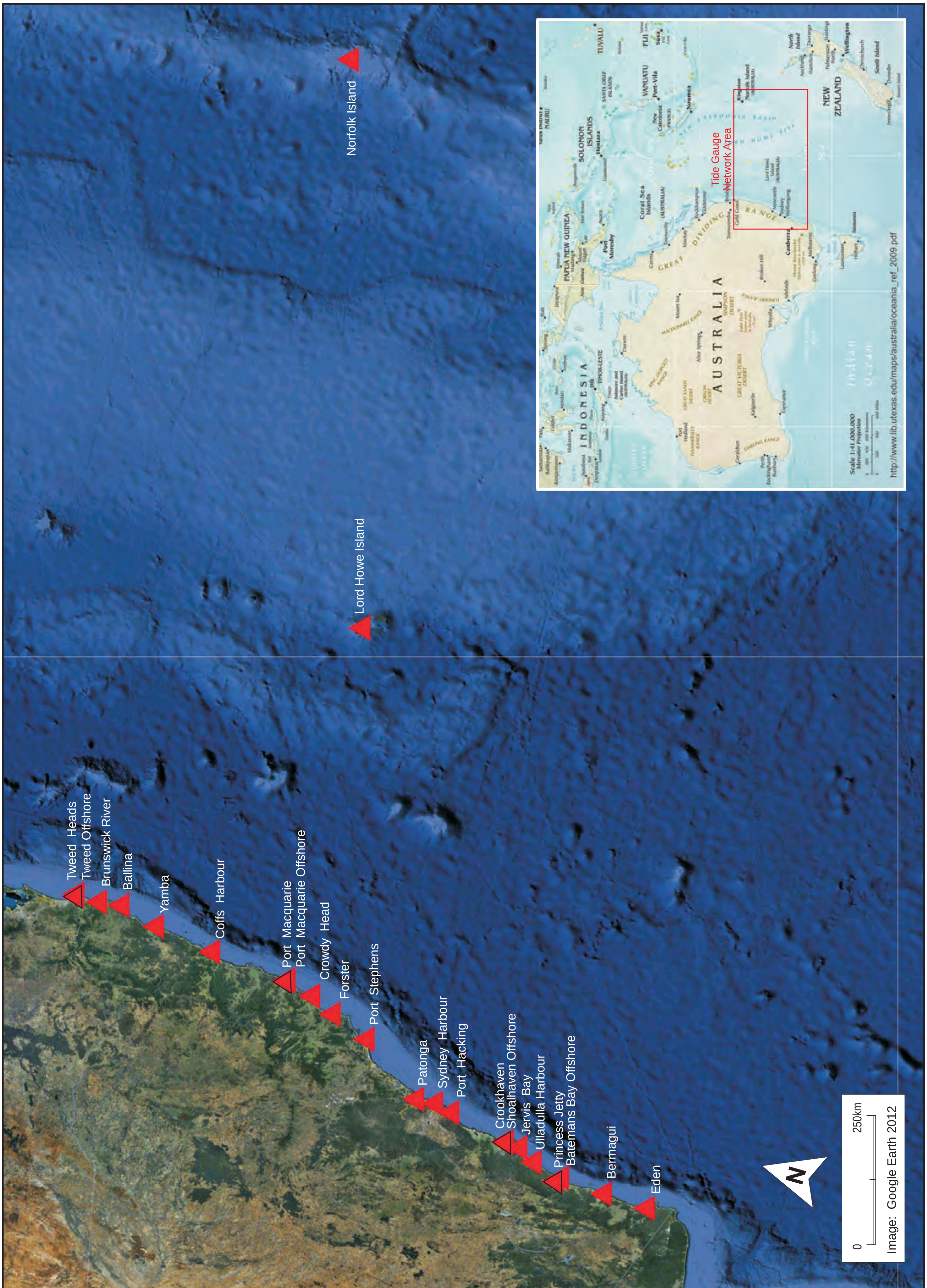
Tidal data is transferred to the NSW Data Collection Warehouse, Data Centre 1 at Ultimo and to MHL's data server and is then immediately available to external users to view. The 15-minute tide data is available on-line in tables or as plots. One minute data is also available on request (see Figure D1).

The data is stored in a database and subjected to a quality assurance process which involves several control steps to ensure data quality is maintained. Computer programs are used to further format and analyse data.

The database is backed up daily and data archived to magnetic tape as a security measure at regular intervals. A complete mirrored backup database is also kept at Data Centre 1.

The station locations and data summaries for 2012-2013 are presented in Appendix A.

Historical tide chart records converted and available in a digitised format are catalogued in Appendix B. Appendix C contains the remaining historical database which is retained at the Laboratory in chart form.



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OCEAN TIDE GAUGE NETWORK

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Figure 1.1

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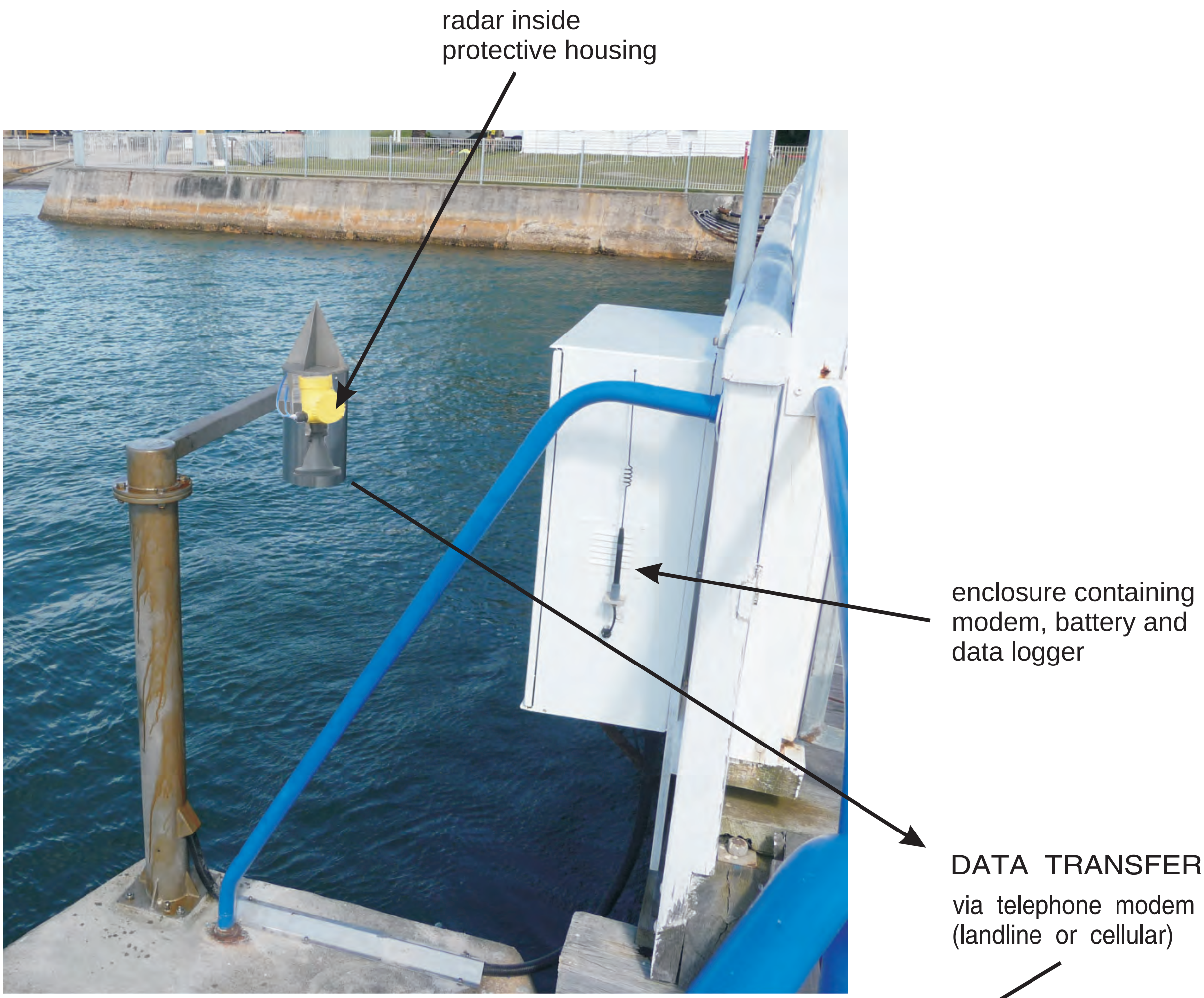
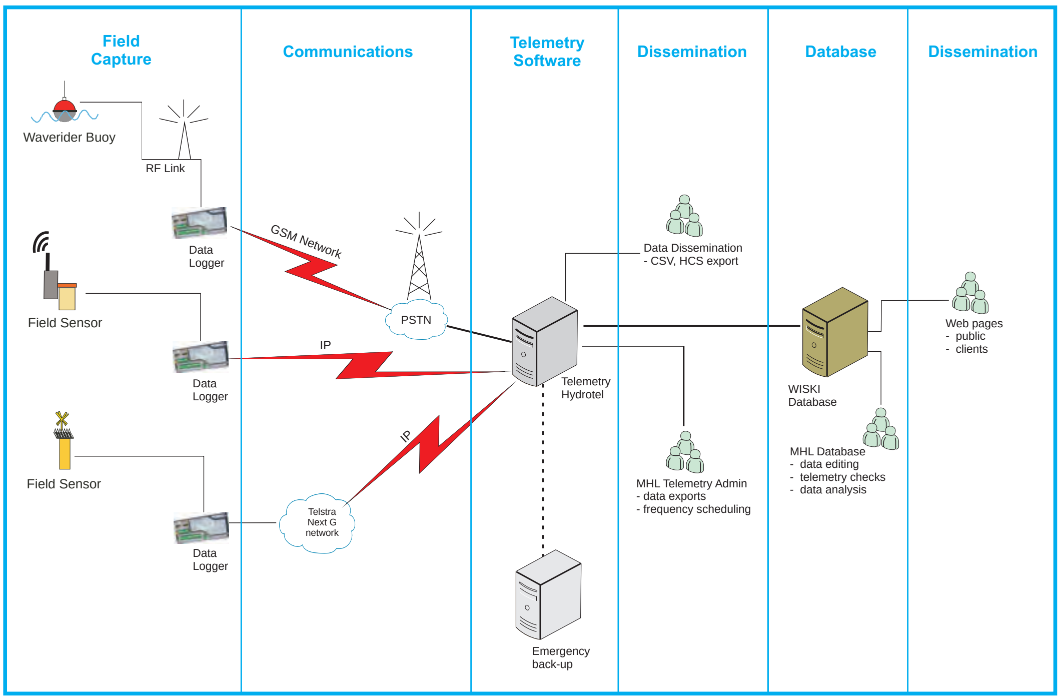
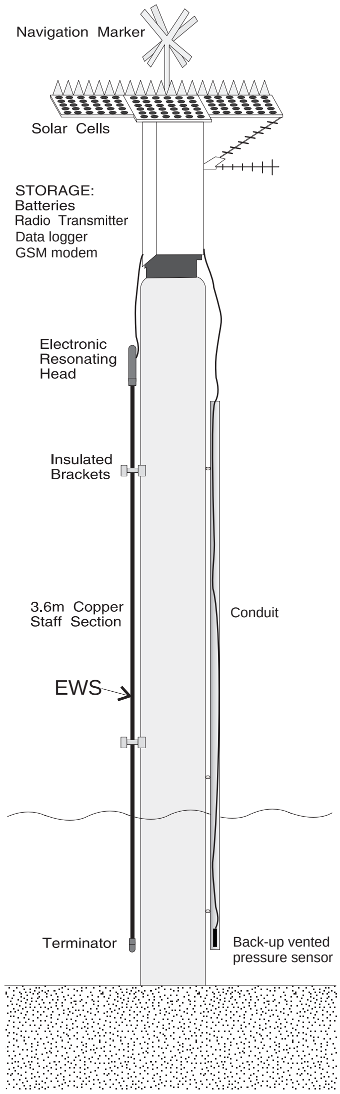
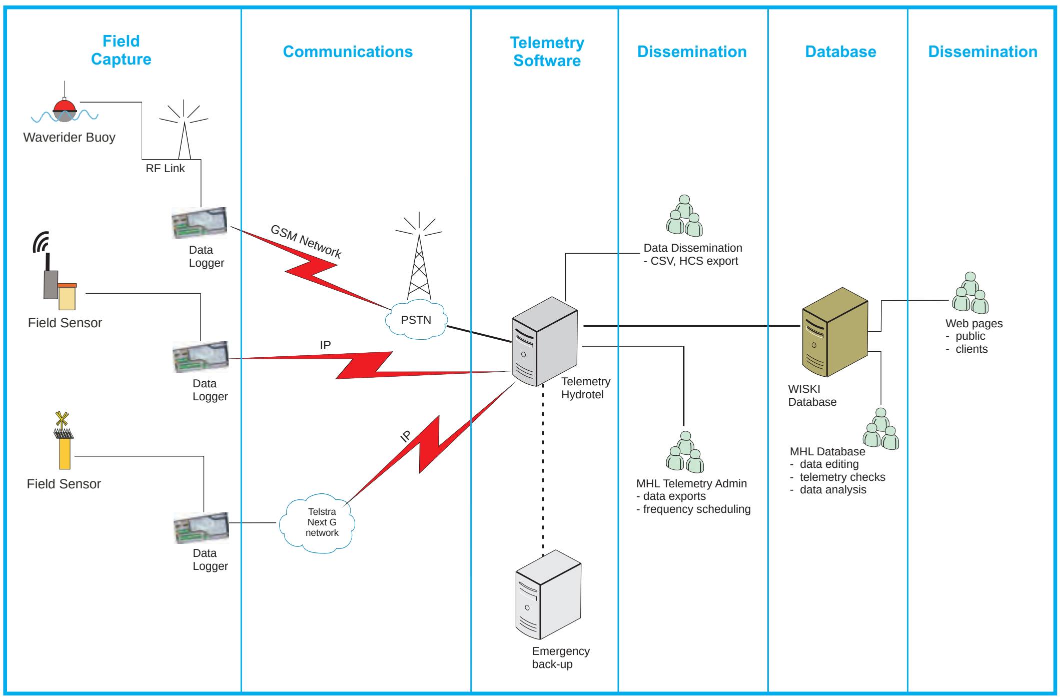




NSW GOVERNMENT **Public Works** Manly Hydraulics Laboratory	TYPICAL RADAR SENSOR	MHL Report 2219 Figure 1.2 DRAWING 2219-01-02.cdr





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ELECTROMAGNETIC WAVE STAFF AND PRESSURE SENSOR

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Figure 1.3

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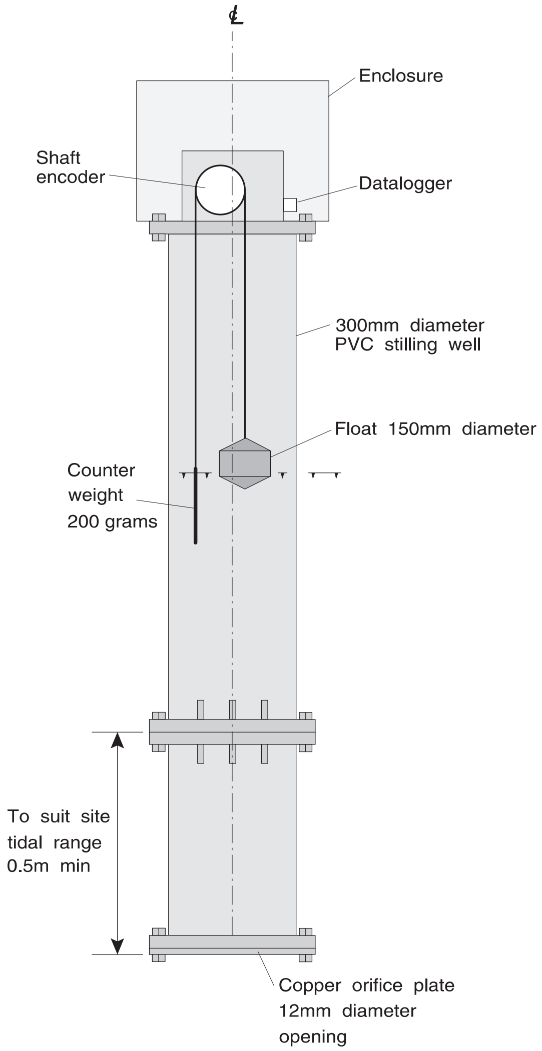

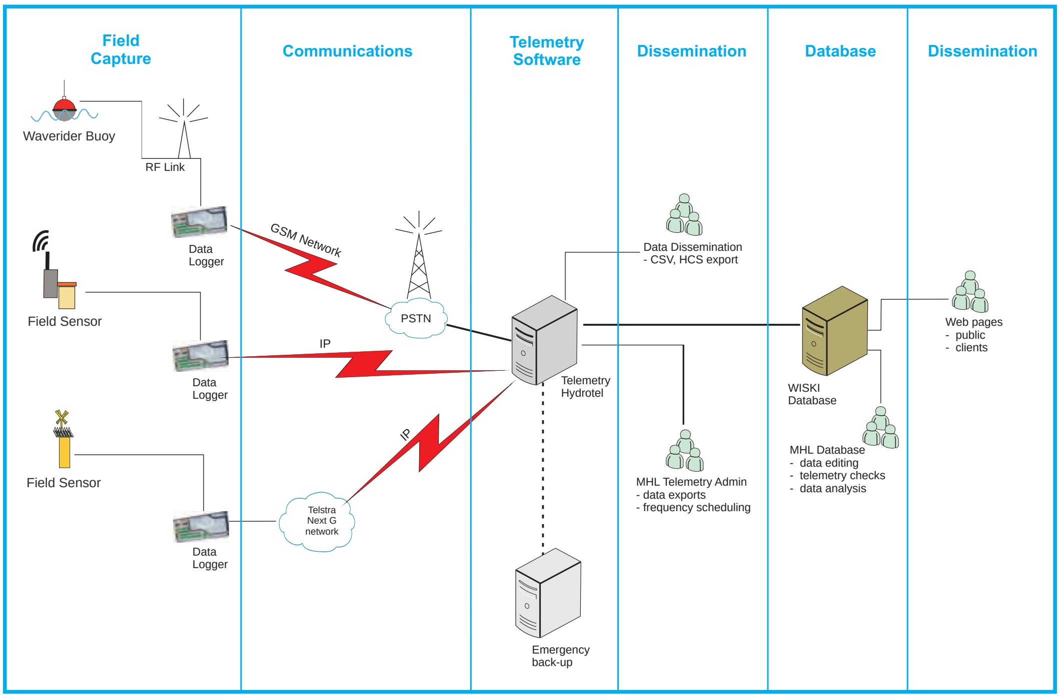

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TYPICAL SOLID STATE FLOATWELL

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Figure 1.4

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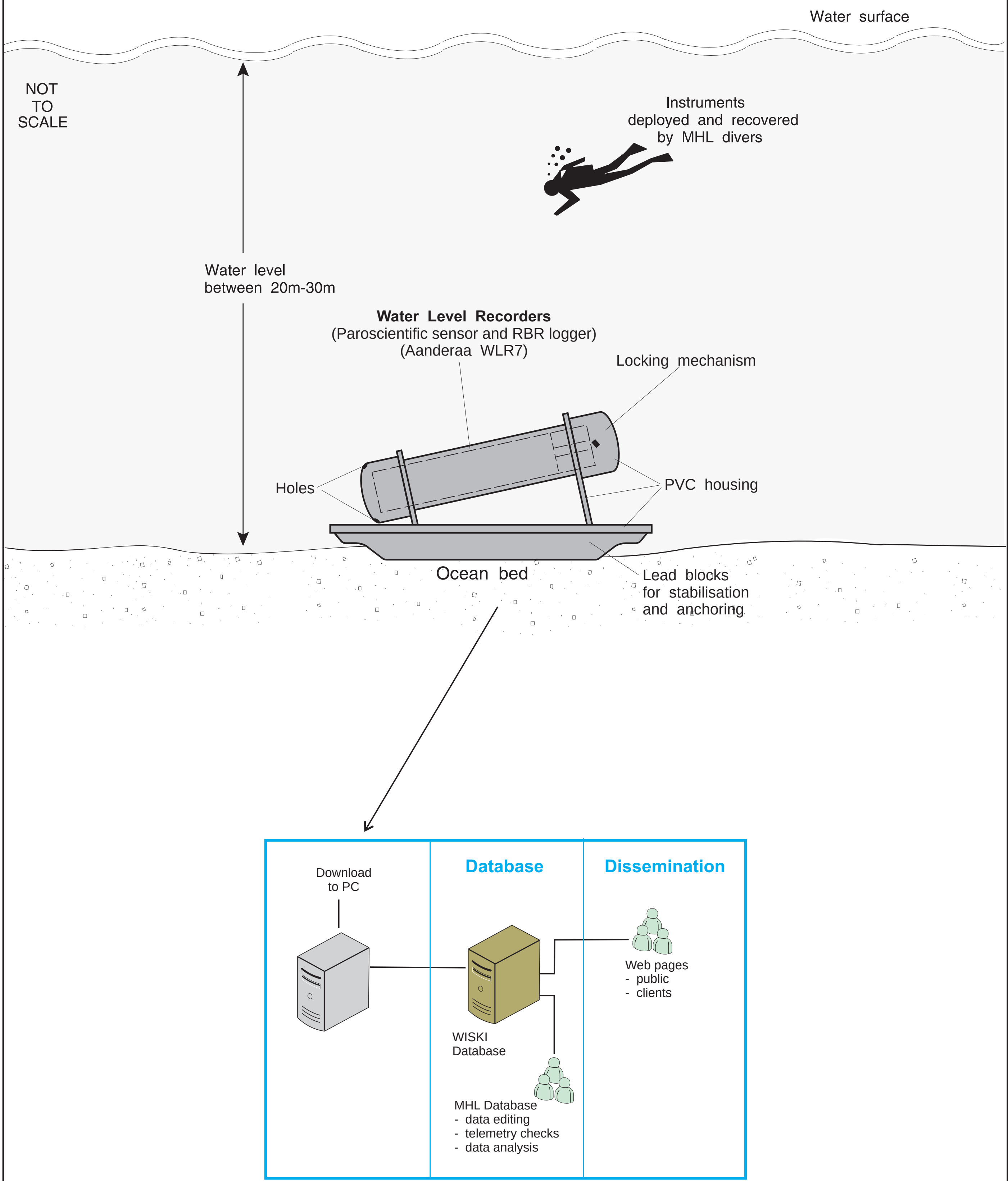

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WATER LEVEL RECORDER

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Figure 1.5

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2. How to Use This Report

2.1 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 New South Wales over the period 1 July 2012 to 30 June 2013. The stations are located in bays, harbours and the entrances of major rivers.

To establish if data is available, first identify the relevant station on the Key Map (Figure 1.1), then refer to the relevant figure for that station. A location map of each station and a plot of the data from that station are provided in Appendix A. The plot confirms the availability of data for the fiscal year 2012-2013. For the availability of historical data which has been collected, refer to Appendices B and C.

Once a selection of data has been made the analysis and/or presentation can be obtained in a variety of formats. The following options are available and samples are shown in Appendix D:

- graphical plots (Figure D1)
- time series data (Figure D2)
- tidal analyses (Figure D3)
- tidal phase difference analysis (Figure D4)
- tidal level ranking (Figure D5)
- tidal predictions (Figure D6).

Data can be request by contacting MHL by email via data-request@mhl.nsw.gov.au

The Laboratory provides a full on-line data access service via the Internet for its clients, and a restricted service for the general public at http://www.mhl.nsw.gov.au

Typically the last seven days of data are available on-line in a non-quality controlled form to aid the fastest possible access to data records. The on-line service for clients can provide access to all data catalogued in Appendix D, including tidal predictions. This data consists of tide levels and can be reviewed in graphical or numerical format.

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 upon request.

2.2 Datums

Most ocean tide water levels are recorded in the local port datum which generally equates to Indian Springs Low Water (ISLW). An indicative adjustment of each station datum level to the local Australian Height Datum (AHD) is shown in Table 2.1. These adjustments were calculated circa 1990 for MHL by NSW Public Works' Survey Branch using tidal harmonic analysis over a tidal epoch. These values should be used with caution, as AHD levels are revised from time to time and improvements to GPS 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 of each instrument deployment. They provide valuable astronomical constituent and anomaly information. Poor survey information is available for Norfolk Island and Lord Howe Island and ongoing survey works hopes to define offsets to AHD in the coming years.

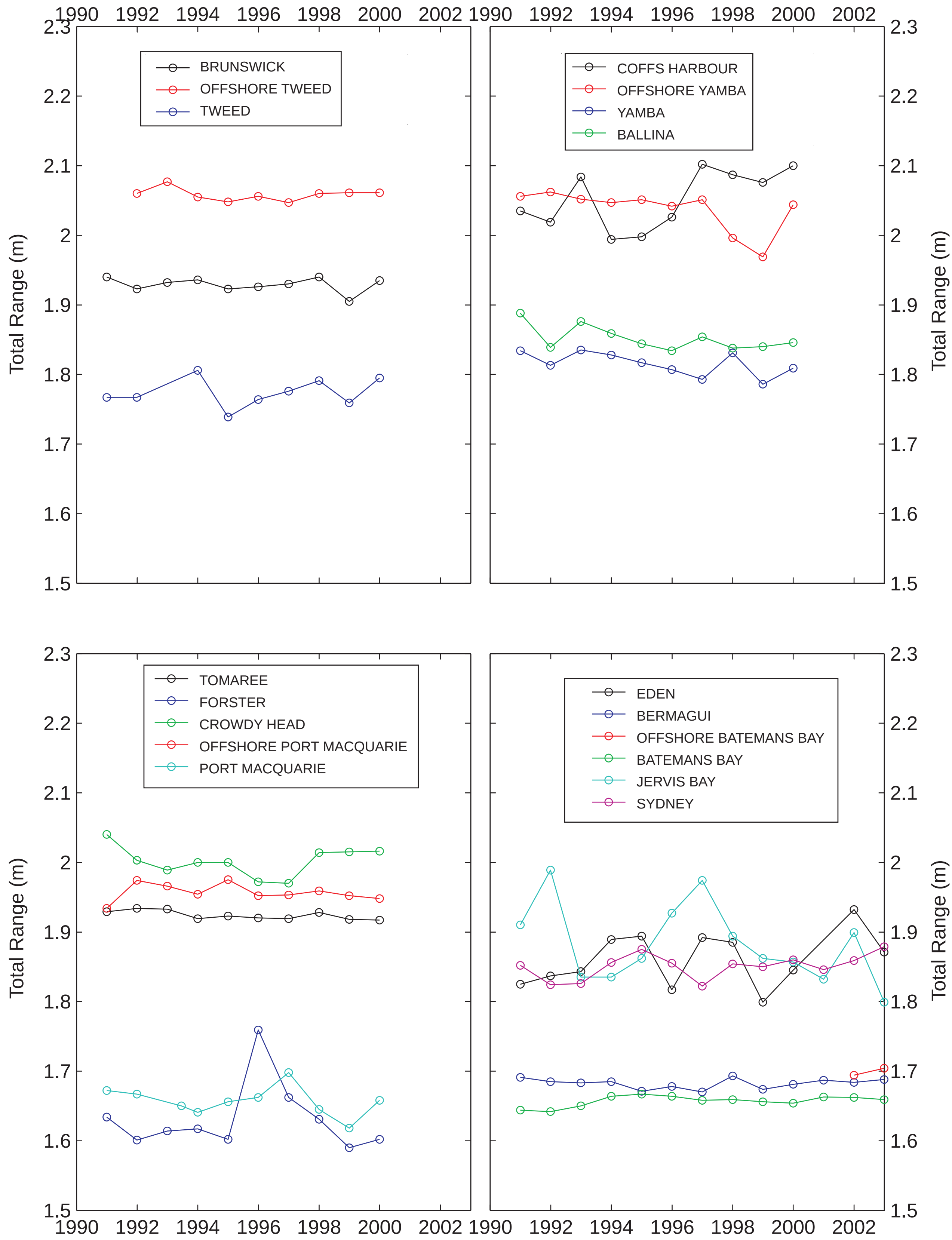
Table 2.1 Summary of Adjustment to Local AHD

Station	Station Datum	Adjustment (Local to AHD[1])
Tweed Heads	Tweed River Hydro Datum	0.893
Tweed Heads Offshore	Mean Sea Level	N/A
Brunswick Heads	Brunswick River Flood Mitigation Datum	0.046
Ballina	Low Water Ordinary Spring Tide	0.860
Yamba	Iluka Port Datum	0.895
Yamba Offshore	Mean Sea Level	N/A
Lord Howe Island	Lord Howe Island Hydro Datum	N/A
Norfolk Island	Norfolk Island Tidal Datum	N/A
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
Port Stephens	Port Stephens Hydro Datum	0.944
Patonga	Australian Height Datum	0.000
Sydney	Zero Camp Cove	0.925
Fort Denison	Zero Camp Cove	0.925
Port Hacking	Indian Spring Low Water	0.925
Shoalhaven Offshore	Mean Sea Level	N/A
Crookhaven Heads	Australian Height Datum	0.000
Jervis Bay	Chart Datum	1.070
Ulladulla	Australian Height Datum	0.000
Batemans Bay Offshore	Mean Sea Level	N/A
Princess Jetty	Australian Height Datum	0.000
Bermagui	Bermagui Local Hydro Datum	0.714
Eden Boat Harbour	Twofold Bay Hydro Datum	0.924

[1] subtract adjustment from data values to convert to AHD.

2.3 Tidal Planes

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 from this trend. It was also concluded that nearshore sites located at the entrance of large bays/ports or as open ocean sites displayed ranges higher than the closest offshore site, whereas nearshore sites located in river entrances displayed total ranges lower than the closest offshore sites. Figure 2.1 shows this variation in graphical form. It is important to recognise such variations when applying data from these ocean tide sites.



Note: Each offshore gauge has been grouped with the closest nearshore gauges for comparison

Source: MHL1269 2005

Public Works Manly Hydraulics Laboratory	TIDAL RANGE FOR GROUPED OFFSHORE AND NEARSHORE GAUGES 1990-2003	MHL Report 2219 Figure 2.1 DRAWING 2219-02-01.cdr

3. Significant Events 2012-2013

Data recovery rates across the NSW Ocean Tide Network in 2012-2013 were very high, with an overall average of 99.9% data collected.

The Great Outdoors Publications Pty Ltd will again produce the NSW Tide Prediction Charts for 2014 from data provided by MHL. The charts will be distributed through all NSW coastal newsagencies and are the most complete authoritative charts for coastal NSW (Figure 3.1). As for the previous tide prediction publications, MHL has adopted the Sydney Harbour Middle Head tide gauge as the primary reference station, and the ocean tide predictions for NSW are based on an analysis of hourly tide levels recorded by this primary gauge. The time difference between the primary and secondary locations in NSW was obtained from an analysis of the tide levels recorded at gauges at each of the secondary locations.

3.1 Tidal Anomalies

Tidal anomalies in this report are calculated as the difference between the recorded data and the Foreman (1977) tidal prediction based on the previous year's (July to June) data. Generally, tidal anomalies are caused by a range of oceanographic and meteorological effects, however for ocean tide gauges located in river entrances hydrological anomalies such as floods can also occur. Further, tsunamis can cause waves that show up on the ocean tide gauges as tidal anomalies.

The anomalies recorded across the NSW coast during the reporting period are shown for a selected group of stations in Figure 3.2. The major anomalies are identified on Figure 3.2 and documented in more detail in Figures 3.3 and 3.4. Figures 3.5–3.8 show the tidal anomalies recorded during the reporting period. Figure 3.9 shows the anomalies for the four offshore tide stations.

The main drivers of anomalies are barometric pressure, wind set-up and coastally trapped waves and the influence of the East Australian Current (EAC). The NSW Ocean Water Levels report (MHL 2011) investigated anomalies recorded on the NSW coast and considered their occurrence and forcing mechanisms. 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.

Significant anomaly events impacting the NSW coastline are documented in Figures 3.3 and 3.4, together with probable causative mechanisms. Most appear to be driven by east coast lows or large high pressure systems.

The Bureau of Meteorology (BoM) recorded two cyclones in North Queensland during the 2012-2013 reporting period:

- 17–29 January 2013, Cyclone Oswald Category 1 – formed in Gulf of Carpentaria then tracked landward down eastern Queensland and into NSW. Torrential rainfall and major flooding also occurred in north-eastern NSW with the system, which eventually tracked as far south as Sydney before finally moving off the coast. The effect of the cyclone can be seen in the data and is highlighted in the anomaly table in Figure 3.3.
- 13–16 March 2013, Cyclone Sandra Category 2 – formed in the Tasman Sea then moved south some 200 km east of Lord Howe Island. A positive anomaly is observable in the Lord Howe data and can be seen in Figure 3.8.

3.2 Tsunami Events

Table 3.1 lists the tsunami events in the Pacific Region for the period of time corresponding to the 2012-2013 data in this report.

Table 3.1 Tsunami Events July 2012 to June 2013

Date	Cause		Location	Observable on NSW Tide Recordings
	Earthquake Magnitude (M_W)	Other Causes		
31/8/2012	7.6	-	Philippine Islands	No
7/12/2012	7.2		Japan – off east coast of Honshu Island	No
6/2/2013	7.9	-	Solomon Islands – Santa Cruz Island	No
8/2/2013	7.0	-	Solomon Islands – Santa Cruz Island	No

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

The Bureau of Meteorology and Geoscience Australia host the Joint Australian Tsunami Warning Centre (JATWC). No tsunami warnings were issued by JATWC from July 2012 to June 2013. The Bureau of Meteorology collects specific tsunami data for issuing warnings, and the data can be requested from BoM for further use.

3.3 Other Tide Events 2012-2013

Other water level events that occurred during the 2012–2013 reporting period included:

- 19 February 2013 - a fishing boat ran aground at Cronulla. The rescue authorities relied on tidal predictions in organising the refloating of the vessel, aware of potential environmental issues with fuel leakage.

  http://www.smh.com.au/nsw/fishermen-rescued-after-trawler-washes-up-on-rocks-20130219-2eo2r.html

- 31 March 2013 – the warm water core of the EAC extended further south than on average and produced an anomaly that can be seen in Figure 3.4 extending as far south as Sydney. Figure 3.10 shows the water level anomaly prediction and the sea surface temperature from the Integrated Marine Observing System (IMOS).

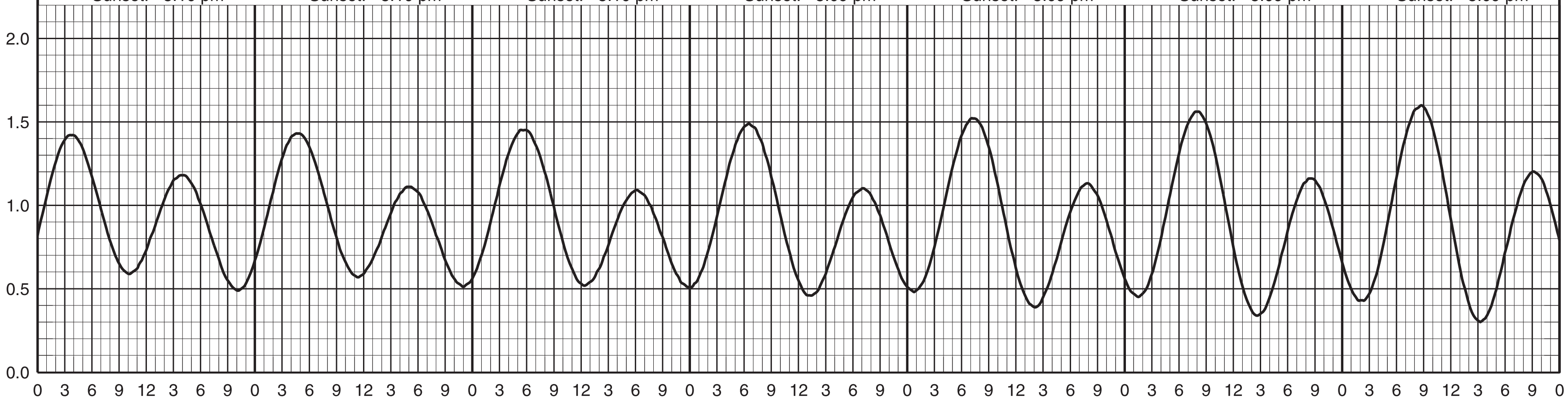
- 6 May 2013 – the Bureau of Meteorology issued a severe weather warning for Norfolk Island. This included 'a deep low is centred near the north island of New Zealand, while a high is situated over Tasmania. Sustained, vigorous winds between these systems are generating larges seas in the area around Norfolk Island. Damaging surf conditions, with waves exceeding 5 metres in the surf zone, may lead to coastal erosion along southwest-facing areas today. The sea water level may exceed the highest tide of the year.' The anomaly reached 0.32 m and can be seen in Figure 3.8.
- 24 June 2013 – a king tide in Sydney produced the highest water level of the year at 2.16 m. The king tide on 12/1/2013 resulted in a level of 2.06 m at Sydney.

The anomalies discussed in last year's Ocean Tide Summary Report (MHL2158) at Lord Howe Island were further examined by Horton et al (2013). Horton concluded that 'wave action (particularly direction) appears to have some effect on water levels in the Lagoon' but that oceanographic effects associated with the EAC and Tasman Front may also affect water levels together with atmospheric pressure and wind variations. Further work is being conducted on these anomalies.

January 9-15, 2014

Daylight Savings Time

9 THURSDAY	10 FRIDAY	11 SATURDAY	12 SUNDAY	13 MONDAY	14 TUESDAY	15 WEDNESDAY
Sunrise: 5.54 am Sunset: 8.10 pm	Sunrise: 5.55 am Sunset: 8.10 pm	Sunrise: 5.56 am Sunset: 8.10 pm	Sunrise: 5.57 am Sunset: 8.09 pm	Sunrise: 5.58 am Sunset: 8.09 pm	Sunrise: 5.58 am Sunset: 8.09 pm	Sunrise: 5.59 am Sunset: 8.09 pm



9 THURSDAY		10 FRIDAY		11 SATURDAY		12 SUNDAY		13 MONDAY		14 TUESDAY		15 WEDNESDAY	
3.43am	**1.42m 4ft 8in**	**4.43am**	**1.43m 4ft 8in**	**5.40am**	**1.46m 4ft 9in**	**6.32am**	**1.48m 4ft 10in**	12.44am	0.48m 1ft 7in	1.29am	0.45m 1ft 6in	2.09am	0.43m 1ft 5in
10.09am	0.59m 1ft 11in	11.22am	0.57m 1ft 10in	12.26pm	0.52m 1ft 8in	1.19pm	0.46m 1ft 6in	**7.19am**	**1.52m 4ft 12in**	**8.01am**	**1.56m 5ft 1in**	**8.39am**	**1.60m 5ft 3in**
3.55pm	**1.18m 3ft 10in**	**5.05pm**	**1.11m 3ft 8in**	**6.09pm**	**1.09m 3ft 7in**	**7.05pm**	**1.10m 3ft 7in**	2.02pm	0.39m 1ft 3in	2.41pm	0.34m 1ft 1in	3.16pm	0.30m 0ft 12in
10.06pm	0.49m 1ft 7in	11.01pm	0.51m 1ft 8in	11.54pm	0.51m 1ft 8in			**7.52pm**	**1.13m 3ft 8in**	**8.33pm**	**1.16m 3ft 10in**	**9.11pm**	**1.20m 3ft 11in**

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NSW TIDAL PREDICTIONS
Extract from 'NSW TIDE CHARTS 2014'

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Figure 3.1

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TIDAL ANOMALIES PLOT
2012-2013

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Figure 3.2

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Event	Tidal Anomaly	Tweed	Brunswick	Ballina Breakwall	Yamba	Coffs	Port Macquarie	Crowdy Head	Forster	Port Stephens	Patonga	Sydney	Port Hacking	Crookhaven	Jervis Bay	Ulladulla Harbour	Princess Jetty	Bermagui	Eden
1 **9-12 July 2012** High pressure system (up to 1037HPa) off coast	**Peak (m)**	-0.22	-0.22	-0.29	-0.3	-0.27	-0.29	-0.27	-0.22										
	Date	11/07	11/07	10/07	10/07	11/07	10/07	09/07	11/07										
	Time	815	745	2245	1900	515	730	0:00	630										
2 **9-13 August 2012** East Coast Low	**Peak (m)**	0.31	0.31	0.44	0.37	0.48	0.51	0.54	0.47	0.40	0.36								
	Date	12/8	11/8	12/8	12/8	12/8	11/8	11/8	11/8	11/8	11/8								
	Time	2145	1500	530	215	145	2030	2300	1900	2100	1915								
3 **5-9 September 2012** Lows and cold fronts passing through Bass Strait	**Peak (m)**															0.30	0.28	0.27	0.34
	Date															7/9	7/9	7/9	8/9
	Time															1815	1715	745	215
4 **24-28 November 2012** High pressure system in Tasman Sea	**Peak (m)**	-0.24	-0.32	-0.30	-0.25	-0.25	-0.26	-0.24											
	Date	27/11	27/11	27/11	26/11	27/11	25/11	25/11											
	Time	1415	1215	115	1445	1700	2215	2015											
5 **4-6 December 2012** East Coast Low	**Peak (m)**									0.20	0.24	0.23	0.25	0.27	0.25	0.25	0.31	0.34	0.45
	Date									05/12	05/12	05/12	05/12	05/12	05/12	05/12	05/12	05/12	05/12
	Time									1800	1700	1630	1615	1930	630	330	1400	615	1445
6 **8-13 January 2013** Inland low and trough	**Peak (m)**					0.21						0.21		0.21	0.22	0.28	0.22	0.36	0.41
	Date					9/1						9/1		9/1	9/1	9/1	9/1	9/1	9/1
	Time					1445						1130		1330	1100	1045	1415	1515	1400
7 **27 January-7 February 2013** Cyclone Oswald tracking down coast from Qld	**Peak (m)**	0.59	0.82	0.40	0.66	0.31	0.72	0.46	0.34	0.36	0.29	0.28	0.27	0.20	0.30	0.29	0.26	0.21	0.24
	Date	28/1	28/1	4/2	31/1	2/2	29/1	3/2	3/2	2/2	2/2	2/2	2/2	2/2	2/2	2/2	1/2	1/2	1/2
	Time	345	1500	1730	200	1515	300	845	2100	1815	700	1300	445	430	700	715	1830	1745	1700

The tidal anomalies were calculated by comparing the actual recorded water level with the predicted water level
The predicted data was generated using harmonic constituents from the previous year
The anomalies in this table are based on a ranking of 15-minute data
Only anomalies of absolute value greater than 0.20m are shown in this table

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TIDAL ANOMALIES
2012-2013

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Figure 3.3

DRAWING 2219-03-03.cdr

Event	Tidal Anomaly	Tweed	Brunswick	Ballina Breakwall	Yamba	Coffs	Port Macquarie	Crowdy Head	Forster	Port Stephens	Patonga	Sydney	Port Hacking	Crookhaven	Jervis Bay	Ulladulla Harbour	Princess Jetty	Bermagui	Eden
8 **19-23 February 2013** East Coast Low in Northern NSW	**Peak (m)**	0.44	0.45	0.61	0.56	0.57	1.47	0.38	0.31										
	Date	22/02	22/02	22/02	22/02	22/02	24/02	22/02	22/02										
	Time	1130	0	1100	2215	2145	115	2315	2300										
9 **22 February-5 March** High Pressure in South Tasman	**Peak (m)**							-0.30	-0.24	-0.27	-0.21	-0.22	-0.26	-0.22	-0.26	-0.25	-0.21	-0.27	-0.29
	Date							26/2	27/2	26/2	26/2	25/2	26/2	27/2	25/2	26/2	27/2	27/2	23/2
	Time							2230	130	515	715	1800	700	700	1715	1445	245	700	315
10 **30 March-5 April 2013** Low pressure, trough and EAC extending south	**Peak (m)**	0.21	0.24	0.27	0.31	0.37	0.31	0.31	0.34	0.32	0.33	0.34	0.31						
	Date	2/4	1/4	2/4	3/4	1/4	2/4	2/4	2/4	2/4	1/4	1/4	31/3						
	Time	915	2200	245	1915	315	2045	2030	1745	615	2145	2200	1445						
11 **19-22 April 2013** East Coast Low	**Peak (m)**	0.23	0.23	0.23	0.31	0.44	0.33	0.46	0.33	0.35	0.34	0.33	0.27	0.27	0.31	0.48	0.35	0.28	0.22
	Date	21/4	21/4	21/4	21/4	21/4	21/4	20/4	20/4	20/4	20/4	20/4	20/4	20/4	19/4	19/4	19/4	19/4	19/4
	Time	1700	1715	2000	630	730	30	2115	1930	1515	315	445	400	600	1945	2045	1945	1715	430
12 **15-26 May 2013** East Coast Low through Bass Strait and into Tasman Sea	**Peak (m)**	0.44	0.35	0.39	0.42	0.48	0.42	0.30	0.26	0.27	0.25	0.23	0.23	0.22	0.24	0.29	0.29	0.31	0.35
	Date	25/5	25/5	25/5	25/5	24/5	24/5	24/5	23/5	23/5	18/5	22/5	18/5	17/5	17/5	16/5	17/5	17/5	17/5
	Time	1115	1430	1200	145	1315	1500	1345	1015	1015	1715	2130	1715	1730	1615	315	345	1745	645
13 **12 - 22 June 2013** Series of East Coast Lows	**Peak (m)**	0.26	0.24	0.22	0.34	0.43	0.34	0.38	0.34	0.34	0.35	0.30	0.25	0.25	0.27	0.31	0.26	0.25	0.23
	Date	18/6	18/6	21/6	17/6	17/6	17/6	16/6	16/6	16/6	16/6	16/6	15/6	15/6	15/6	15/6	15/6	15/6	14/6
	Time																		

The tidal anomalies were calculated by comparing the actual recorded water level with the predicted water level
The predicted data was generated using harmonic constituents from the previous year
The anomalies in this table are based on a ranking of 15-minute data
Only anomalies of absolute value greater than 0.20m are shown in this table

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TIDAL ANOMALIES
2012-2013

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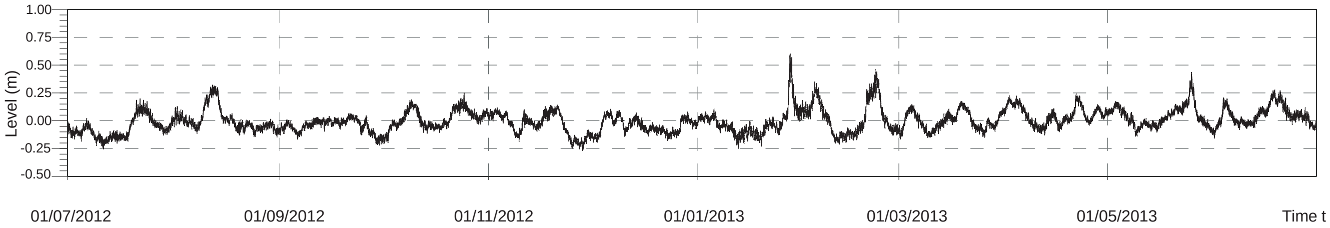
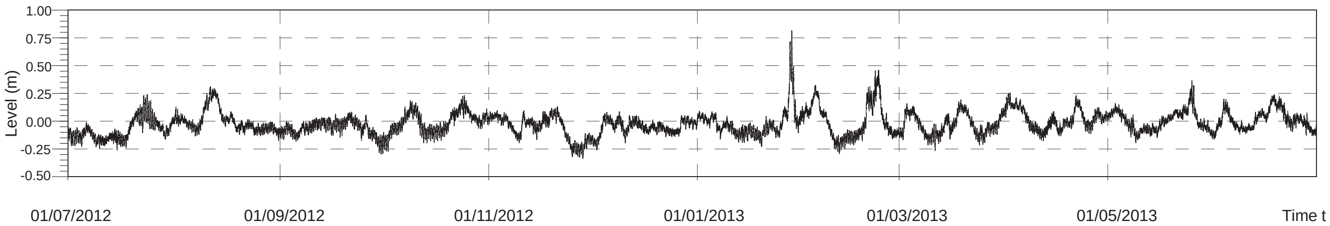
Figure 3.4

DRAWING 2219-03-04.cdr

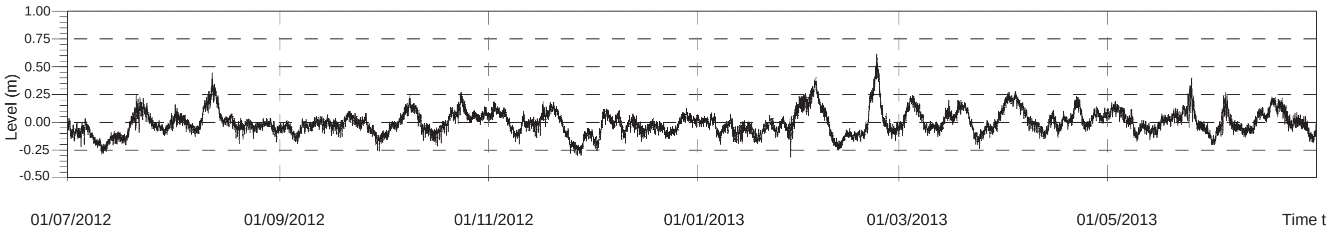
Tweed River at Tweed Heads



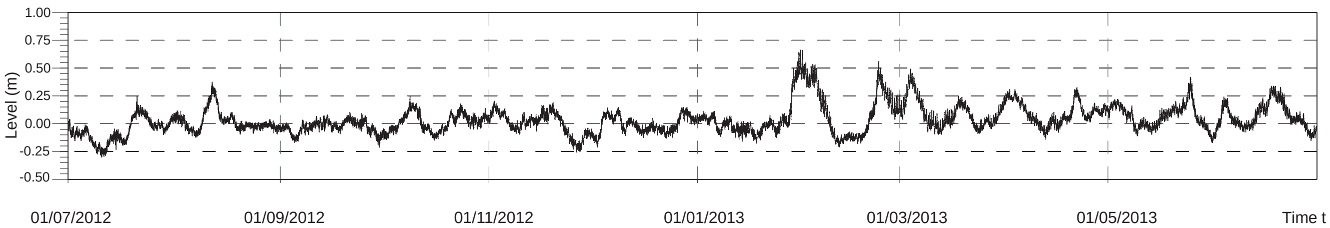
Brunswick River at Brunswick Heads



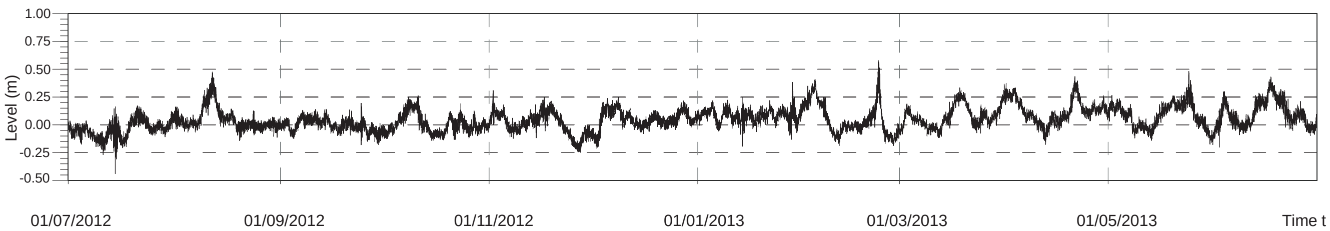
Richmond River at Ballina Breakwall



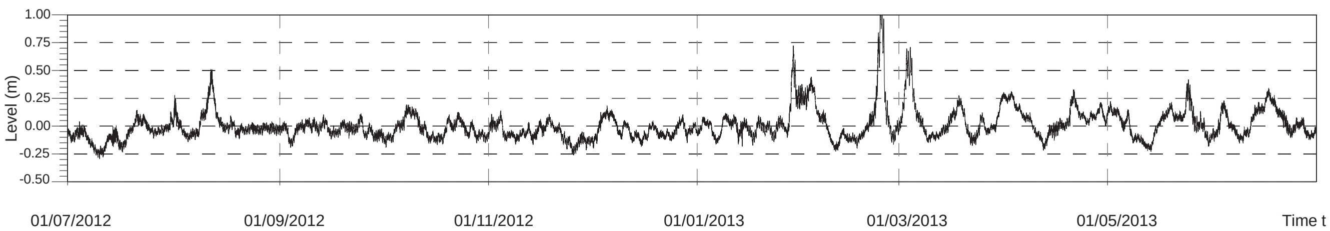
Clarence River at Yamba



Tasman Sea at Coffs Harbour



Hastings River, Port Macquarie



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TIDAL ANOMALIES 2012-2013
TWEED HEADS TO PORT MACQUARIE

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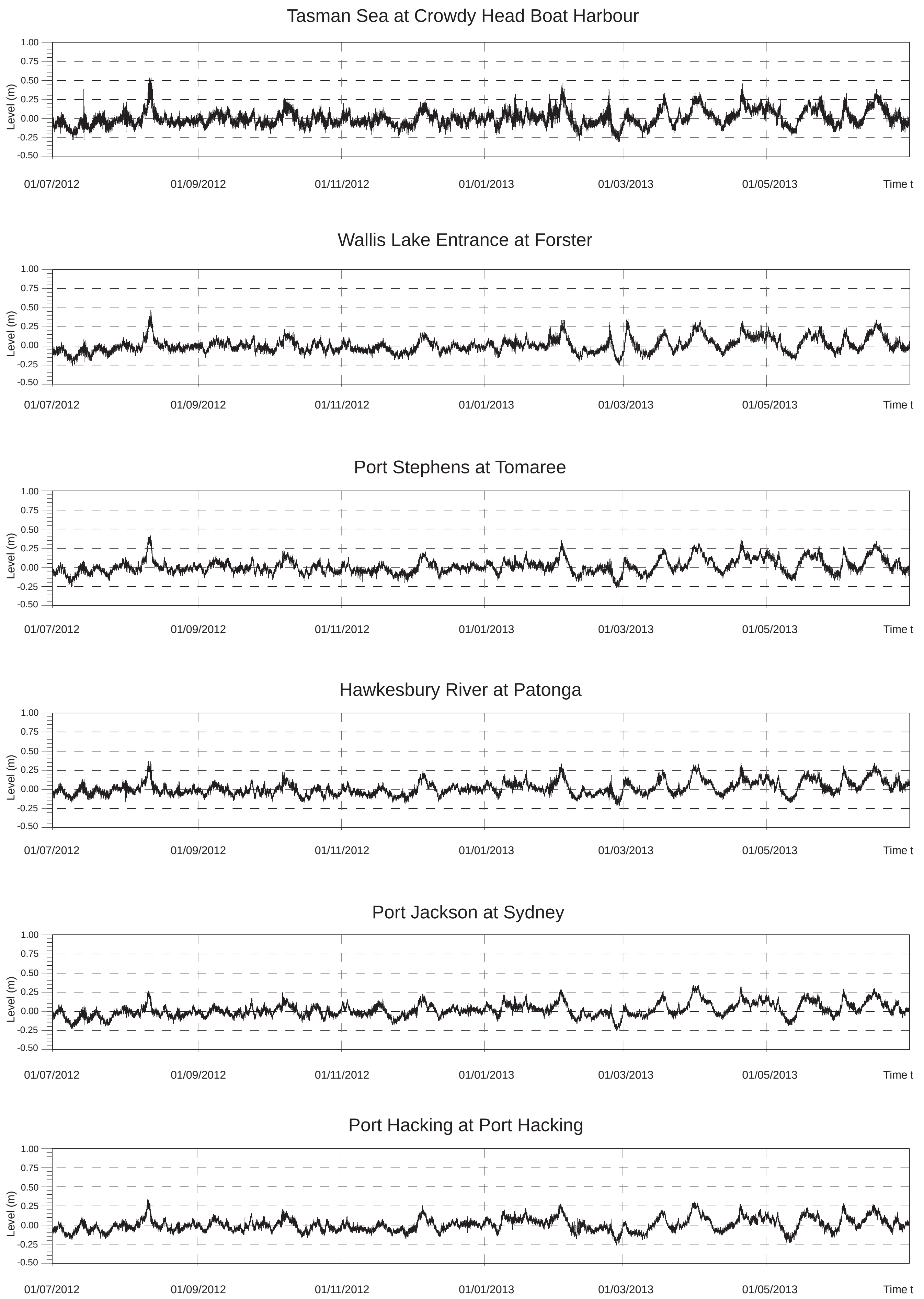
Figure 3.5

DRAWING 2219-03-05.cdr



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TIDAL ANOMALIES 2012-2013
CROWDY HEAD TO PORT HACKING

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Figure 3.6

DRAWING 2219-03-06.cdr

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TIDAL ANOMALIES 2012-2013
CROOKHAVEN TO EDEN

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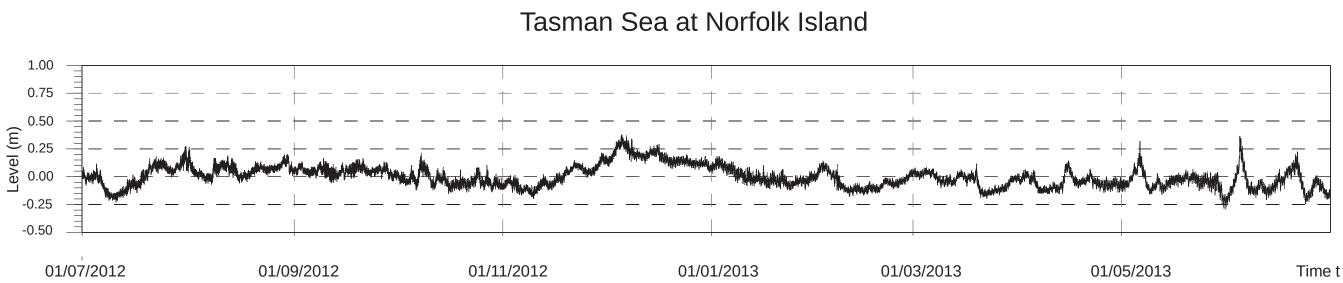
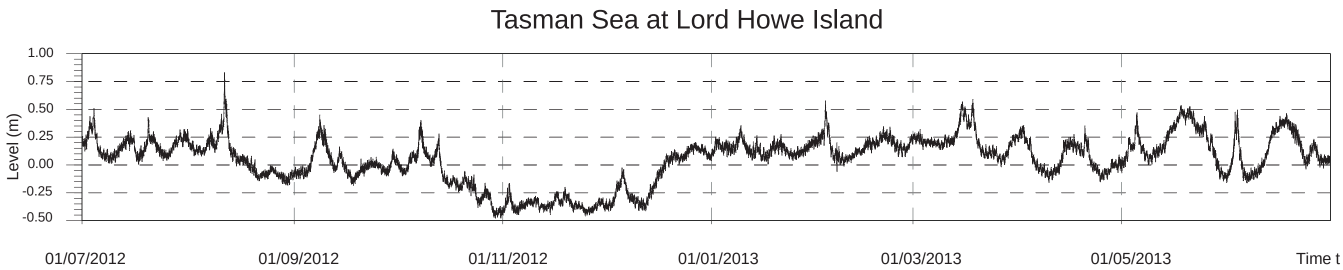
Figure 3.7

DRAWING 2219-03-07.cdr





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TIDAL ANOMALIES 2012-2013
NORFOLK ISLAND AND LORD HOWE ISLAND

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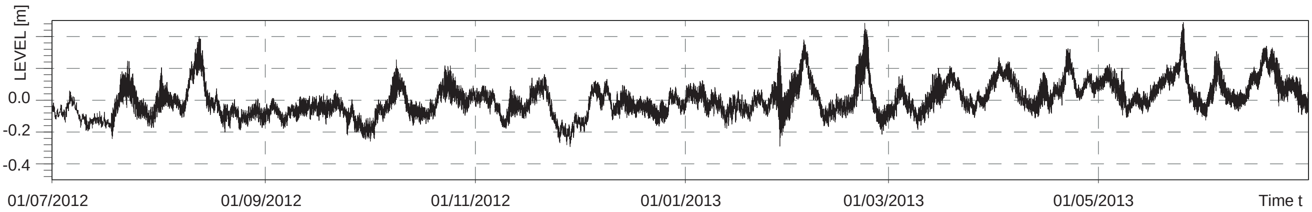
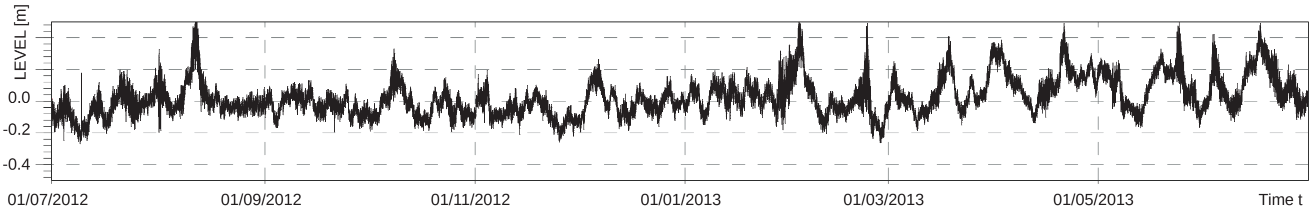
Figure 3.8

DRAWING 2219-03-08.cdr

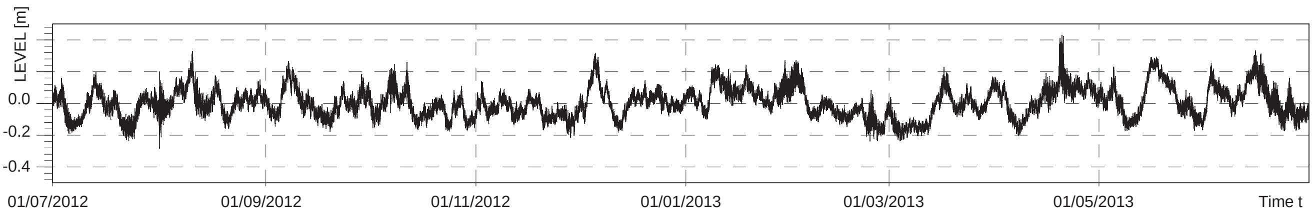
Tweed Heads Offshore



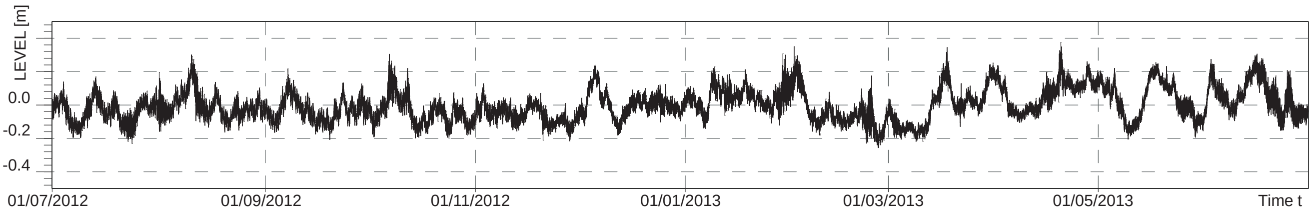
Port Macquarie Offshore



Batemans Bay Offshore



Shoalhaven Offshore



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TIDAL ANOMALIES 2012-2013
OFFSHORE TIDE GAUGES

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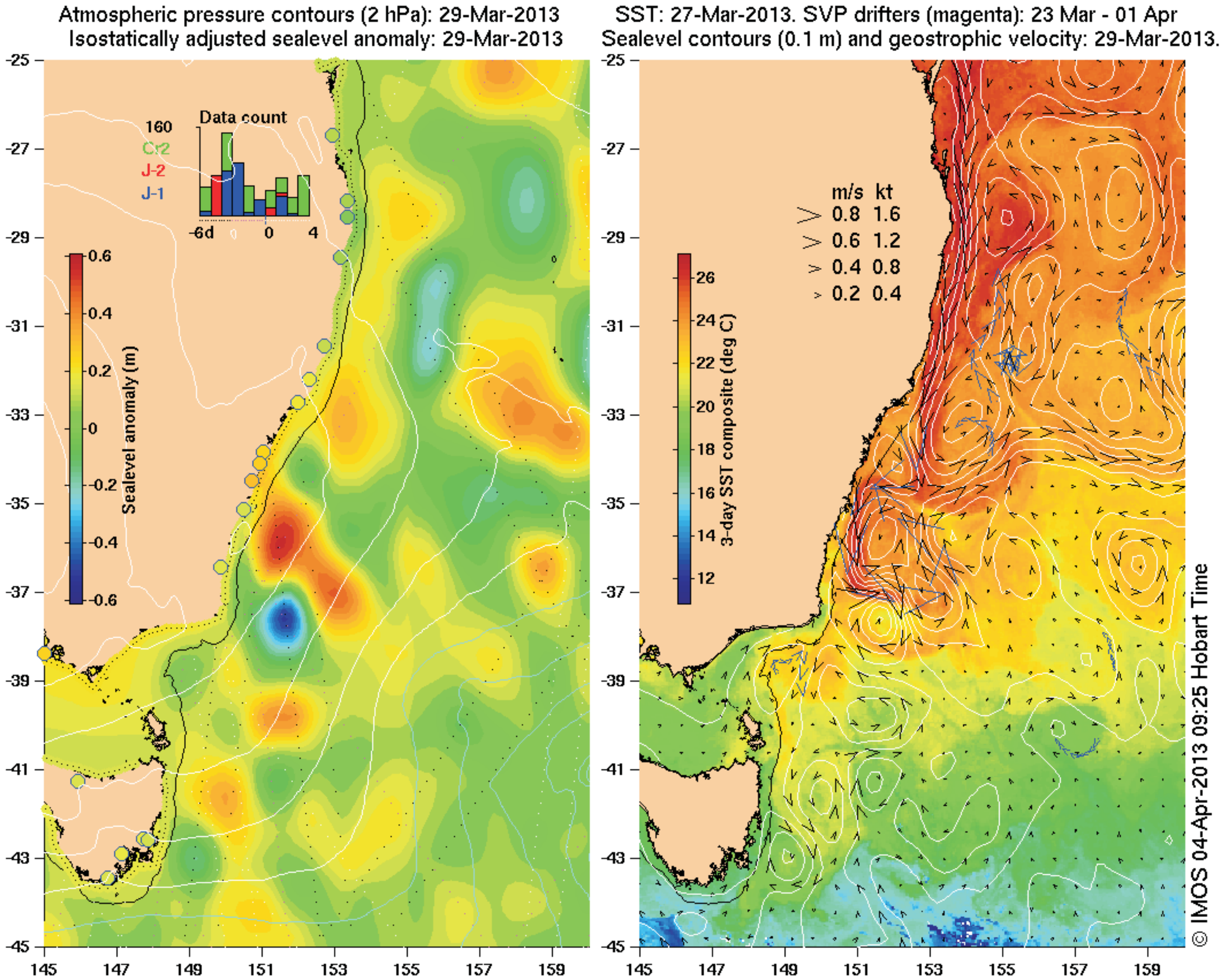
Figure 3.9

DRAWING 2219-03-09.cdr



Data was sourced from the Integrated Marine Observing System (IMOS). IMOS is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative

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IMOS PREDICTED ANOMALY AND SEA SURFACE TEMPERATURES 31 MARCH 2013

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Figure 3.10

DRAWING 2219-03-10.cdr

4. Program Developments 2012-2013

4.1 Classification of Sites

An increasing interest in sea level rise, tsunami and storm surge data has led to the adoption of a classification of each of the sites based on the type of data they represent from their recording location. As the Ocean Tide and River Entrance Program collects data from a variety of recording locations, from offshore sites to sites inside the entrances of rivers and inside ports, this classification of sites highlights to users of the data possible variability of data based on recording location.

The four classifications are:

- Onshore River Entrance – sites that are located within a river a short distance upstream of the entrance usually maintained open by training walls. Good representation of ocean water levels but show a reduction of tidal range between 0.1 and 0.2 m compared to ocean tide, and may be affected by entrance conditions and floods
- Onshore Bay or Port - bank or pole-mounted sensor located in an embayment or harbour. Effective at measuring the ocean water levels where there is no influence by floods. Can be influenced by harbour motions (i.e. seiches)
- Onshore Open Ocean - jetty or bank-mounted sensor located in an open ocean location. Effective at measuring the ocean water levels, but may have problems if located in the surf zone
- Offshore Open Ocean – bottom-mounted sensors that are located between 2 and 5 km offshore of the coast generally in about 25 m depth of water. Very effective at measuring ocean water level but datum cannot be accurately determined.

The classification indicates sites that are similar in their location and gives an indication to the end user of the data of the site location type that would be most representative for the required analysis for a specific project. Table 4.1 lists the classification of each of the sites in the program.

Table 4.1 Ocean and River Entrance Tide Site Classification

Station	Classification	Classification Code
Tweed Heads	Onshore River Entrance	OR
Tweed Heads	Offshore Open Ocean	O
Brunswick Heads	Onshore River Entrance	OR
Ballina Breakwall	Onshore River Entrance	OR
Yamba	Onshore River Entrance	OR
Norfolk Island	Onshore Open Ocean	OO
Lord Howe Island	Onshore Open Ocean	OO
Coffs Harbour	Onshore Bay or Port	OB

Station	Classification	Classification Code
Port Macquarie	Onshore River Entrance	OR
Port Macquarie	Offshore Open Ocean	O
Crowdy Head	Onshore Bay or Port	OB
Forster	Onshore River Entrance	OR
Port Stephens	Onshore Bay or Port	OB
Patonga	Onshore Bay or Port	OB
Sydney	Onshore Bay or Port	OB
Port Hacking	Onshore Bay or Port	OB
Shoalhaven	Offshore Open Ocean	O
Crookhaven	Onshore River Entrance	OR
Jervis Bay	Onshore Bay or Port	OB
Ulladulla	Onshore Bay or Port	OB
Princess Jetty	Onshore River Entrance	OR
Batemans Bay	Offshore Open Ocean	O
Bermagui	Onshore River Entrance	OR
Eden	Onshore Bay or Port	OB

4.2 Program Improvements/Changes

Further improvements and changes to the network have continued in 2012-2013. Table 4.2 shows the status of the sites as of June 2013. The following summarises the major changes:

- Lord Howe, Princess Jetty and Patonga sites primary sensor upgraded to record at 1- second intervals to onsite data storage card (see example data in Figure D1).
- Crowdy Head site upgraded and relocated to a new wharf location.
- Primary sensors upgraded to radars at Coffs Harbour, Port Macquarie, Crowdy Head, Patonga and Princess Jetty.
- Legacy Aanderaa loggers used as second sensor/logger at offshore tide sites as a backup for the newer RBR instrumentation.
- Further development of the new public website for MHL and WISKI database.

Table 4.2 MHL Tidal Logging and Sensing System Status June 2011

Station	Site Classification[1]	Primary Loggers	Secondary Loggers	Primary Sensors	Secondary Sensors	Station	
						Sampling	Logging
Tweed Heads	OR	CR800		Vented Pressure	Vented Pressure	120 samples averaged 1 minute either side of the quarter hour and 60 samples averaged 30 seconds either side of each minute Lord Howe, Patonga and Princess Jetty sites logging at 1 second to onsite data storage card	15 minutes on the quarter hour and 1 minute on the minute
Brunswick Heads	OR	CR800	-	Vented Pressure	Vented Pressure		
Ballina Breakwall	OR	CR800	-	Vented Pressure	Vented Pressure		
Yamba	OR	CR800	-	Vented Pressure	Vented Pressure		
Coffs Harbour	OB	CR800		Radar	Vented Pressure		
Port Macquarie	OR	CR800	-	Radar	Vented Pressure		
Crowdy Head[3]	OB	CR800	-	Radar	Vented Pressure		
Forster	OR	CR800	-	Vented Pressure	Vented Pressure		
Port Stephens	OB	CR800	-	Radar	Vented Pressure		
Patonga	OB	CR800		Radar	Vented Pressure		
Sydney	OB	CR800		Radar	n/a		
Sydney Backup	OB	CR800		Vented Pressure	Vented Pressure		
Port Hacking	OB	CR800	MetOcean	Electromagnetic	Vented Pressure		
Crookhaven	OR	CR800	-	Vented Pressure	Vented Pressure		
Jervis Bay	OB	CR800	-	Radar	Vented Pressure		
Ulladulla	OB	CR800	-	Vented Pressure	Vented Pressure		
Princess Jetty	OR	CR800		Radar	Vented Pressure		
Bermagui	OR	CR800	-	Vented Pressure	Vented Pressure		
Eden	OB	CR800n		Radar	Vented Pressure		
Norfolk Island	OO	CR800	-	Floatwell	Vented Pressure		
Lord Howe Island	OO	CR1000	-	Radar	Vented Pressure		
Tweed Heads[2]	O	WLR7	-	Submersible Paroscientific Pressure Sensor and RBR Logger	Aanderaa Submersible Pressure	Integrated over 40 seconds	RBR 5 minutes Aanderaa 60 minutes
Port Macquarie[2]	O	WLR7	-				
Shoalhaven[2]	O	WLR7	-				
Batemans Bay[2]	O	WLR7	-				

[1] Classification: O = Offshore Open Ocean, OO = Onshore Open Ocean, OR = Onshore River entrance, OB = Onshore Bay or Port
[2] Offshore tidal site

4.3 Program Plans 2013-2014

MHL is continuing to upgrade the Ocean Tide program to adopt best practice in data collection, maximise the efficiency of maintaining the program, increase data accuracy and capture, improve data resolution and increase the value of the data collected. The planned 2013-2014 program upgrades include:

- last stage of rollout of radar sensors to be progressively installed at possibly Tweed Heads, Yamba and Ulladulla
- automated status reports from the field to the database
- high frequency logging (1 second) upgrades at Port Stephens, Sydney, Jervis Bay and Eden.

5. References

Foreman, M.G.G. 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)

Horton, P, Britton, G and Kelly, D, 2013, 'Lord Howe Island – Unique Coastal Processes and Challenging Coastal Management', *Coasts and Ports Conference*, Sydney, September 2013.

MHL 2005, *Investigation into Tidal Planes Compilation – NSW Tidal Planes Data Compilation Stage 3*, MHL Report 1269, November 2005.

MHL 2011, *NSW Ocean Water Levels,* MHL Report 1881, March 2011.

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Appendix A

Annual Data Site Summaries

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STATION LOCATION
TWEED HEADS

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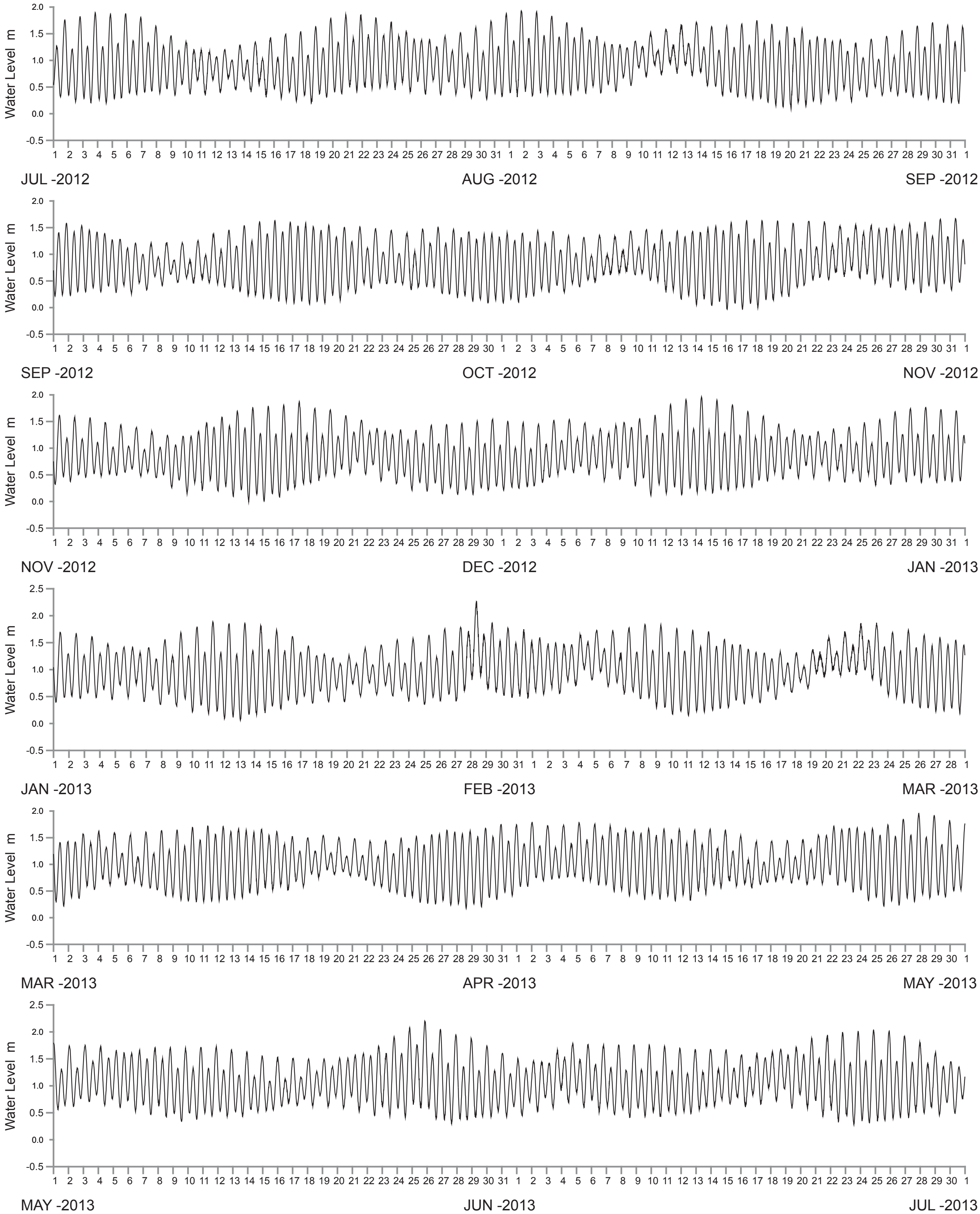
Figure A1

DRAWING 2219-A1.cdr



WATER LEVEL REFERENCED TO TWEED RIVER HYDRO DATUM

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

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Public Works
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TWEED RIVER AT TWEED HEADS
2012-2013

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Figure
A2

DRAWING 2219-A2

Public Works
Manly Hydraulics Laboratory

TWEED HEADS OFFSHORE
TIDE GAUGE LOCATION

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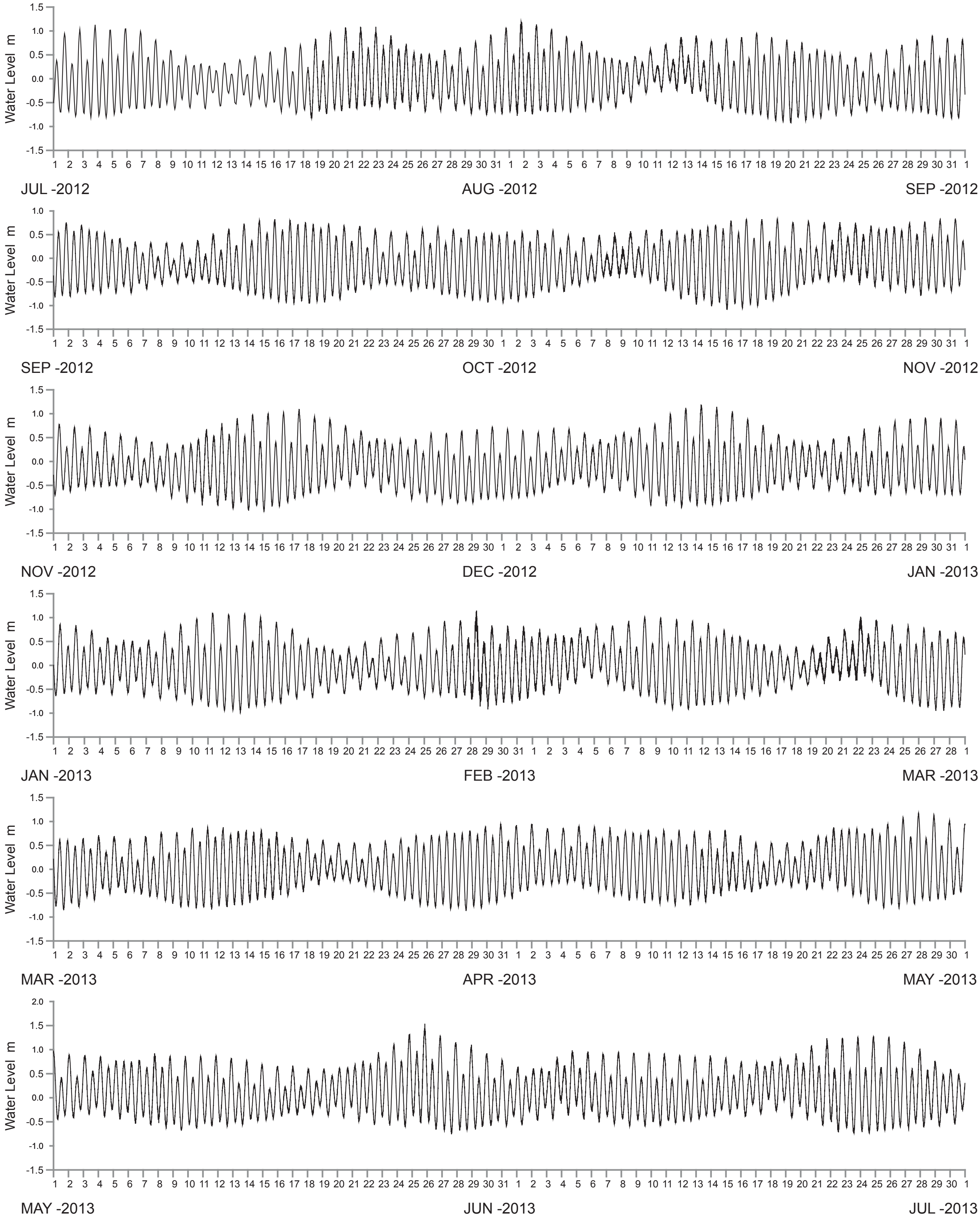
Figure A3

DRAWING 2219-A3.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

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

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TASMAN SEA AT TWEED HEADS OFFSHORE 2012-2013

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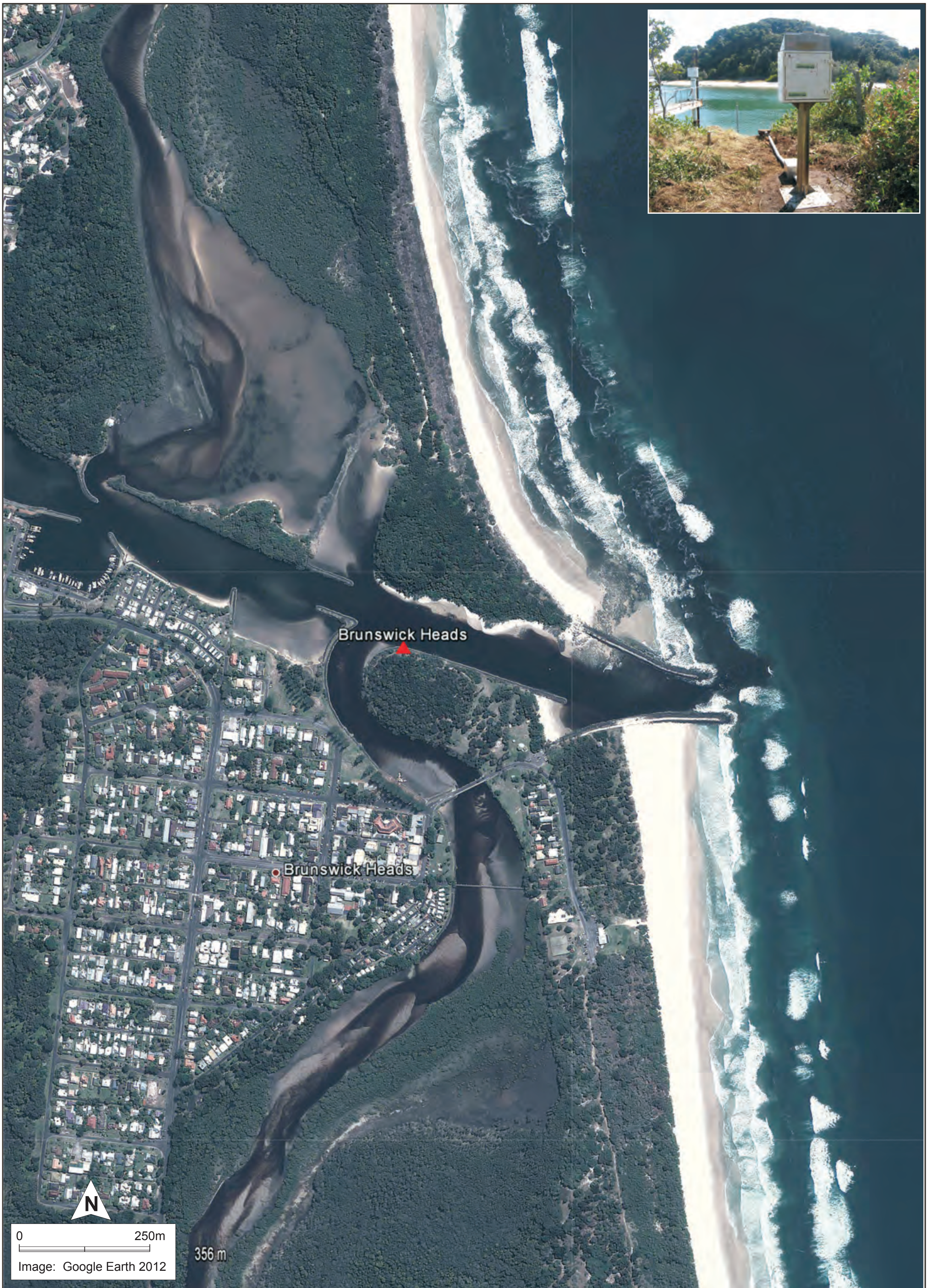
Figure A4

DRAWING 2219-A4



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STATION LOCATION
BRUNSWICK HEADS

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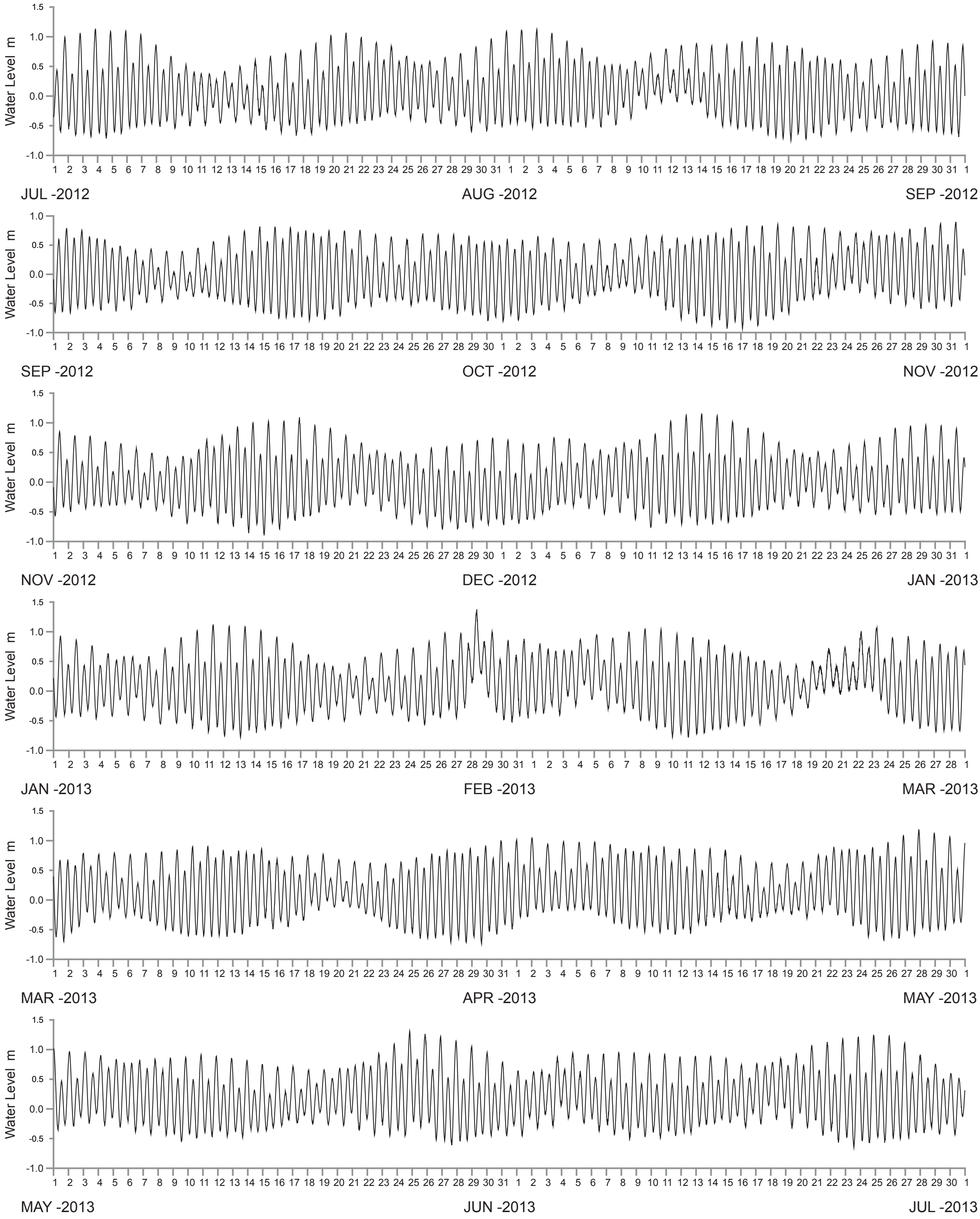
Figure A5

DRAWING 2219-A5.cdr



WATER LEVEL REFERENCED TO BRUNSWICK RIVER FLOOD MITIGATION DATUM

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

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory	BRUNSWICK RIVER AT BRUNSWICK HEADS 2012-2013	MHL Report 2219 Figure A6 DRAWING 2219-A6

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Manly Hydraulics Laboratory

STATION LOCATION
BALLINA BREAKWALL

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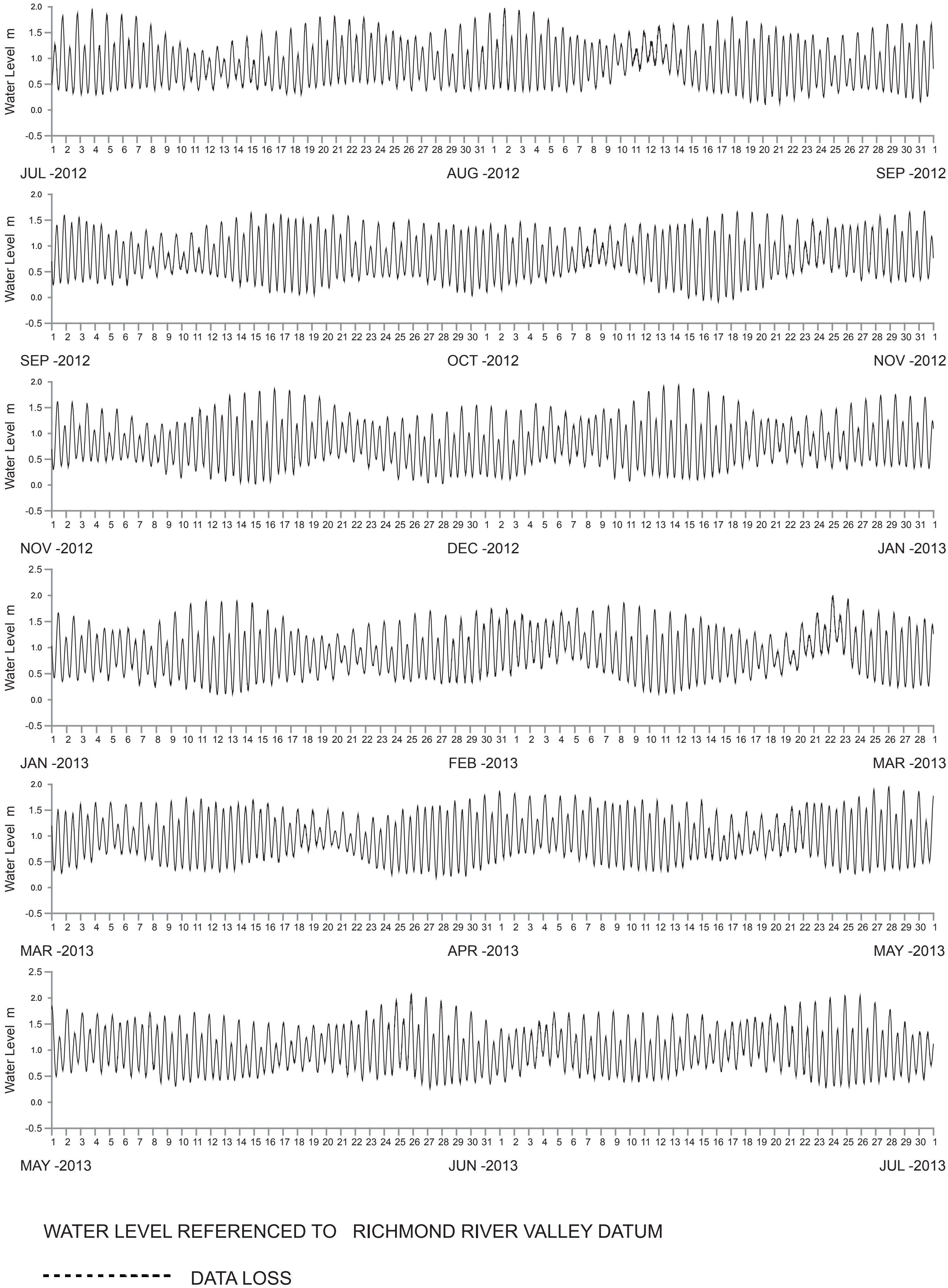
Figure
A7

DRAWING 2219-A7.cdr



Public Works
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RICHMOND RIVER AT BALLINA BREAKWALL
2012-2013

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Figure A8

DRAWING 2219-A8

NSW GOVERNMENT

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Manly Hydraulics Laboratory

STATION LOCATION
YAMBA

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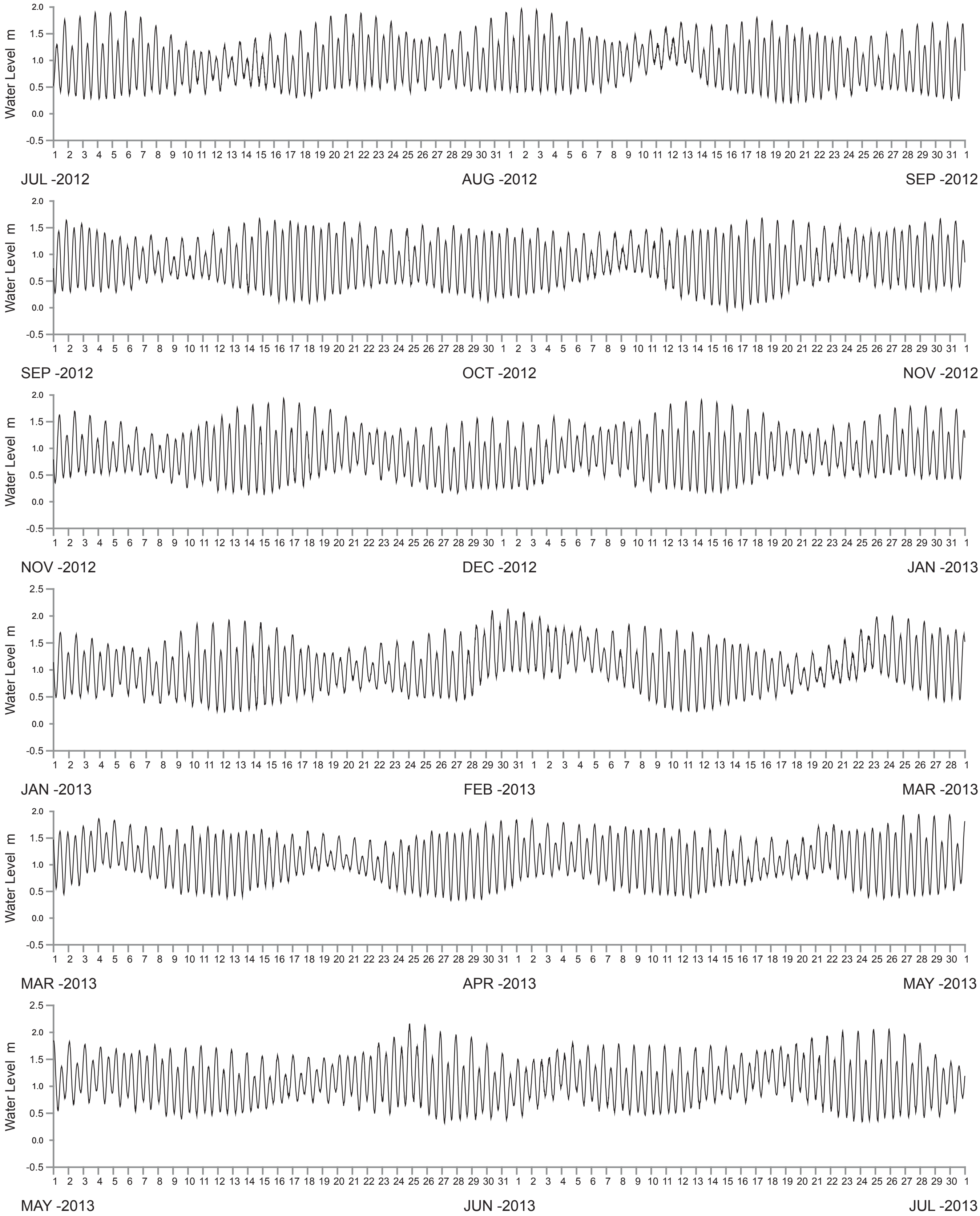
Figure A9

DRAWING 2219-A9.cdr



WATER LEVEL REFERENCED TO ILUKA PORT DATUM

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

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CLARENCE RIVER AT YAMBA
2012-2013

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Figure A10

DRAWING 2219-A10

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STATION LOCATION
COFFS HARBOUR

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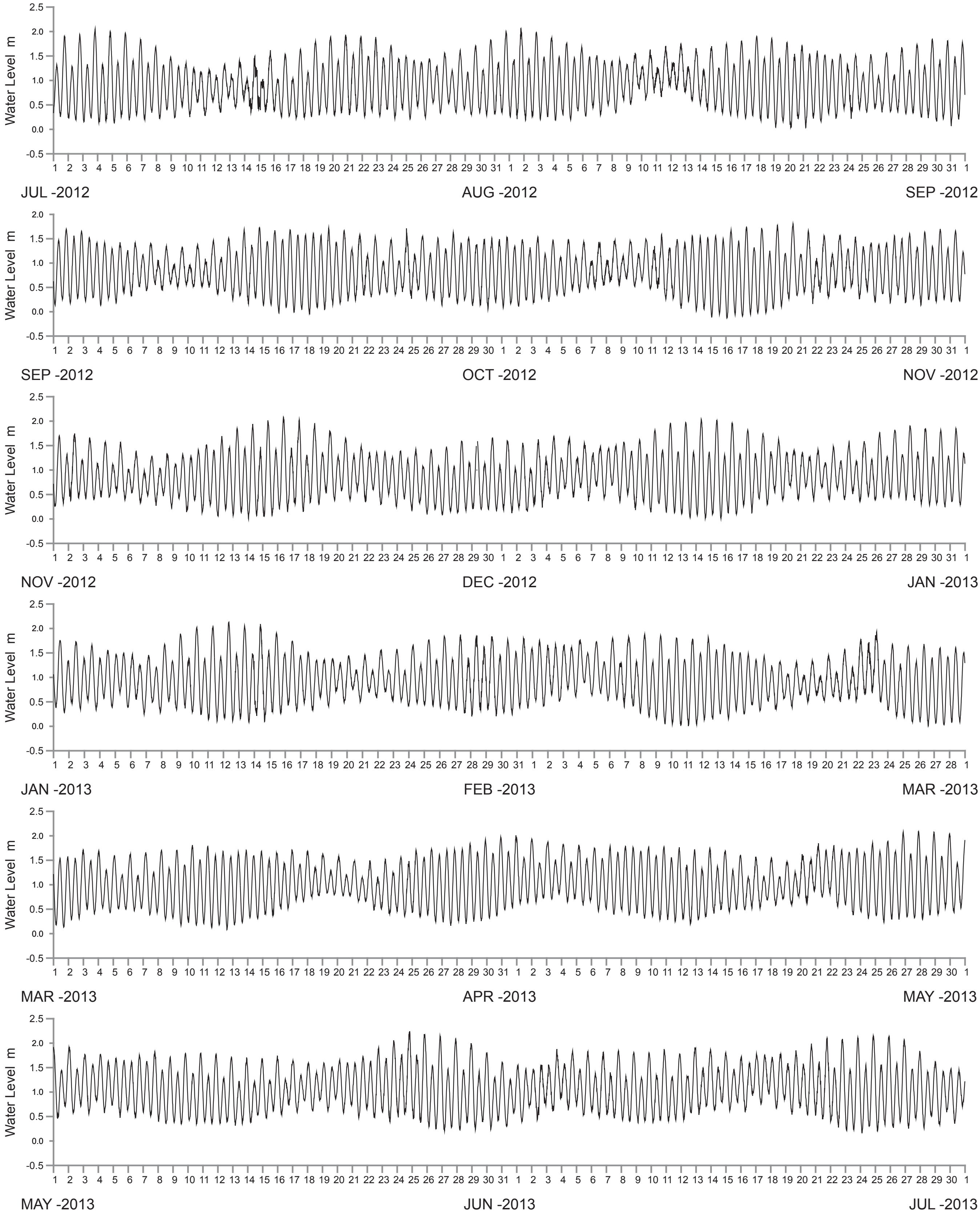
Figure A11

DRAWING 2219-A11.cdr



WATER LEVEL REFERENCED TO COFFS PORT DATUM

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

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TASMAN SEA AT COFFS HARBOUR
2012-2013

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Figure A12

DRAWING 2219-A12

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STATION LOCATION
PORT MACQUARIE

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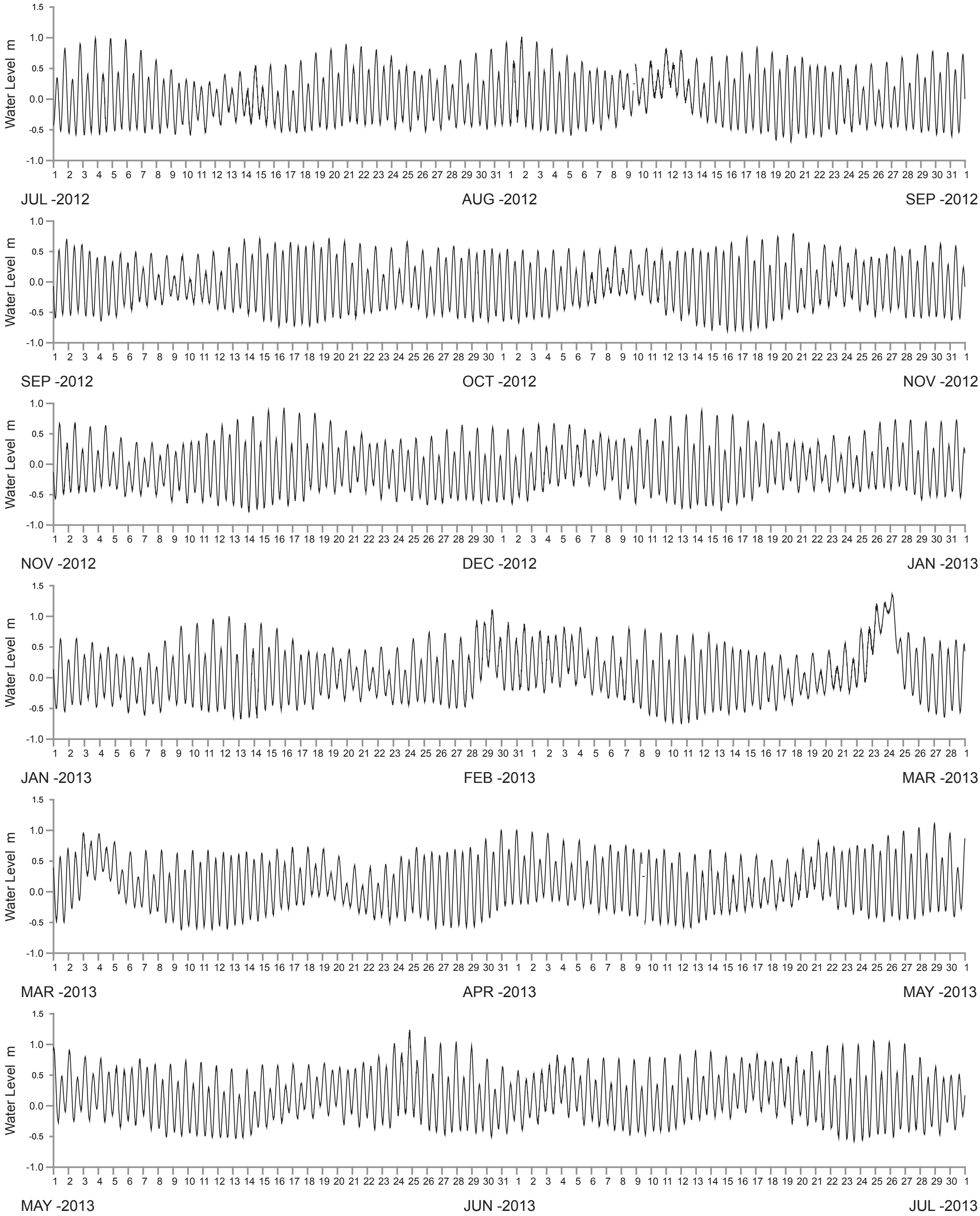
Figure A13

DRAWING 2219-A13.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

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Manly Hydraulics Laboratory

HASTINGS RIVER AT PORT MACQUARIE
2012-2013

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Figure A14

DRAWING 2219-A14

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PORT MACQUARIE
OFFSHORE TIDE GAUGE LOCATION

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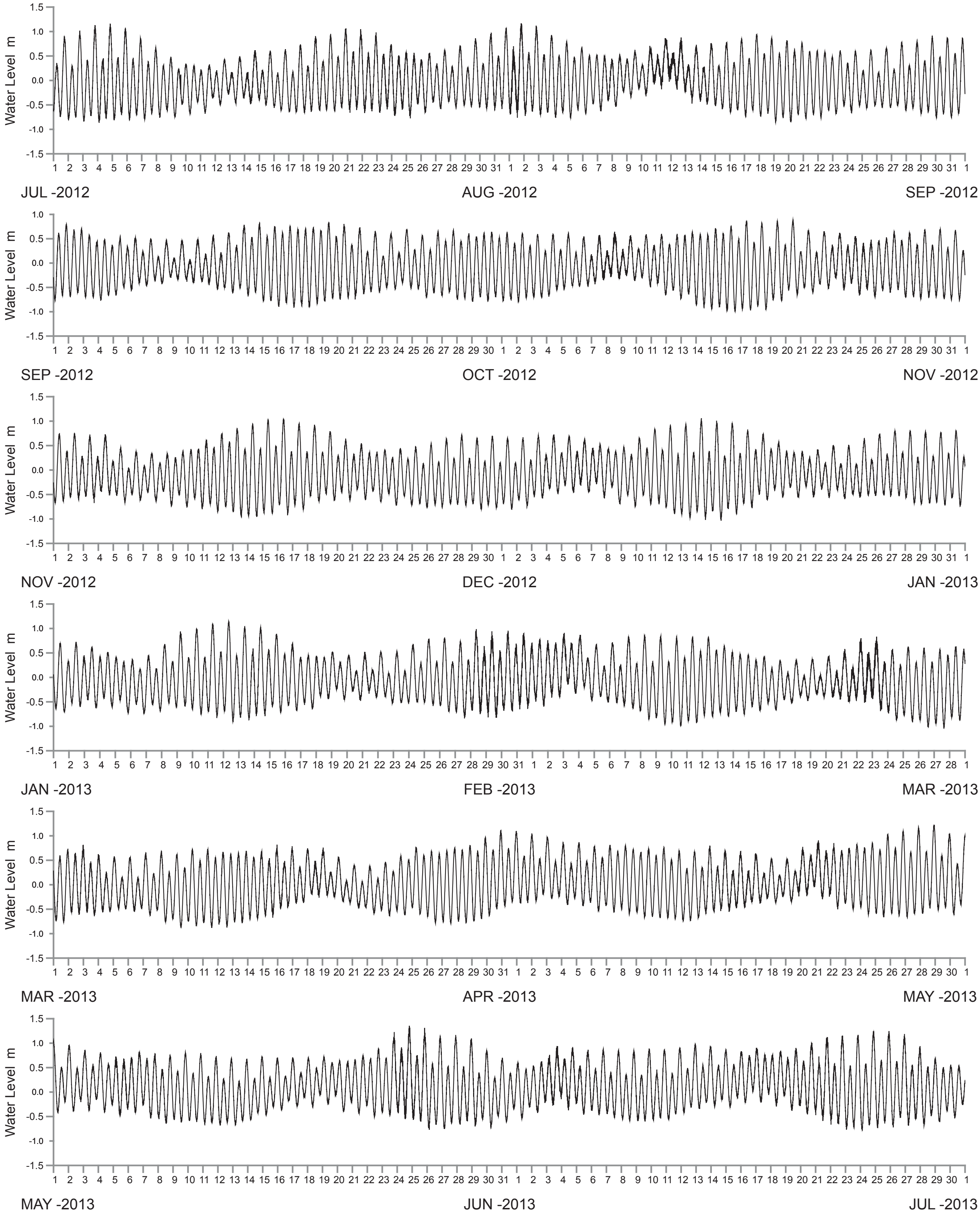
Figure A15

DRAWING 2219-A15.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

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

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TASMAN SEA AT PORT MACQUARIE OFFSHORE
2012-2013

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Figure A16

DRAWING 2219-A16

Public Works
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STATION LOCATION
CROWDY HEAD

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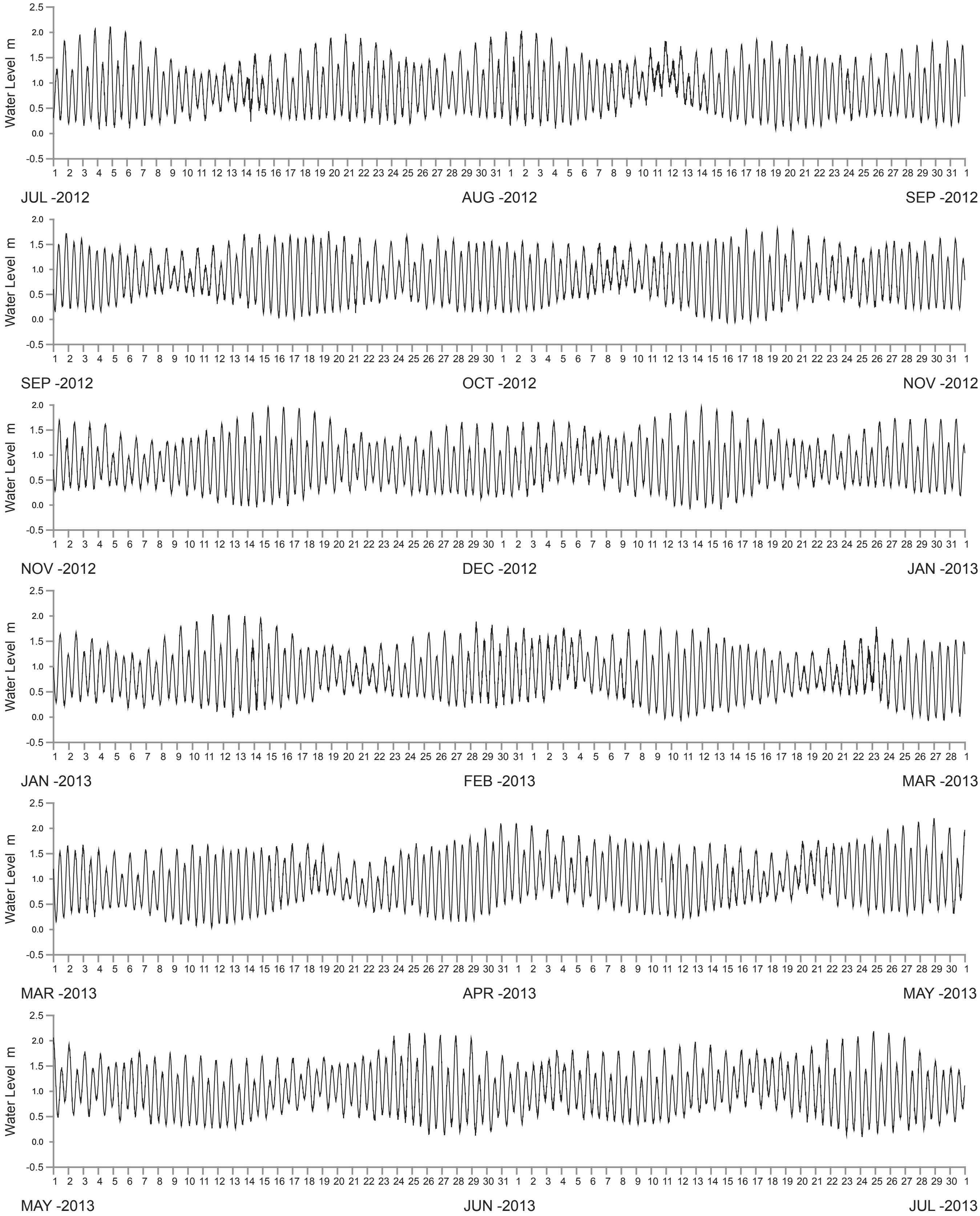
Figure A17

DRAWING 2219-A17.cdr



WATER LEVEL REFERENCED TO CROWDY HEAD DATUM

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

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TASMAN SEA AT CROWDY HEAD BOAT HARBOUR
2012-2013

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Figure A18

DRAWING 2219-A18

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Manly Hydraulics Laboratory

STATION LOCATION
FORSTER

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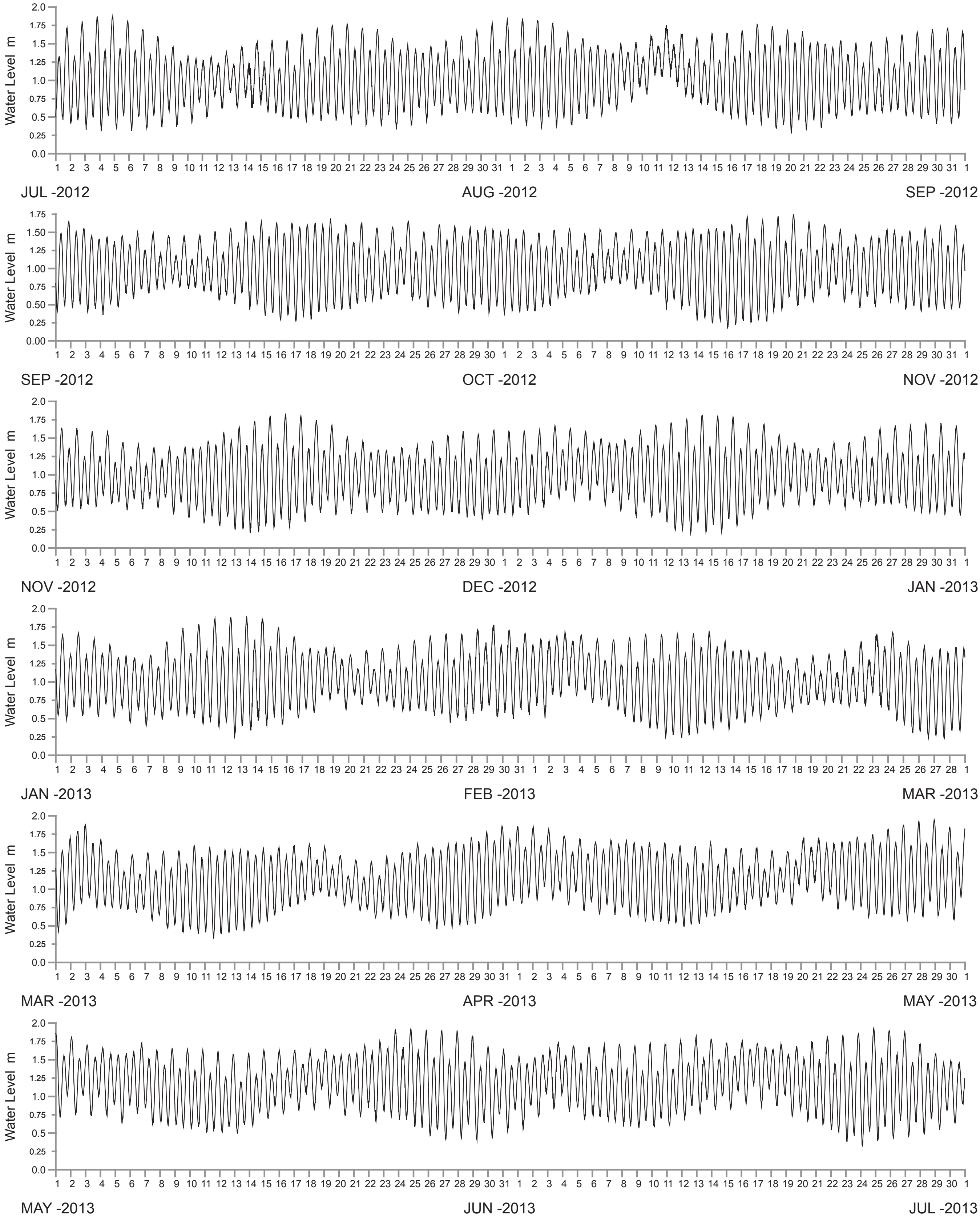
Figure
A19

DRAWING 2219-A19.cdr



WATER LEVEL REFERENCED TO FORSTER HYDRO DATUM

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

Public Works
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WALLIS LAKE ENTRANCE AT FORSTER
2012-2013

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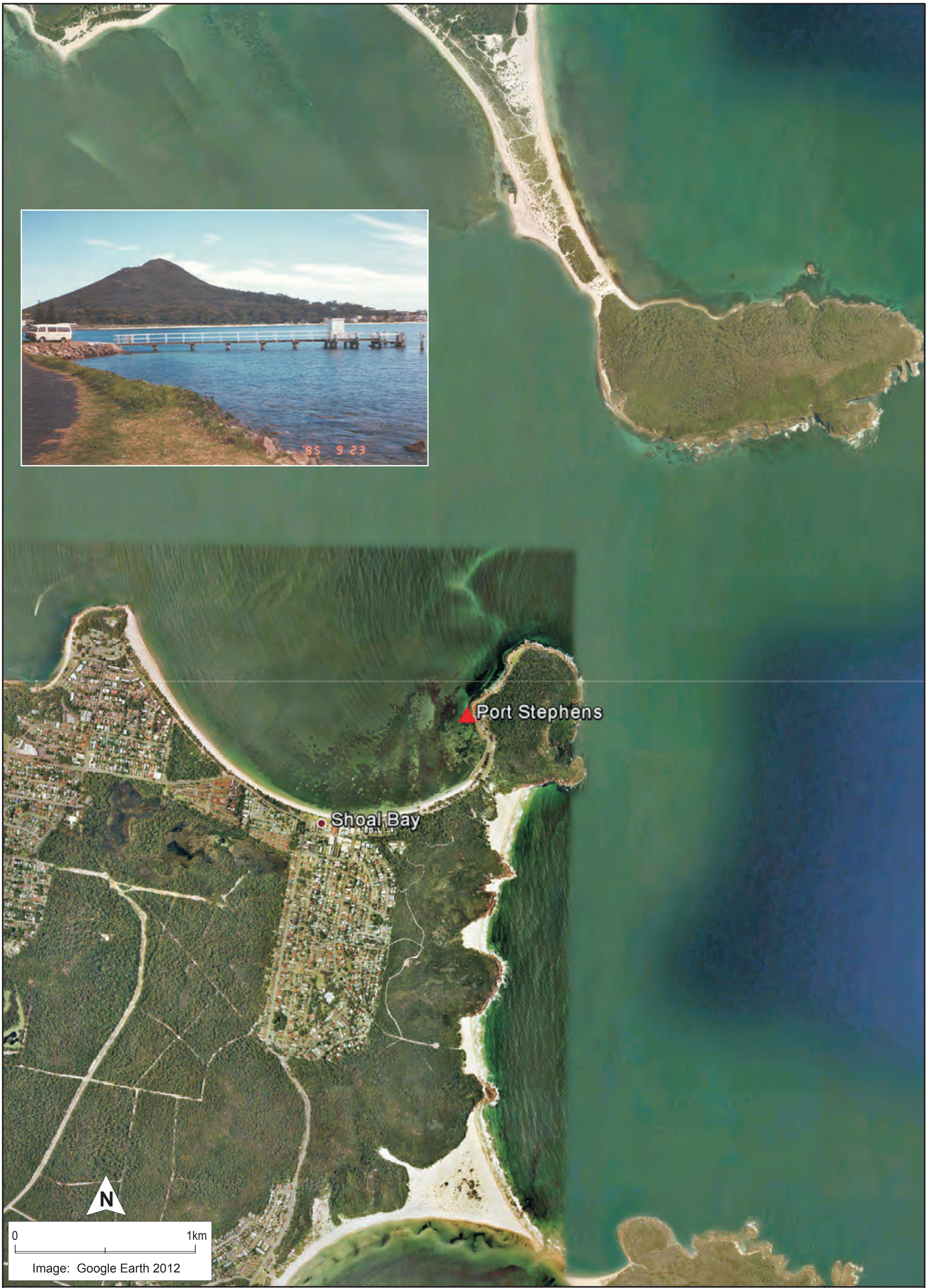
Figure A20

DRAWING 2219-A20



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STATION LOCATION
PORT STEPHENS

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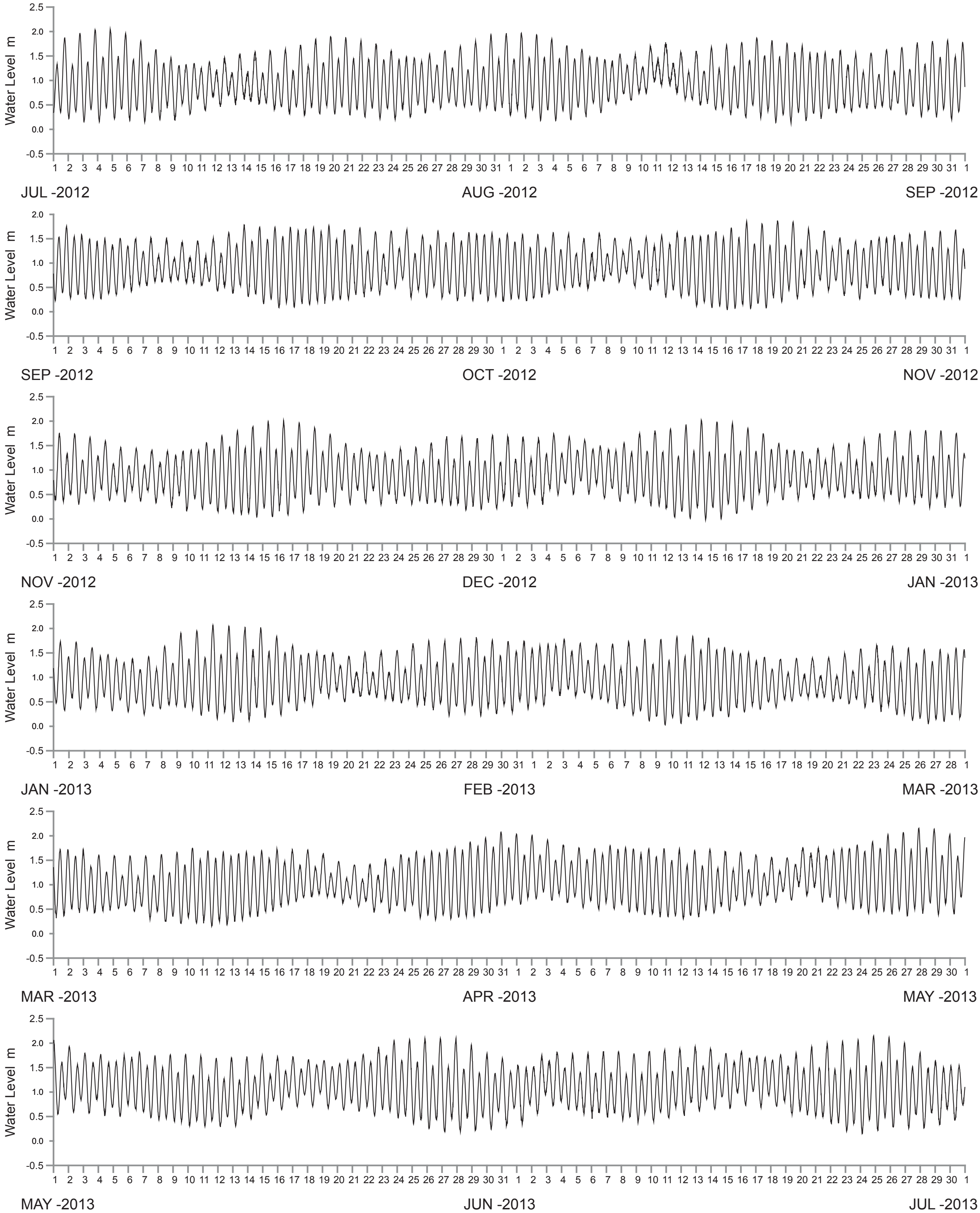
Figure A21

DRAWING 2219-A21.cdr



WATER LEVEL REFERENCED TO PORT STEPHENS HYDRO DATUM

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

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PORT STEPHENS AT TOMAREE
2012-2013

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Figure A22

DRAWING 2219-A22

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STATION LOCATION
PATONGA

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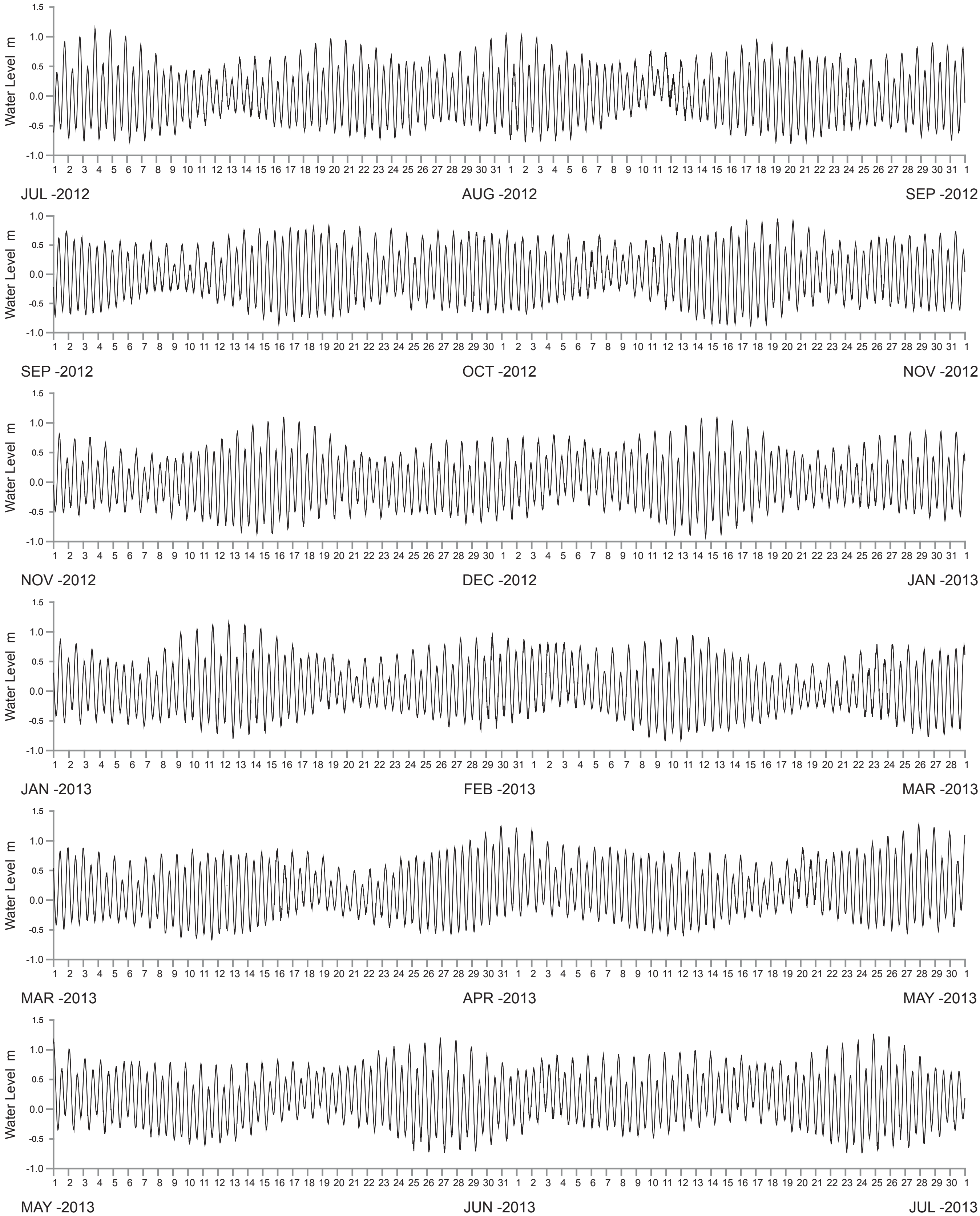
Figure A23

DRAWING 2219-A23.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory

HAWKESBURY RIVER AT PATONGA
2012-2013

MHL Report 2219

Figure A24

DRAWING 2219-A24

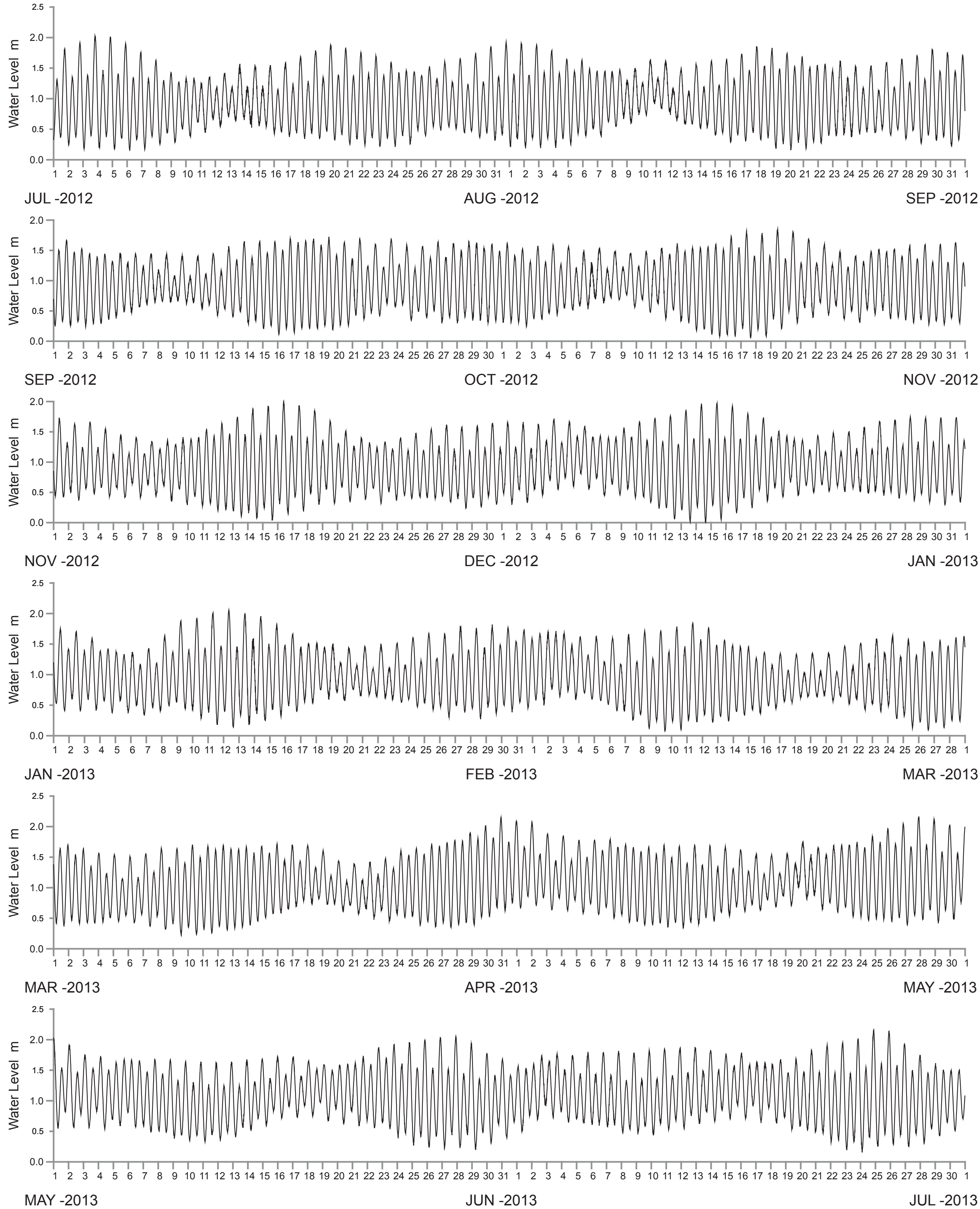
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
SYDNEY HARBOUR

MHL Report 2219

Figure A25

DRAWING 2219-A25.cdr



WATER LEVEL REFERENCED TO ZERO CAMP COVE

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

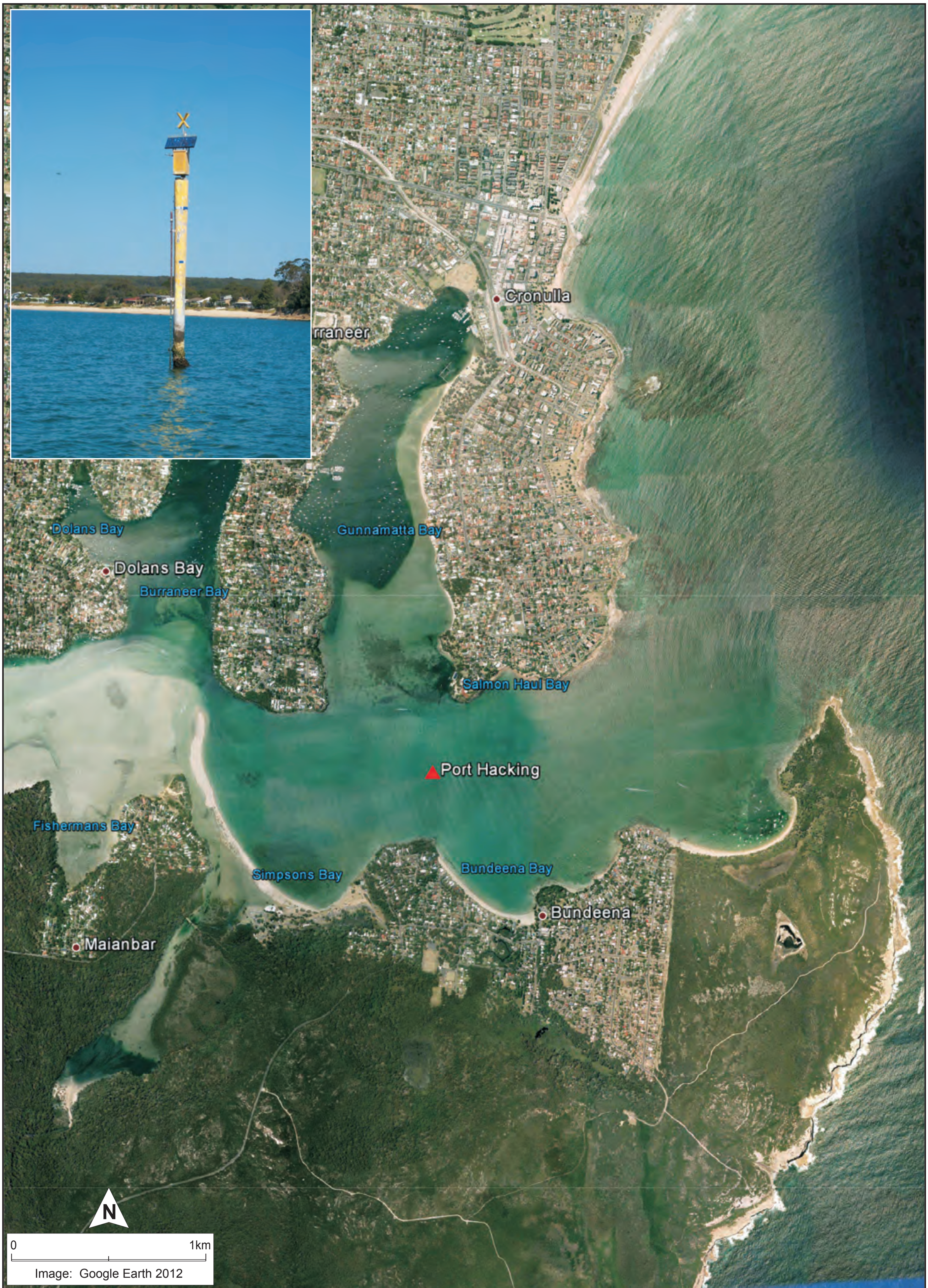
NSW GOVERNMENT Public Works Manly Hydraulics Laboratory

SYDNEY PORT JACKSON AT HMAS PENGUIN
2012-2013

MHL Report 2219

Figure A26

DRAWING 2219-A26



NSW GOVERNMENT

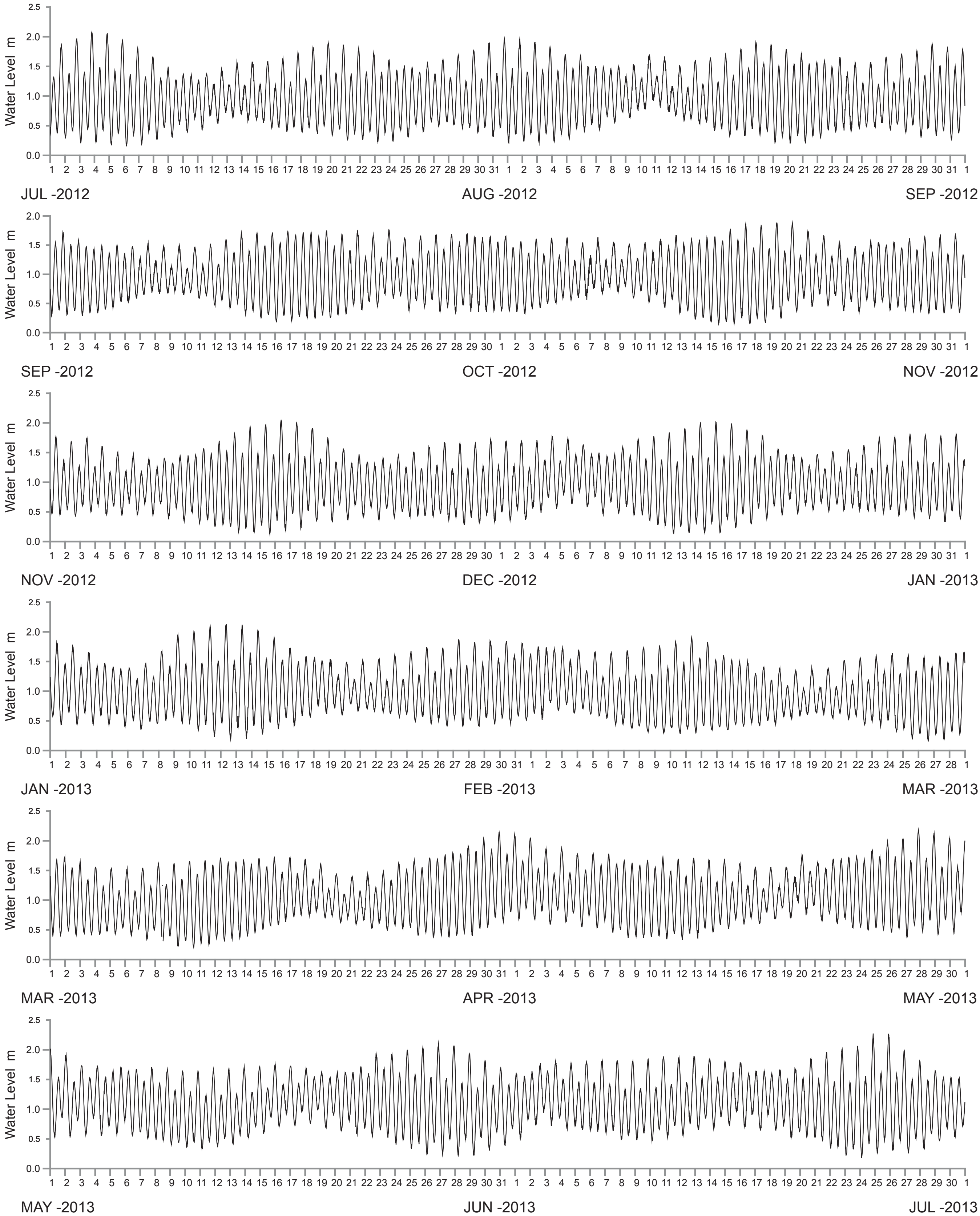
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
PORT HACKING

MHL Report 2219

Figure A27

DRAWING 2219-A27.cdr



WATER LEVEL REFERENCED TO INDIAN SPRING LOW WATER

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

Public Works
Manly Hydraulics Laboratory

PORT HACKING AT PORT HACKING
2012-2013

MHL Report 2219

Figure A28

DRAWING 2219-A28

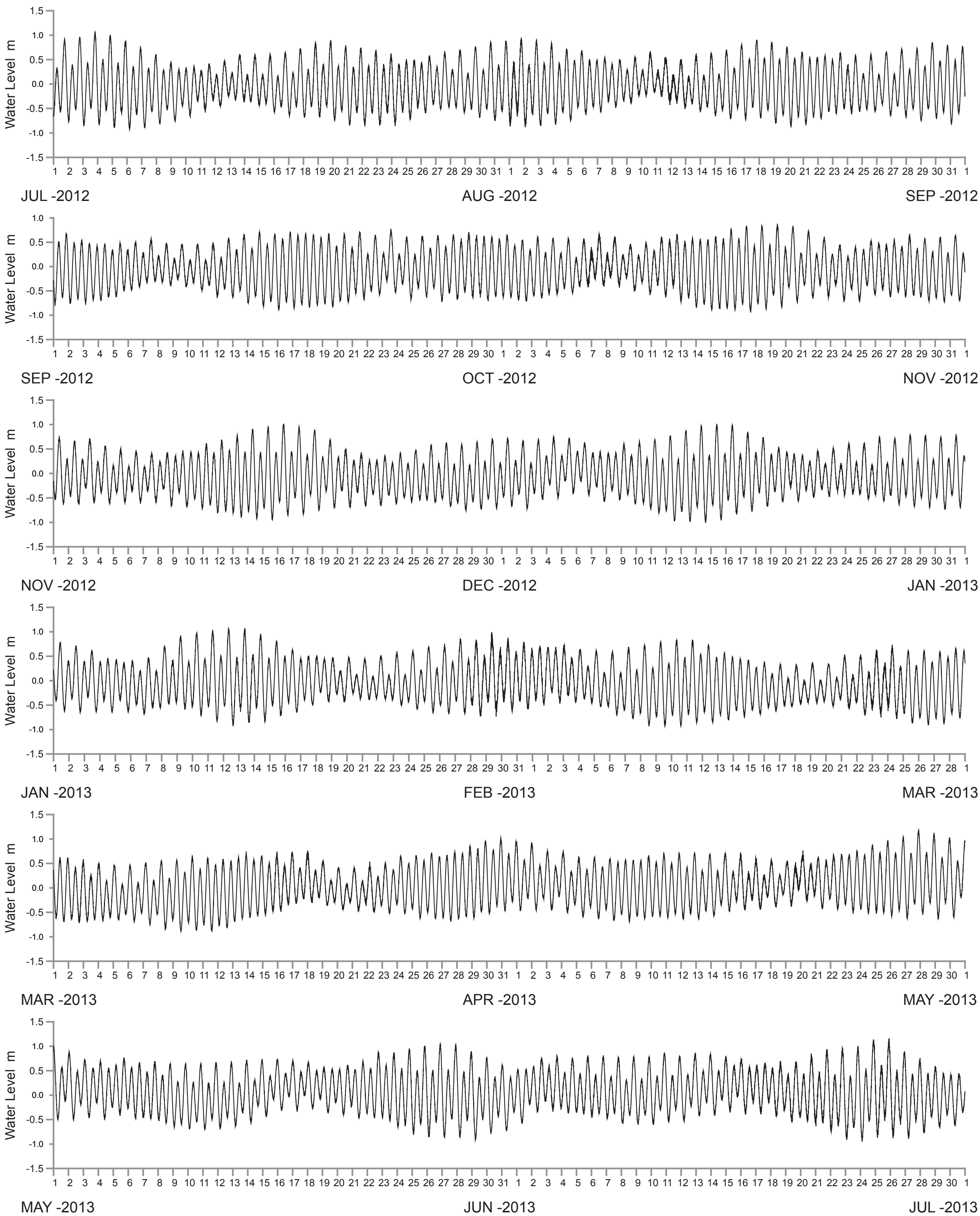
NSW GOVERNMENT
Public Works
Manly Hydraulics Laboratory

SHOALHAVEN OFFSHORE
TIDE GAUGE LOCATION

MHL Report 2219

Figure A29

DRAWING 2219-A29.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

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

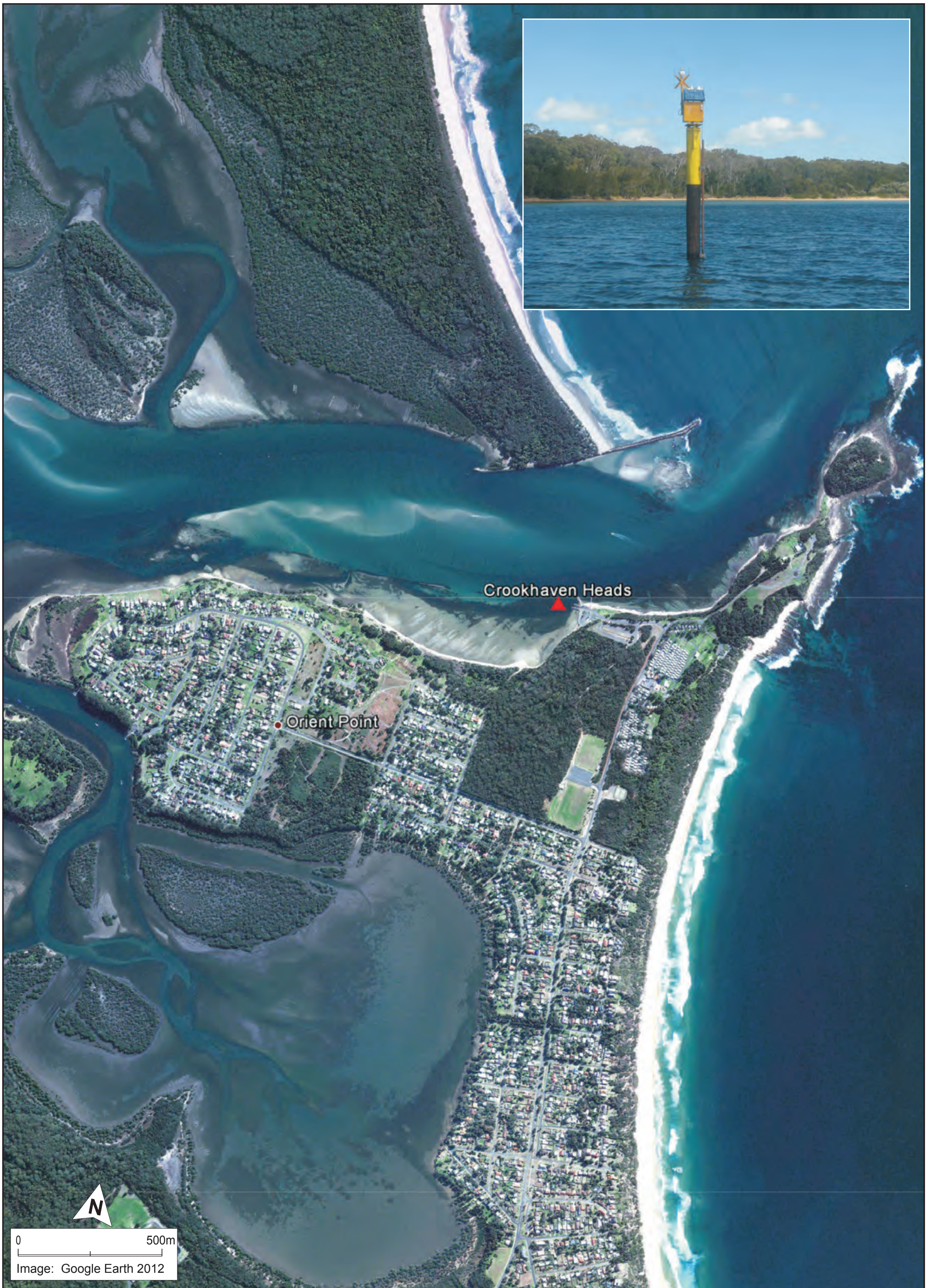
NSW GOVERNMENT Public Works
Manly Hydraulics Laboratory

TASMAN SEA AT SHOALHAVEN OFFSHORE
2012-2013

MHL Report 2219

Figure A30

DRAWING 2219-A30



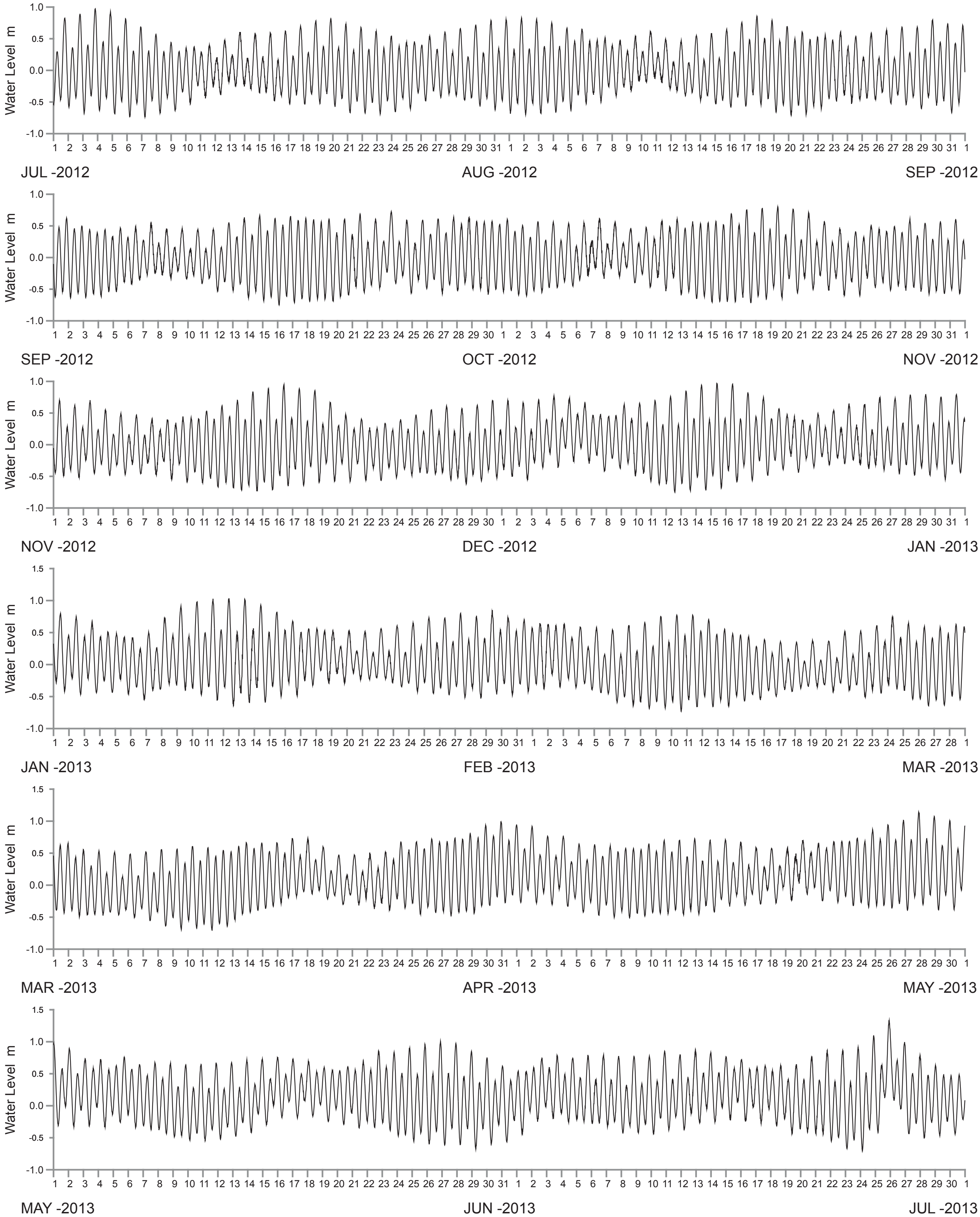
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
CROOKHAVEN

MHL
Report 2219

Figure
A31

DRAWING 2219-A31.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

Public Works
Manly Hydraulics Laboratory

CROOKHAVEN RIVER AT CROOKHAVEN HEADS
2012-2013

MHL Report 2219

Figure A32

DRAWING 2219-A32

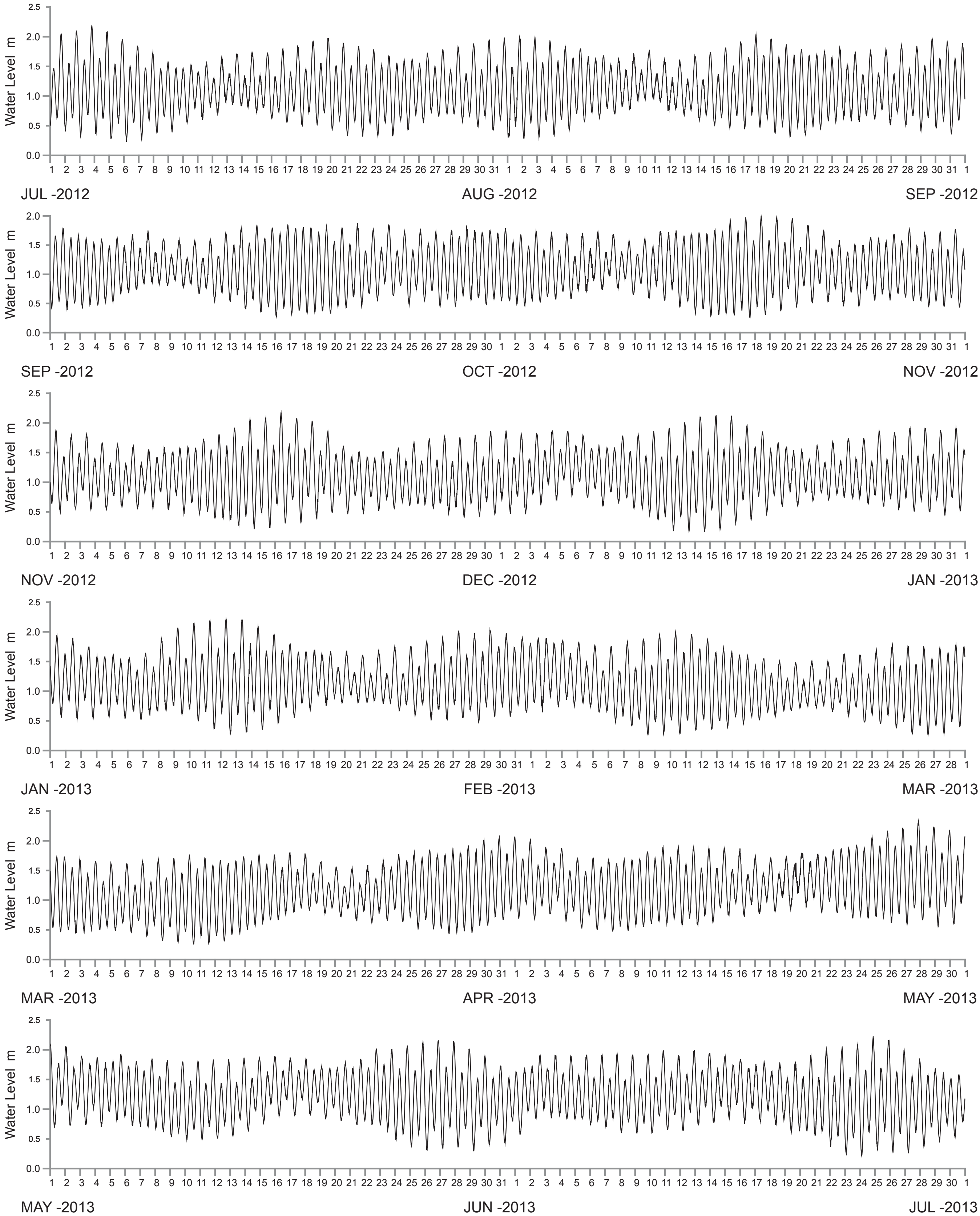
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
JERVIS BAY, HMAS CRESWELL

MHL Report 2219

Figure A33

DRAWING 2219-A33.cdr



WATER LEVEL REFERENCED TO CHART DATUM (JERVIS BAY PORT DATUM)

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

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory

JERVIS BAY AT HMAS CRESWELL
2012-2013

MHL Report 2219

Figure A34

DRAWING 2219-A34

NSW GOVERNMENT

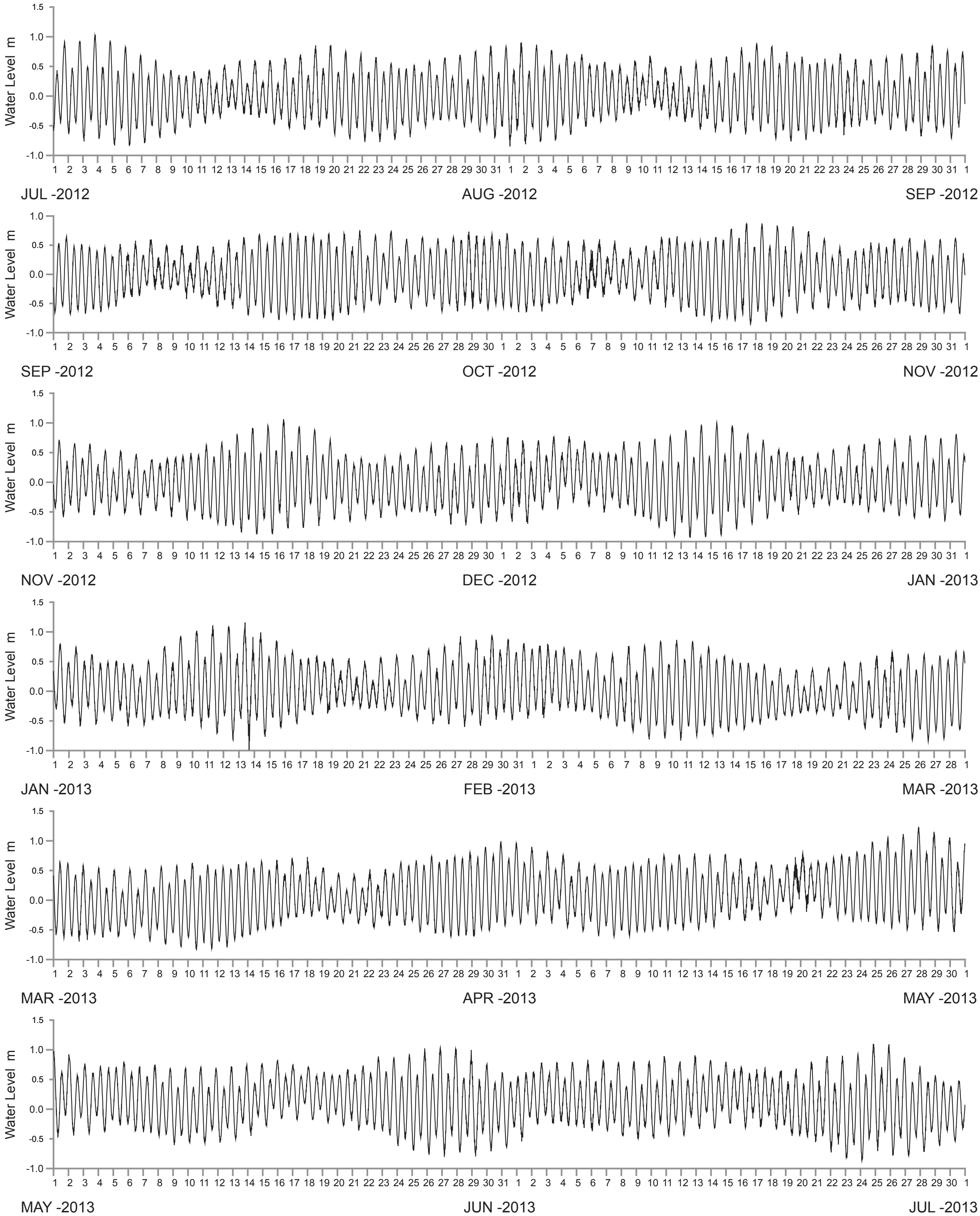
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
ULLADULLA

MHL Report 2219

Figure A35

DRAWING 2219-A35.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

NSW GOVERNMENT Public Works
Manly Hydraulics Laboratory

TASMAN SEA AT ULLADULLA BOAT HARBOUR
2012-2013

MHL Report 2219

Figure A36

DRAWING 2219-A36

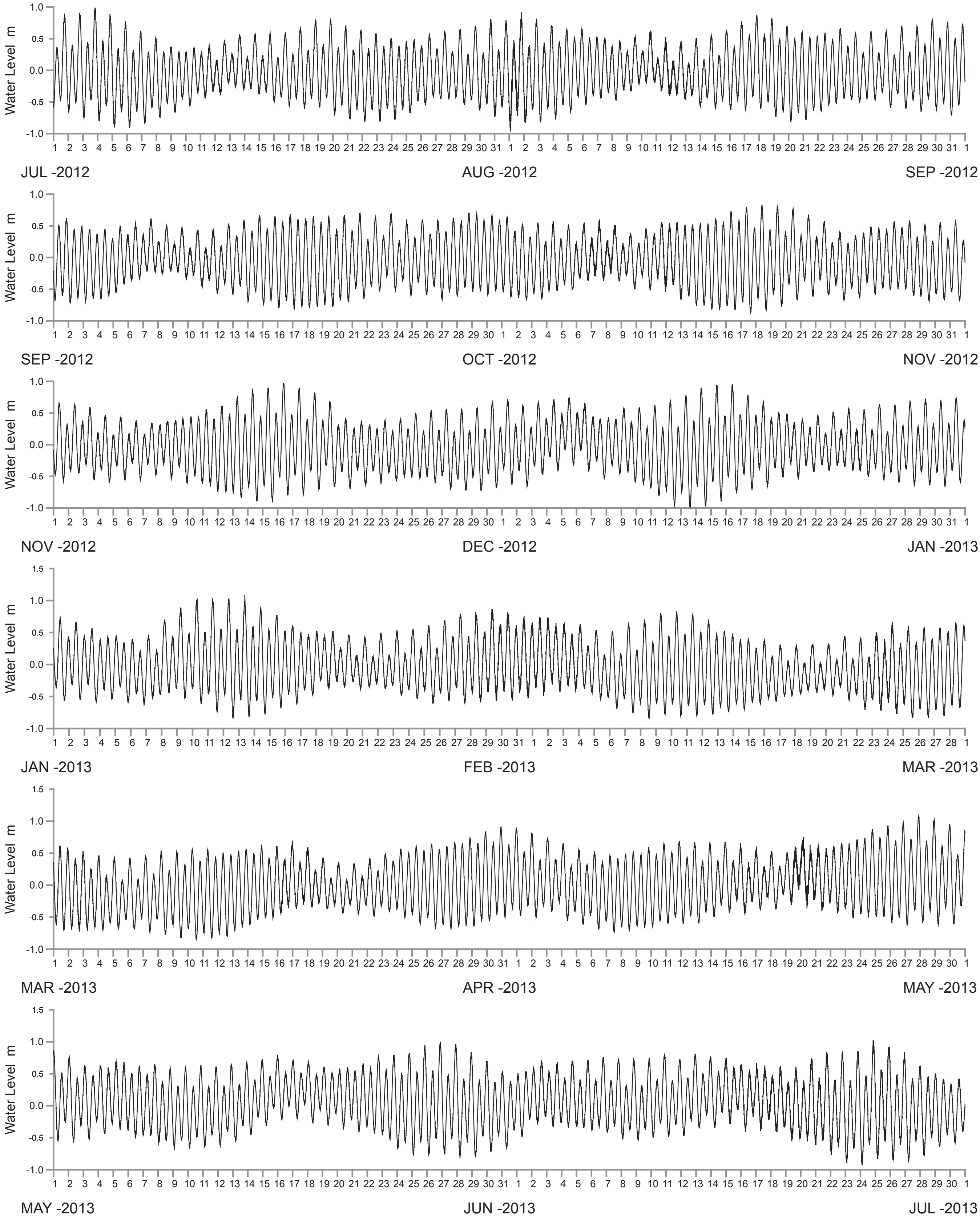
Public Works
Manly Hydraulics Laboratory

BATEMANS BAY
OFFSHORE TIDE GAUGE LOCATION

MHL Report 2219

Figure A37

DRAWING 2219-A37.cdr



WATER LEVEL REFERENCED TO MEAN SEA LEVEL

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

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory

TASMAN SEA AT BATEMANS BAY OFFSHORE
2012-2013

MHL Report 2219

Figure A38

DRAWING 2219-A38

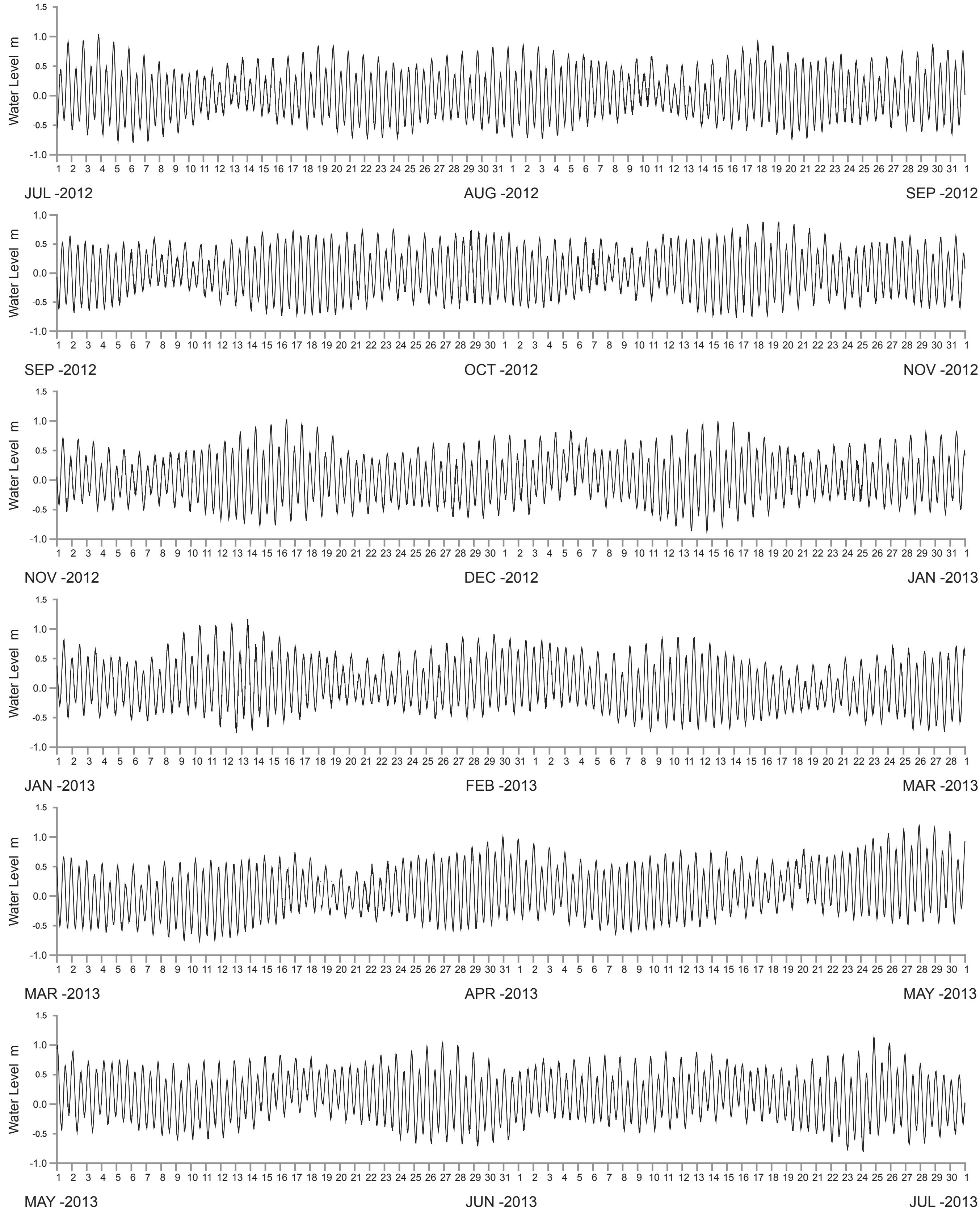
NSW GOVERNMENT
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
PRINCESS JETTY

MHL Report 2219

Figure A39

DRAWING 2219-A39.cdr



WATER LEVEL REFERENCED TO AUSTRALIAN HEIGHT DATUM

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

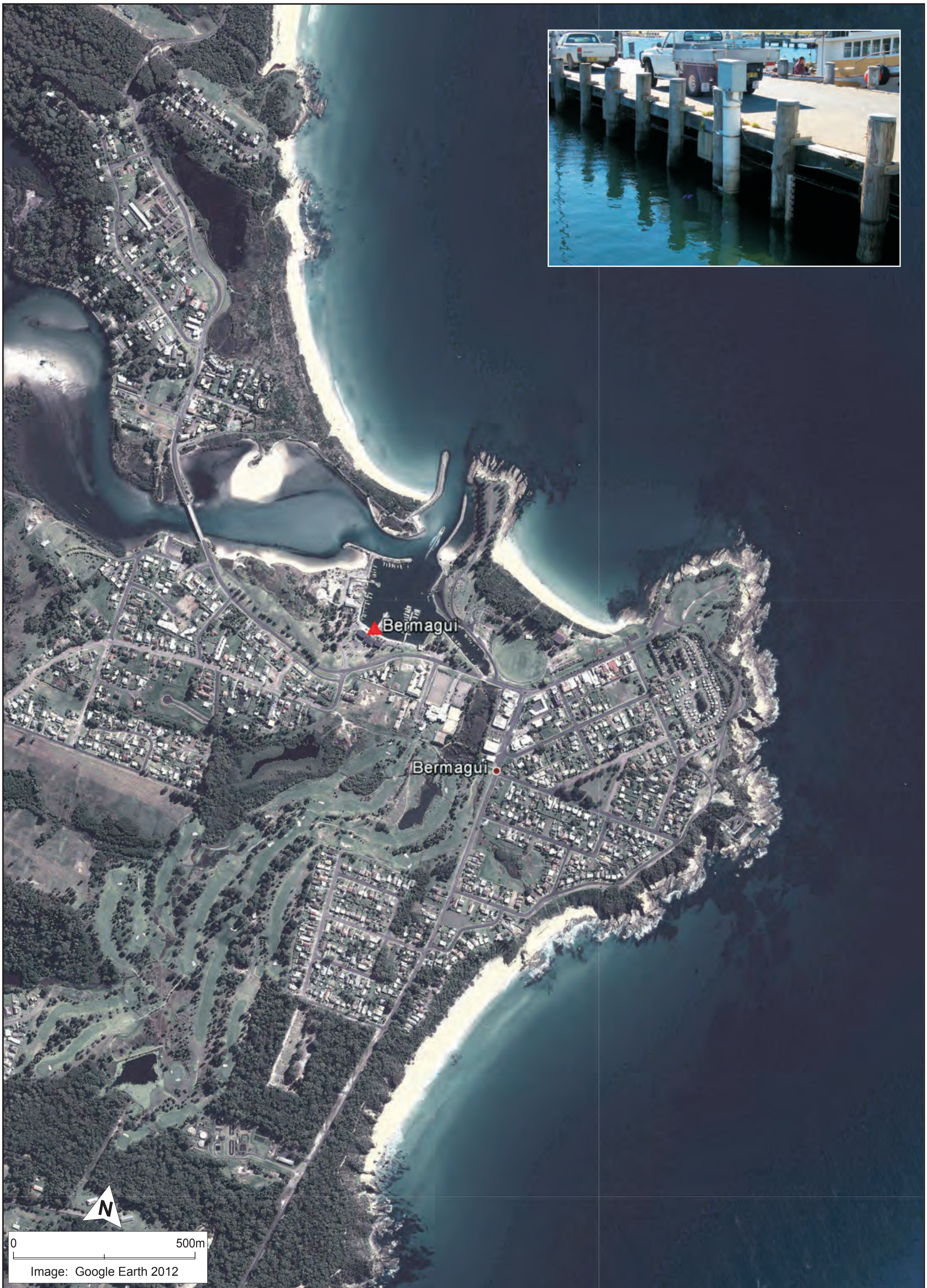
NSW GOVERNMENT Public Works Manly Hydraulics Laboratory

BATEMANS BAY CLYDE RIVER AT PRINCESS JETTY
2012-2013

MHL Report 2219

Figure A40

DRAWING 2219-A40



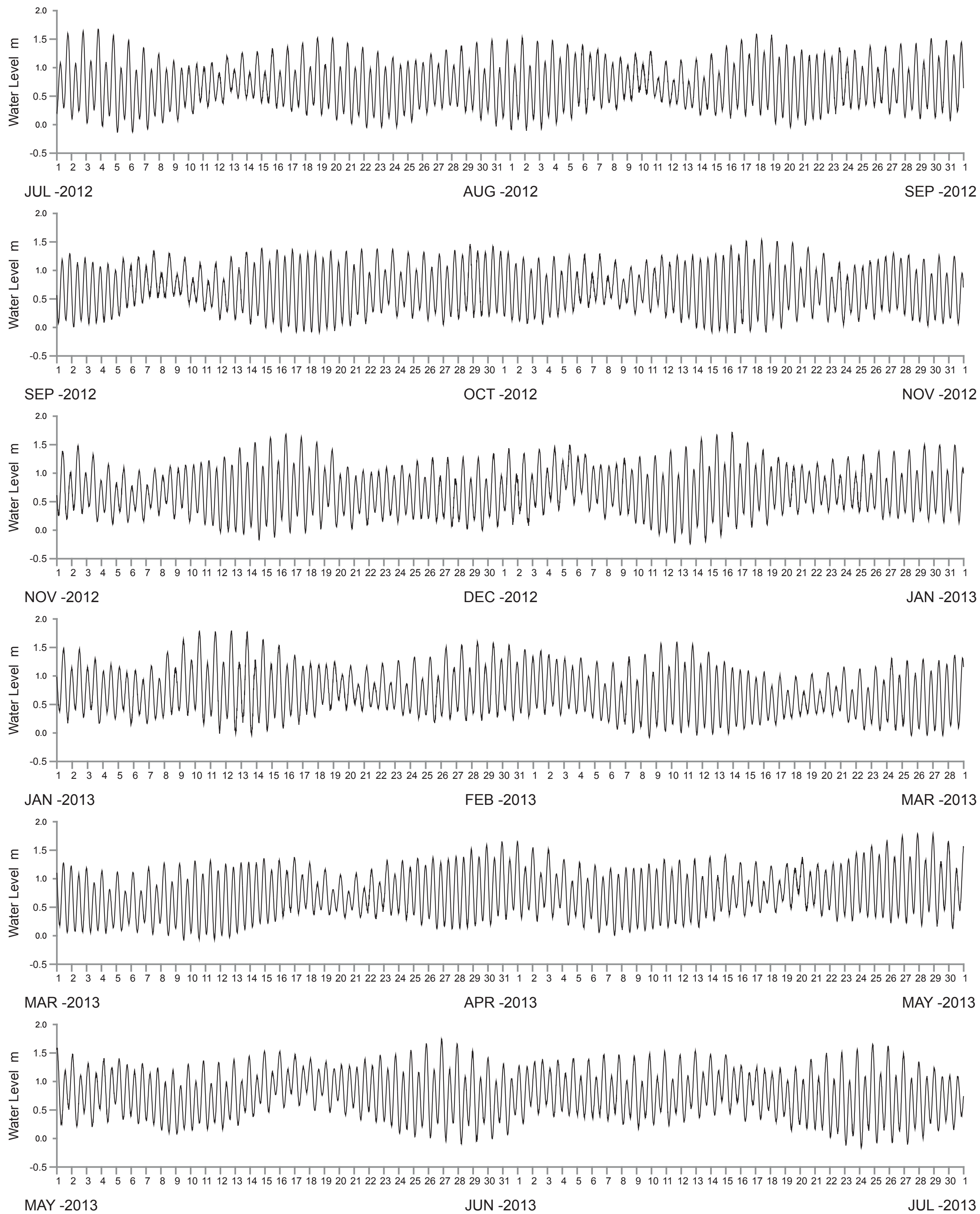
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
BERMAGUI

MHL
Report 2219

Figure
A41

DRAWING 2219-A41.cdr



WATER LEVEL REFERENCED TO BERMAGUI LOCAL HYDRO DATUM

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

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory

BERMAGUI HARBOUR AT BERMAGUI
2012-2013

MHL Report 2219

Figure A42

DRAWING 2219-A42

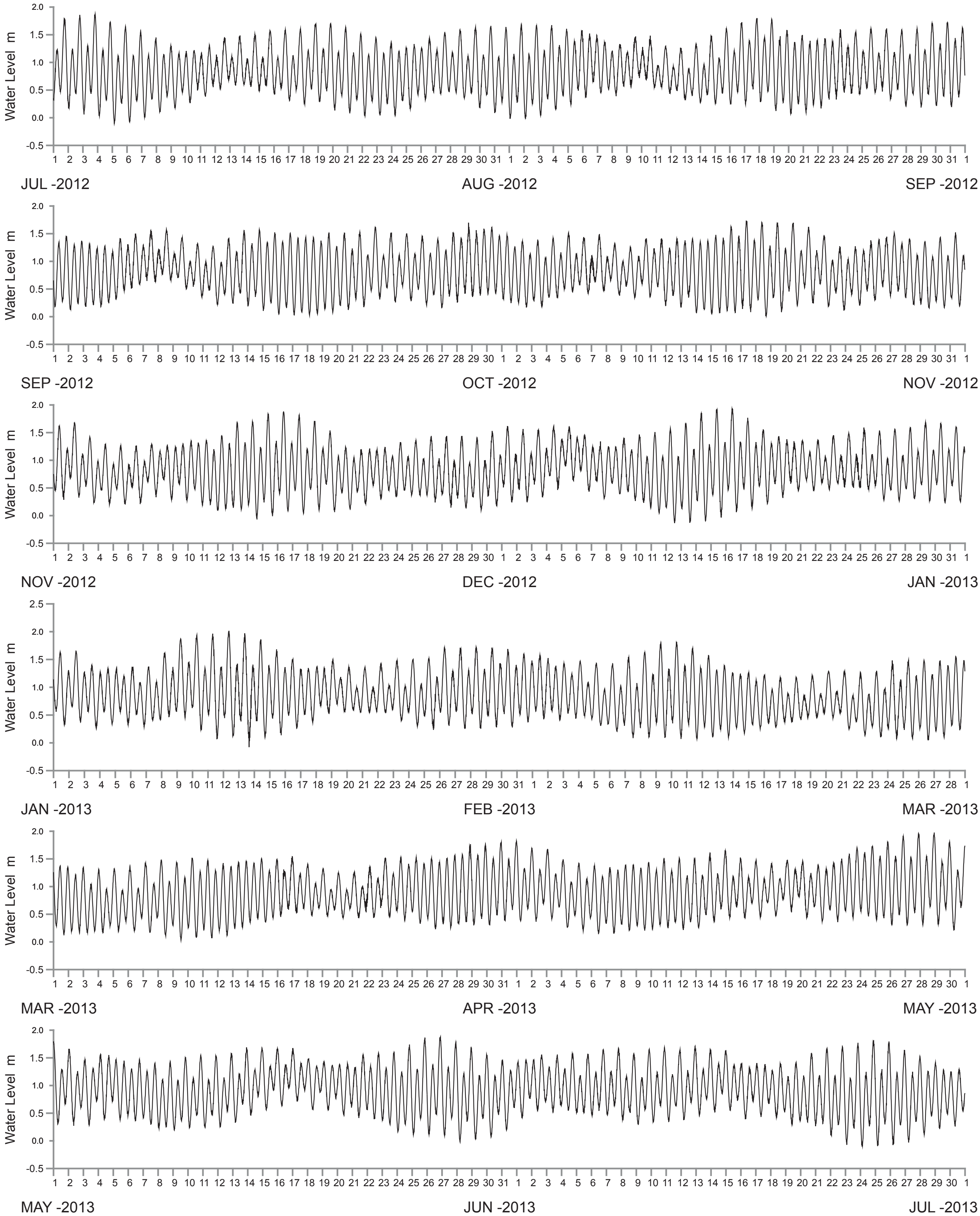
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
EDEN

MHL
Report 2219

Figure
A43

DRAWING 2219-A43.cdr



WATER LEVEL REFERENCED TO TWOFOLD BAY HYDRO DATUM

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

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TASMAN SEA AT EDEN BOAT HARBOUR
2012-2013

MHL Report 2219

Figure A44

DRAWING 2219-A44

NSW GOVERNMENT

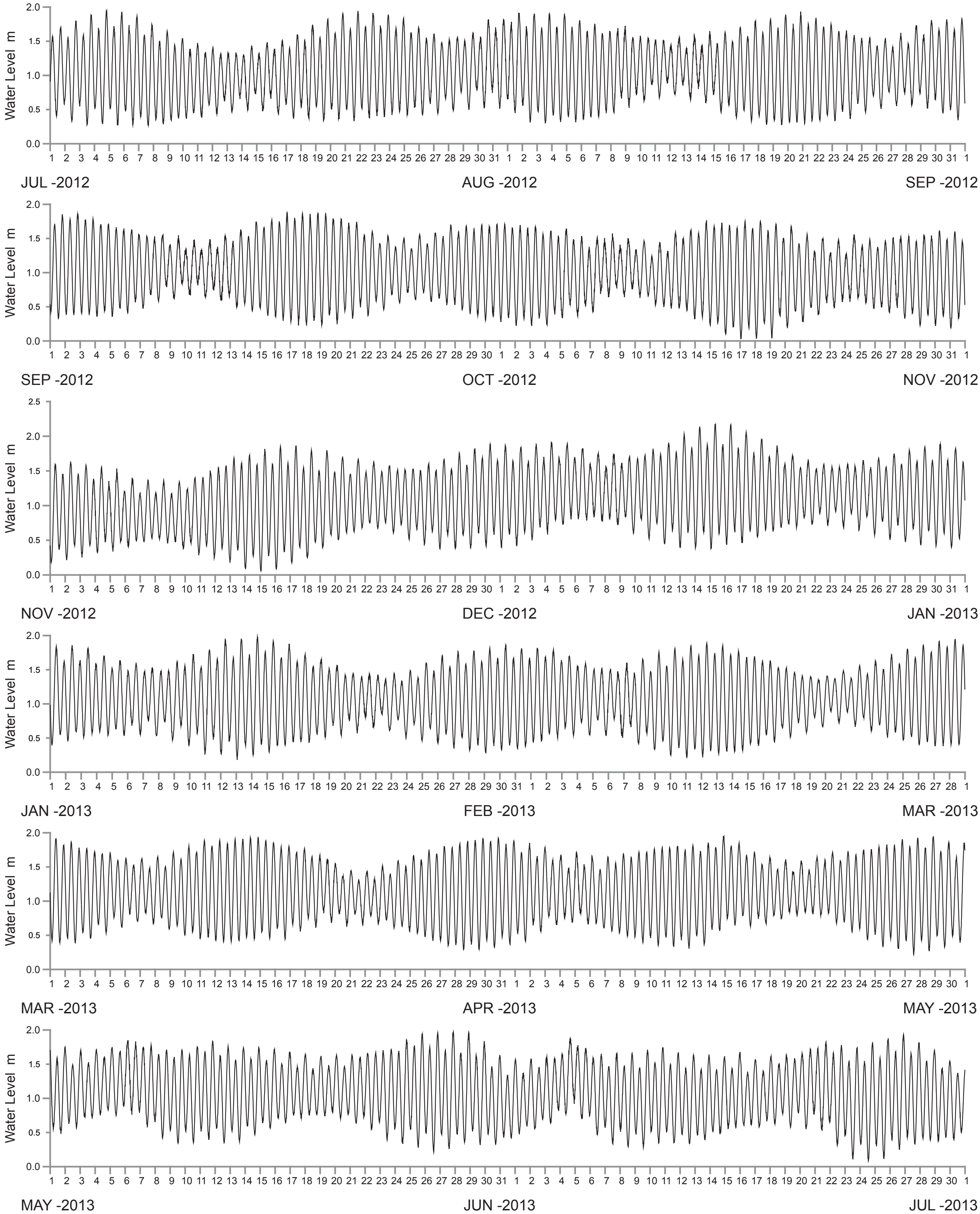
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
NORFOLK ISLAND

MHL Report 2219

Figure A45

DRAWING 2219-A45.cdr



WATER LEVEL REFERENCED TO LOWEST ASTRONOMICAL TIDE

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

NSW GOVERNMENT Public Works Manly Hydraulics Laboratory

TASMAN SEA AT NORFOLK ISLAND

2012-2013

MHL Report 2219

Figure A46

DRAWING 2219-A46

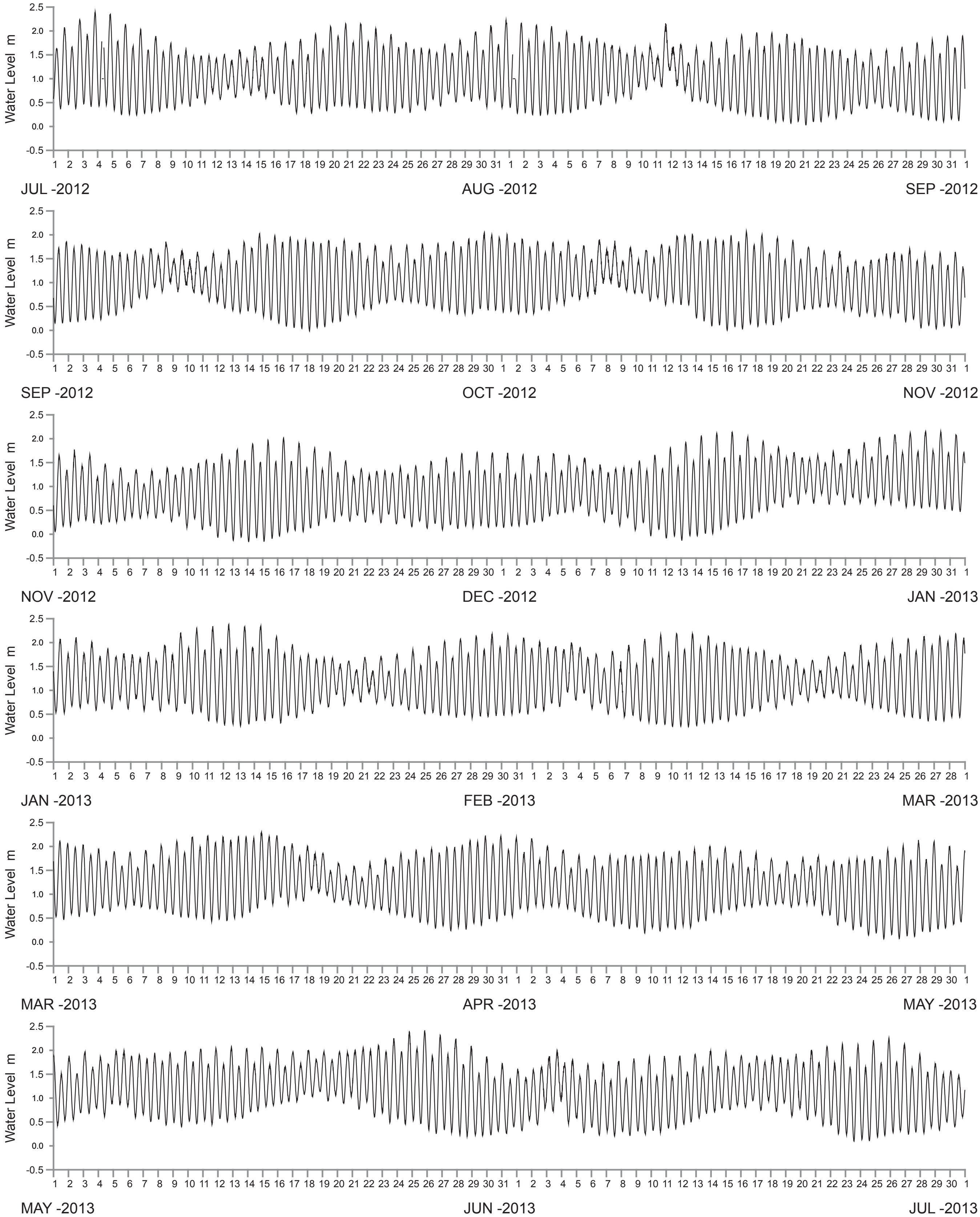
Public Works
Manly Hydraulics Laboratory

STATION LOCATION
LORD HOWE ISLAND

MHL Report 2219

Figure A47

DRAWING 2219-A47.cdr



WATER LEVEL REFERENCED TO LORD HOWE ISLAND TIDAL DATUM

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

Public Works
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TASMAN SEA AT LORD HOWE ISLAND
2012-2013

MHL Report 2219

Figure A48

DRAWING 2219-A48

Appendix B

Data On-line

Table B1 Current Sites Data On-Line

Coastal Region	Site Name	Location	Period of Data
North	Tweed Regional	Breakwater	Feb 1987-ongoing
North	Tweed Offshore	Offshore	Dec 1982-ongoing
North	Brunswick Heads	Breakwater	Mar 1986-ongoing
North	Ballina	Breakwater	Apr 1986-ongoing
North	Yamba	Breakwater	Jul 1986-ongoing
North	Coffs Harbour	Harbour	Jul 1978-ongoing
Mid North	Port Macquarie	Breakwater	Mar 1986-ongoing
Mid North	Port Macquarie Offshore	Offshore	Dec 1984-ongoing
Mid North	Crowdy Head	Harbour	Jul 1986-ongoing
Mid North	Forster	Breakwater	Jul 1986-ongoing
Central	Tomaree	Hospital jetty	Oct 1985-ongoing
Central	Patonga	River	Jun 1992-ongoing
Central	Sydney	Middle Head	Sep 1987-ongoing
Central	Port Hacking	Hungry Point	Nov 1987-ongoing
Central	Jervis Bay	HMAS Creswell	Sep 1989-ongoing
South	Shoalhaven Offshore	Offshore	Sep 2005-ongoing
South	Princess Jetty	River	Dec 1985-ongoing
South	Batemans Bay Offshore	Snapper Island	Sep 2000-ongoing
South	Bermagui	Working jetty	Mar 1987-ongoing
South	Eden	Working jetty	Sep 1986-ongoing
North Tasman Sea	Lord Howe Island	Main wharf	Aug 1994–ongoing
North Tasman Sea	Norfolk Island	Main jetty	Sep 1994–ongoing

Appendix C

Historical Tide Data

Table C1 Historical Tide Data

Coastal Region	Site Name	Location	Period of Record
North	Tweed Regional	Breakwater	1914–1916
North	Tweed Regional	Breakwater	Jan 1978–Dec 1978
North	Tweed Regional	Breakwater	Jan 1980–Dec 1980
North	Richmond River	Breakwater	1889–1912
North	Richmond River	Breakwater	1898–1901
North	Richmond River	Breakwater	1901–1905
North	Richmond River	Breakwater	1905–1909
North	Richmond River	Breakwater	1914–1916
North	Richmond River	Ballina	1959–1963
North	Clarence River	Yamba	1900–1924
North	Clarence River	Iluka	1956–1969
North	Clarence River	Breakwater	1900–1904
North	Clarence River	Breakwater	1909–1913
North	Clarence River	Breakwater	1913–1917
North	Clarence River	Breakwater	1914–1916
North	Clarence River	Breakwater	1921–1924
North	Clarence River	Breakwater	Jan 1957–Jun 1957
North	Clarence River	Breakwater	Jun 1957–Dec 1957
North	Clarence River	Breakwater	Dec 1957–May1958
North	Coffs Harbour	Main harbour	1966–68 and 1969–72
North	Coffs Harbour	Main harbour	Mar 1972–May 1972
North	Coffs Harbour	Main harbour	Sep 1972–Feb 1973
North	Coffs Harbour	Main harbour	Jan 1961–Dec 1964
North	Coffs Harbour	Main harbour	Jul 1952–Dec 1952
North	Coffs Harbour	Main harbour	Aug 1951–Feb 1952
North	Coffs Harbour	Main harbour	1953–1960
North	Bellinger/Kalang River	Entrance	1914–1916
North	Macleay River	Entrance	1901–1905
North	Macleay River	Entrance	1902–1903
North	Macleay River	Entrance	1905–1909
North	Macleay River	Entrance	1909–1913
North	Macleay River	Entrance	1914–1916
Mid North	Hastings River	Breakwater	1914–1916
Mid North	Camden Haven River	Breakwater	1914–1916
Mid North	Manning River	Breakwater	1914–1916
Mid North	Forster	Breakwater	1914–1916
Central	Newcastle	Boat harbour	1899–1921
Central	Newcastle	Breakwater	1889–1902

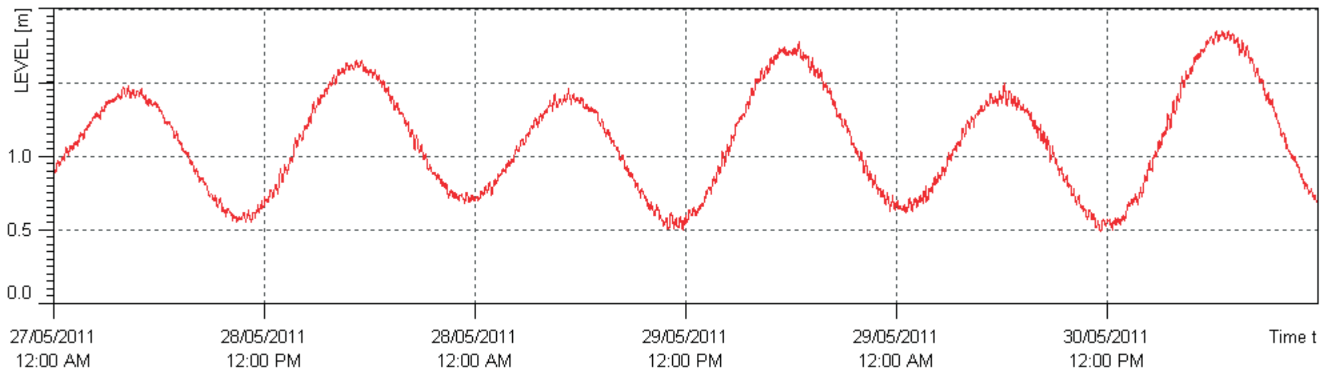
Coastal Region	Site Name	Location	Period of Record
Central	Newcastle	Breakwater	1903–1907
Central	Newcastle	Breakwater	1903–1904
Central	Newcastle	Breakwater	1907–1911
Central	Newcastle	Breakwater	1909–1913
Central	Newcastle	Breakwater	1915–1921
Central	Port Jackson	Fort Denison	1956–1959
Central	Port Kembla		1957–1960
Central	Port Kembla		1961–1965
Central	Crookhaven River	Entrance	1914–1916
Central	Jervis Bay	HMAS Creswell	1914–1919
Central	Jervis Bay	Huskisson	1987–1989
South	Batemans Bay Offshore	Snapper Island	1986–1990
South	Moruya River	Entrance	1914–1916
South	Moruya River	Entrance	1951–1952
South	Moruya River	Entrance	Mar 1952–Aug 1952
South	Moruya River	Entrance	Aug 1952–Sep 1952
South	Eden	Snug Cove	1954–1956

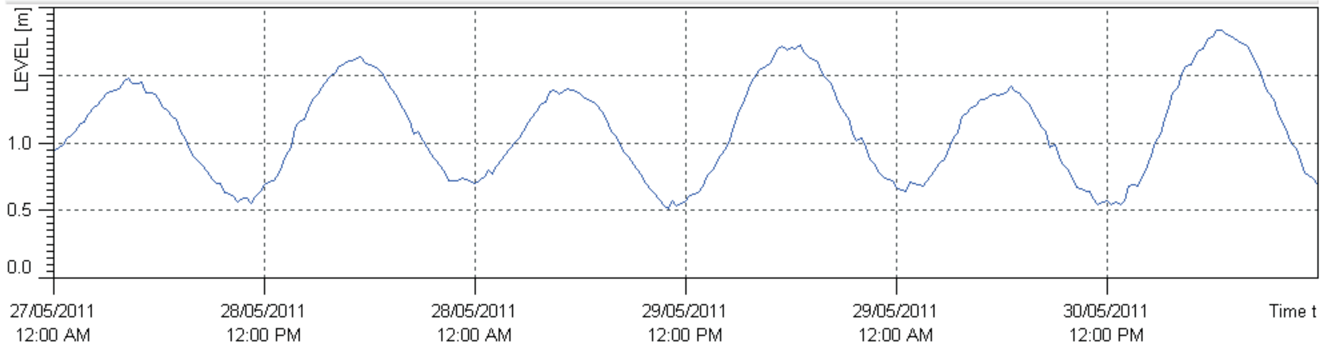
Fort Denison data courtesy of Sydney Ports Corporation and BoM National Tidal Centre.

Appendix D

Sample Outputs

Coffs Harbour 1-minute data





Coffs Harbour 15-minute data

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1-MINUTE AND 15-MINUTE
SAMPLE DATA PLOTS

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Figure D1

DRAWING 2219-D1.cdr

```
Station Name,  Port Stephens (Live),,
Station Number,209471,,
Latitude,+152:10:56.06,,
Longitude,-32:42:53.57,,
Datum,PSHD,,
,,,
date,time,value,value.status
5/07/2011,0:00:00,1.61325,6 (Good)
5/07/2011,0:15:00,1.56495,6 (Good)
5/07/2011,0:30:00,1.47403,6 (Good)
5/07/2011,0:45:00,1.39316,6 (Good)
5/07/2011,1:00:00,1.3186,6 (Good)
5/07/2011,1:15:00,1.22369,6 (Good)
5/07/2011,1:30:00,1.10246,6 (Good)
5/07/2011,1:45:00,1.03073,6 (Good)
5/07/2011,2:00:00,0.949726,6 (Good)
5/07/2011,2:15:00,0.84358,6 (Good)
5/07/2011,2:30:00,0.756913,6 (Good)
5/07/2011,2:45:00,0.658031,6 (Good)
5/07/2011,3:00:00,0.573691,6 (Good)
5/07/2011,3:15:00,0.504744,6 (Good)
5/07/2011,3:30:00,0.423529,6 (Good)
5/07/2011,3:45:00,0.361451,6 (Good)
5/07/2011,4:00:00,0.317804,6 (Good)
5/07/2011,4:15:00,0.276461,6 (Good)
5/07/2011,4:30:00,0.214138,6 (Good)
5/07/2011,4:45:00,0.196576,6 (Good)
5/07/2011,5:00:00,0.182245,6 (Good)
5/07/2011,5:15:00,0.190659,6 (Good)
5/07/2011,5:30:00,0.205091,6 (Good)
5/07/2011,5:45:00,0.22192,6 (Good)
5/07/2011,6:00:00,0.237748,6 (Good)
5/07/2011,6:15:00,0.291828,6 (Good)
5/07/2011,6:30:00,0.337178,6 (Good)
5/07/2011,6:45:00,0.395157,6 (Good)
5/07/2011,7:00:00,0.441683,6 (Good)
5/07/2011,7:15:00,0.495641,6 (Good)
```

***************NSW PUBLIC WORKS, MANLY HYDRAULICS LABORATORY***************

110B KING STREET, MANLY VALE N.S.W. 2093, AUSTRALIA. TELEPHONE (02)9949 0200

ANALYSIS OF TIDAL OBSERVATIONS

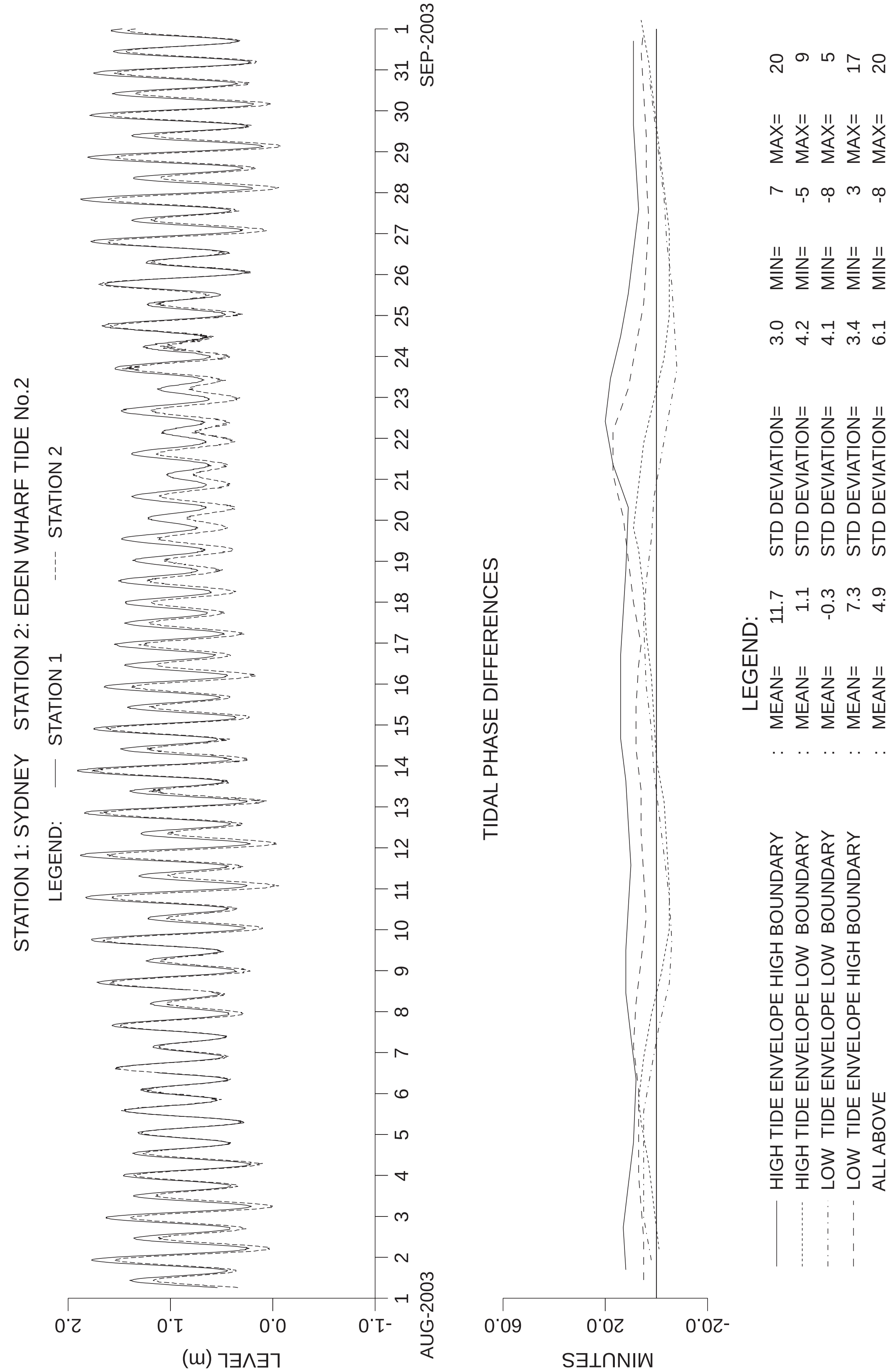
TIME OF ANALYSIS	:	1555:20/12/2006
ANALYSIS PERFORMED BY	:	ES using INTERACTIVE program MTIDE1DBX V1.0
STATION LOCATION	:	EDEN, N.S.W., AUSTRALIA
STATION NAME	:	BOAT HARBOUR
STATION LATITUDE	:	037 DEG 04 MIN SOUTH
STATION LONGITUDE	:	149 DEG 54 MIN EAST
DATUM	:	TWOFOLD BAY HYDRO DATUM
ANALYSIS PERIOD START TIME	:	0000:01/07/2005
ANALYSIS PERIOD FINISH TIME	:	2300:01/07/2006
MID POINT TIME	:	2300:30/12/2005
PERIOD OF ANALYSIS	:	366 DAYS 00 HRS
LOCAL TIME ZONE NAME	:	EASTERN STANDARD TIME
LOCAL TIME FACTOR	:	GMT +10.00 HRS
TIME MERIDIAN	:	-9.99 HRS

TIDAL PLANES IN METRES ABOVE ZERO OF LOCAL GAUGE VALUES

High High Water (Solstices Springs)	H.H.W.(S.S.)	:	1.823
Mean High Water Springs	M.H.W.S.	:	1.423
Mean High Water	M.H.W.	:	1.320
Mean High Water Neaps	M.H.W.N.	:	1.216
Mean Sea Level	M.S.L.	:	0.856
Mean Low Water Neaps	M.L.W.N.	:	0.495
Mean Low Water	M.L.W.	:	0.392
Mean Low water Springs	M.L.W.S.	:	0.288
Indian Spring Low Water	I.S.L.W.	:	0.003

TIDAL RANGES IN METRES

Mean Spring Range	(M.H.W.S. - M.L.W.S.)	:	1.135
Mean Neap Range	(M.H.W.N. - M.L.W.N.)	:	0.721
Mean Range	(M.H.W. - M.L.W.)	:	0.928
Range	(H.H.W.(S.S.) - I.S.L.W.)	:	1.821



Public Works
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TIDAL PHASE DIFFERENCES BETWEEN SYDNEY AND EDEN

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Figure D4

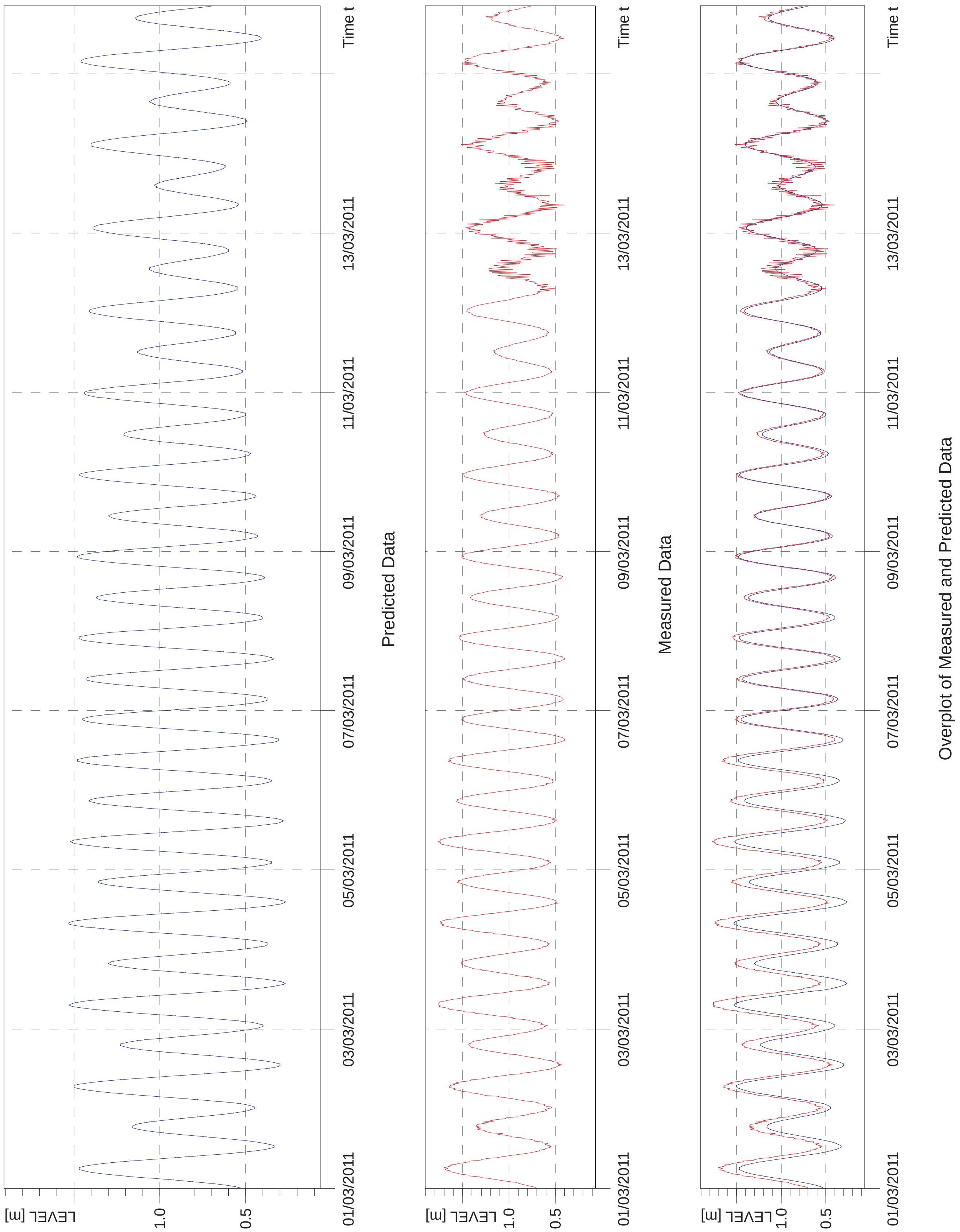
DRAWING 2219-D4.cdr

NSW PUBLIC WORKS, MANLY HYDRAULICS LABORATORY
110B KING STREET, MANLY VALE N.S.W. 2093, AUSTRALIA. TELEPHONE 02-9949-0200

TIDAL LEVEL STATISTICS

STATION NAME	:	SYDNEY TIDE GAUGE
RECORDER TYPE	:	DATATAKER
LATITUDE/LONGITUDE	:	33-50 DEG. SOUTH, 151-15 DEG. EAST
DATA START	:	01-JUL-2005
DATA FINISH	:	30-JUN-2006
TOTAL YEARS OF DATA	:	1.00
DATABASE TIME INTERVAL (min)	:	60
THRESHOLD LEVEL (m)	:	1.93
DATUM	:	ZERO CAMP COVE
DATE OF ISSUE	:	1617:20/12/2006
ANALYSIS PERFORMED BY	:	ES using INTERACTIVE program WDBRNKX V1.0
COMMENTS	:	Recorded levels.

RANK	PEAK (m)	DATE	TIME	START	DURATION (hr)	MAX RISE (cm/hr)	PERIOD (yr)
1	2.21	28-APR-2006	20:00	28-APR-2006	2.0	4.0	2.0
2	2.11	27-APR-2006	20:00	27-APR-2006	N/A	N/A	1.0
3	2.08	03-JAN-2006	11:00	03-JAN-2006	3.0	16.0	0.7
4	2.06	20-AUG-2005	21:00	20-AUG-2005	2.0	5.0	0.5
5	2.05	02-JAN-2006	10:00	02-JAN-2006	2.0	4.0	0.4
6	2.04	19-AUG-2005	20:00	19-AUG-2005	2.0	10.0	0.3
7	2.04	13-DEC-2005	06:00	13-DEC-2005	2.0	12.0	0.3
8	2.04	17-DEC-2005	09:00	17-DEC-2005	2.0	9.0	0.2
9	2.04	01-FEB-2006	10:00	01-FEB-2006	2.0	14.0	0.2
10	2.03	18-DEC-2005	10:00	18-DEC-2005	2.0	2.0	0.2
11	2.02	01-JAN-2006	09:00	01-JAN-2006	2.0	5.0	0.2
12	2.02	31-JAN-2006	09:00	31-JAN-2006	1.0	N/A	0.2
13	2.02	29-APR-2006	21:00	29-APR-2006	1.0	N/A	0.2
14	2.00	16-SEP-2005	19:00	16-SEP-2005	1.0	6.0	0.1
15	2.00	30-JAN-2006	09:00	30-JAN-2006	1.0	3.0	0.1
16	1.98	28-FEB-2006	08:00	28-FEB-2006	1.0	N/A	0.1
17	1.97	21-AUG-2005	22:00	21-AUG-2005	1.0	1.0	0.1
18	1.96	17-SEP-2005	20:00	17-SEP-2005	1.0	3.0	0.1
19	1.96	29-JAN-2006	08:00	29-JAN-2006	1.0	3.0	0.1
20	1.95	01-MAR-2006	09:00	01-MAR-2006	0.0	N/A	0.1
21	1.95	30-APR-2006	22:00	30-APR-2006	1.0	N/A	0.1
22	1.94	21-JUL-2005	20:00	21-JUL-2005	0.0	N/A	0.1
23	1.94	24-JUL-2005	23:00	24-JUL-2005	1.0	4.0	0.1
24	1.94	15-NOV-2005	07:00	15-NOV-2005	1.0	N/A	0.1
25	1.94	16-NOV-2005	08:00	16-NOV-2005	N/A	N/A	0.1
26	1.94	03-DEC-2005	09:00	03-DEC-2005	N/A	N/A	0.1
27	1.94	05-DEC-2005	11:00	05-DEC-2005	1.0	2.0	0.1
28	1.94	14-DEC-2005	07:00	14-DEC-2005	1.0	6.0	0.1
29	1.94	16-DEC-2005	08:00	16-DEC-2005	1.0	N/A	0.1
30	1.94	23-APR-2006	04:00	23-APR-2006	1.0	5.0	0.1
31	1.94	25-APR-2006	06:00	25-APR-2006	N/A	N/A	0.1
32	1.93	22-JUL-2005	21:00	22-JUL-2005	N/A	N/A	0.1
33	1.93	08-OCT-2005	11:00	08-OCT-2005	0.0	N/A	0.1
34	1.93	31-DEC-2005	08:00	31-DEC-2005	N/A	N/A	0.1
35	1.93	16-APR-2006	22:00	16-APR-2006	1.0	5.0	0.1
36	1.93	24-MAY-2006	17:00	24-MAY-2006	0.0	N/A	0.1



NSW GOVERNMENT

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SAMPLE TIDAL PREDICTION
DATA PLOT

MHL Report 2219

Figure D6

DRAWING 2219-D6.cdr

Appendix E

Glossary of Terms

Glossary of Terms

Amplitude (H)	One-half the range of a constituent tide. By analogy, it may be applied also to the maximum speed of a constituent current.
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° 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
Encoder	A device that translates tidal movement into computer readable data.
Ellipsoid	an idealised model representing the mean sea level of the earth and is used as a computational reference for global position fixing
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 will 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° per solar hour.
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.
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 and mean low water springs
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.
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

Publications of Interest

Data Reports

MHL Annual Ocean Tide Levels Summaries available from 1986-87 to 2011-12
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).

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University of Queensland, 2010, Tropical Cyclone ‘Roger’ Storm Surge Assessment, Research Report CE162, J. Stewart, D. Callaghan and P. Nielsen, July 2010

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