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19 June 2020

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Dear Dimitrios,

MHL2761 – Tweed Sand Bypass Tidal Analysis 2019/20

MHL is pleased to provide this report for a tidal analysis of the Tweed River entrance for the period March 2019 – February 2020. The study consists of a tidal harmonics analysis for three locations on the Eastern Australia coastline: two in northern NSW and one on the Sunshine Coast in QLD (Figure 1). By observing long term trends in tidal response characteristics against two control sites, it can be determined if the entrance dynamics of an estuary are changing over time.

Figure 1 – Location of study area

1 Tweed Entrance Behaviour

A tidal harmonic analysis was performed on three tidal measurement datasets: Letitia 2A at the Tweed River entrance, Coffs Harbour Jetty, and Mooloolaba on the Sunshine Coast. This harmonic analysis can be used to, among other things, remove meteorological and flood events from a measured tidal signal, extracting from the noisy measurements only those components which can be described by periodic astronomical forcings. From these components, descriptive characteristics of the tidal signal at the given location can be generated and it is these characteristics which are analysed and compared over time to gain insight into whether the morphology of the entrance is changing.

Figure 2 shows the Mean Water Level behaviour over the preceding 12 months. Mean levels behave consistently between all three sites with Mooloolaba and Letitia behaving nearly identically over the period. There were no significant meteorological events which affected all three sites. The most significant event was a large flood in February 2020 which elevated levels on the Tweed River, causing significant positive anomaly at Letitia 2A for a period of weeks. Two localised meteorological events occurred at Coffs Harbour in March and September 2019, causing a notable positive anomaly across multiple tidal cycles.

The Spring Tidal Range is steady across the 12-month period and consistent with the previous year's analysis. The ratio of Spring Tides between sites similarly remains consistent with last year's records.

For this period of analysis, the monthly residuals range from high of 0.22m at Letitia 2A, down to 0.048m, with the median residuals of 0.11m for Coffs Harbour, 0.07m for Mooloolaba, and 0.10m for Letitia 2A.

Monthly rainfall at Murwillumbah is presented in Table 1. Similar to last year, this 12-month period was characterised by very little rain, with only two months exceeding long-term values, and a particularly dry Spring. Around 80% of the long-term rainfall was recorded over this period, with over 40% of that occurring in February 2020. Apart from this flooding, no significant meteorological events were observed at Letitia 2A over the period.

2 Tidal Comparison

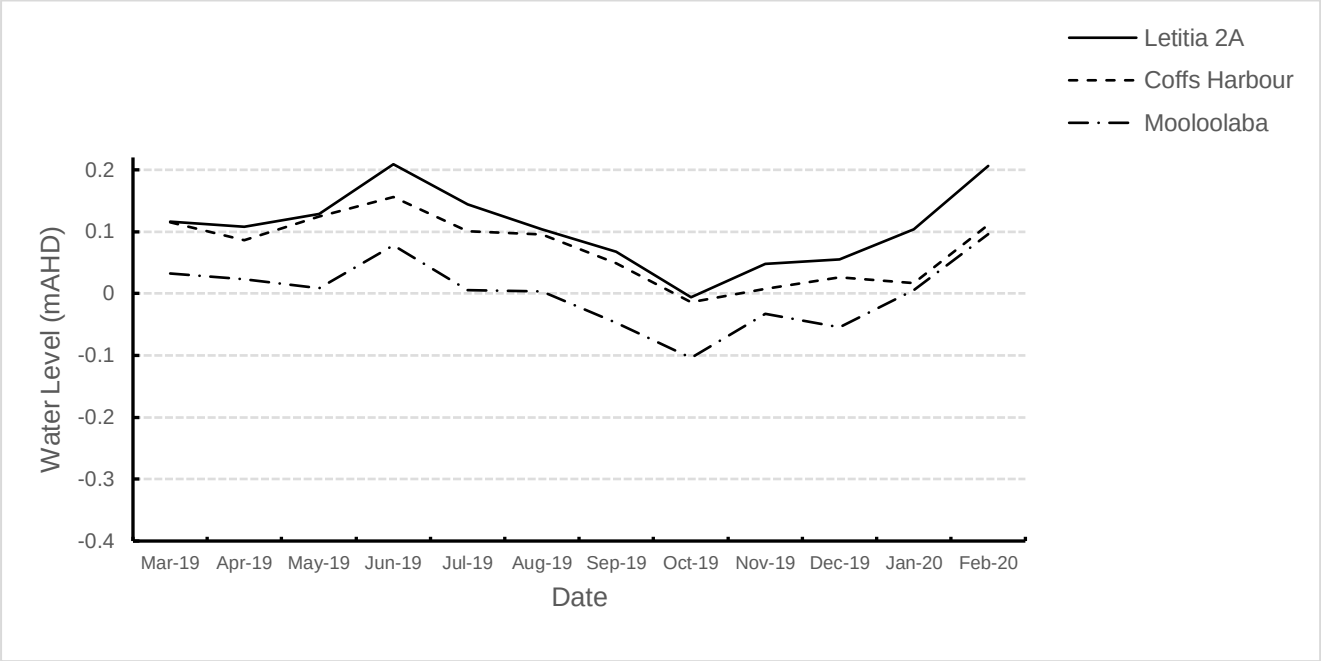


Figure 2 – Mean Water Level Comparison

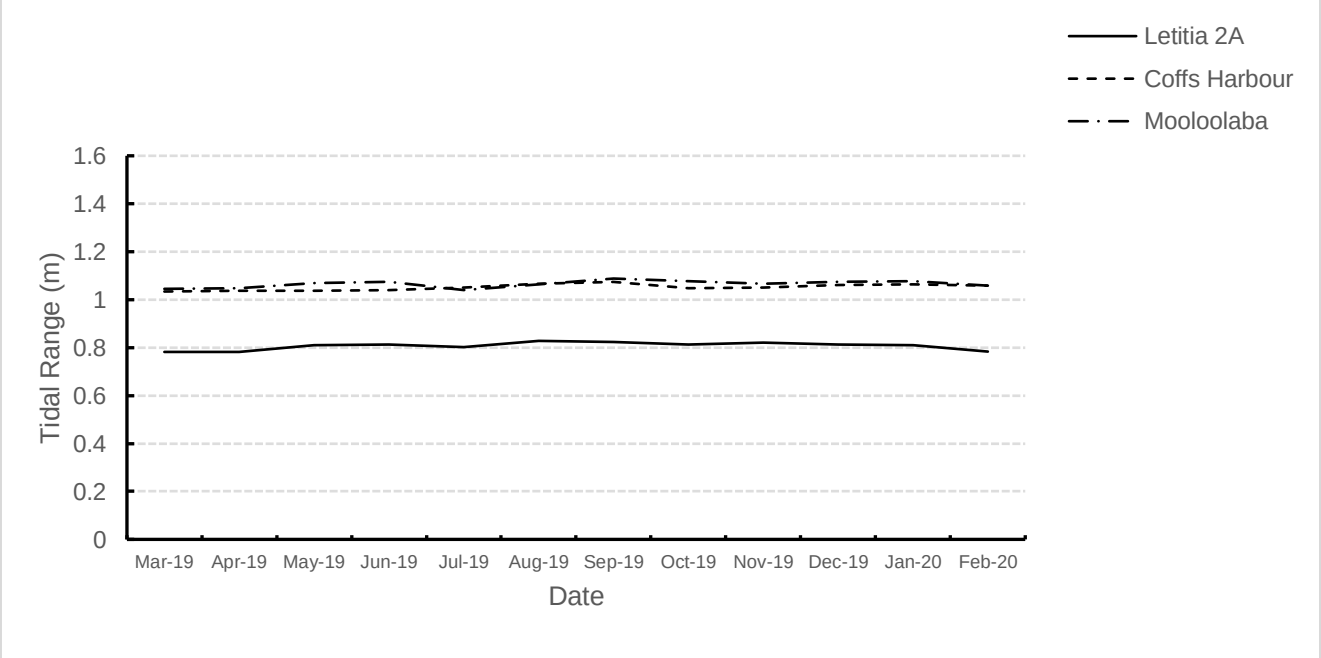


Figure 3 – Spring Tidal Range Comparison

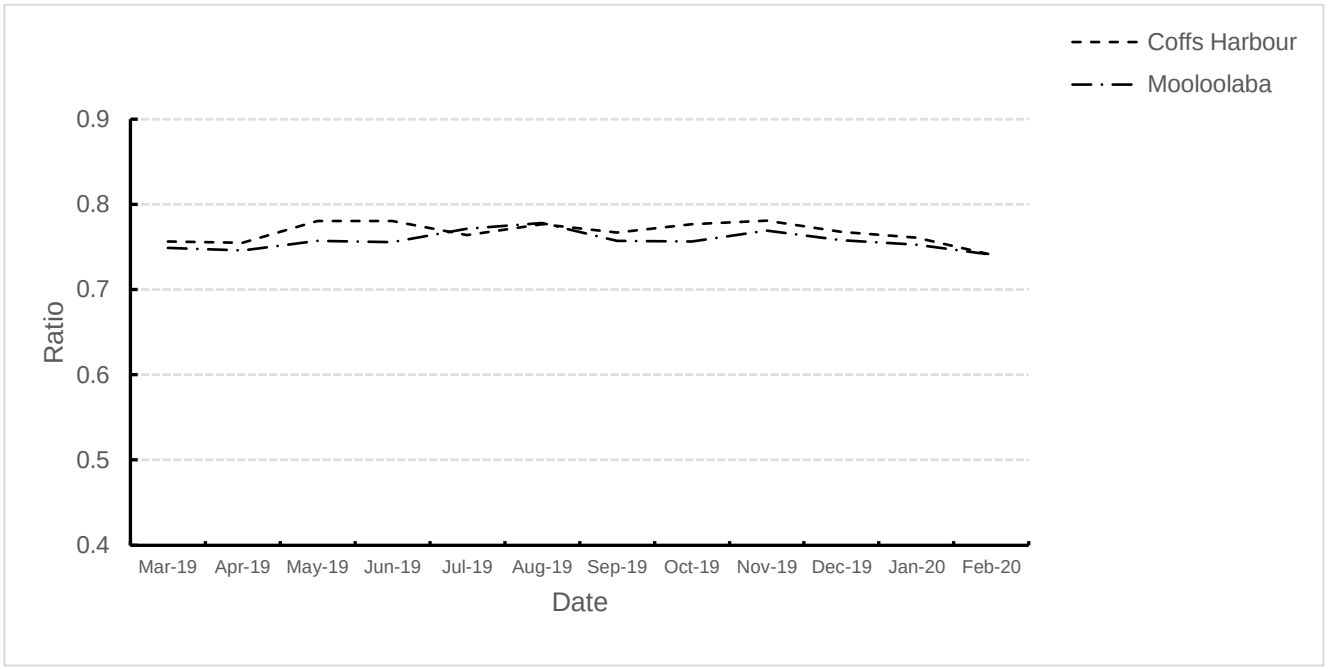


Figure 4 – Spring Tidal Range Ratio Comparison (Letitia 2A to Other Sites)

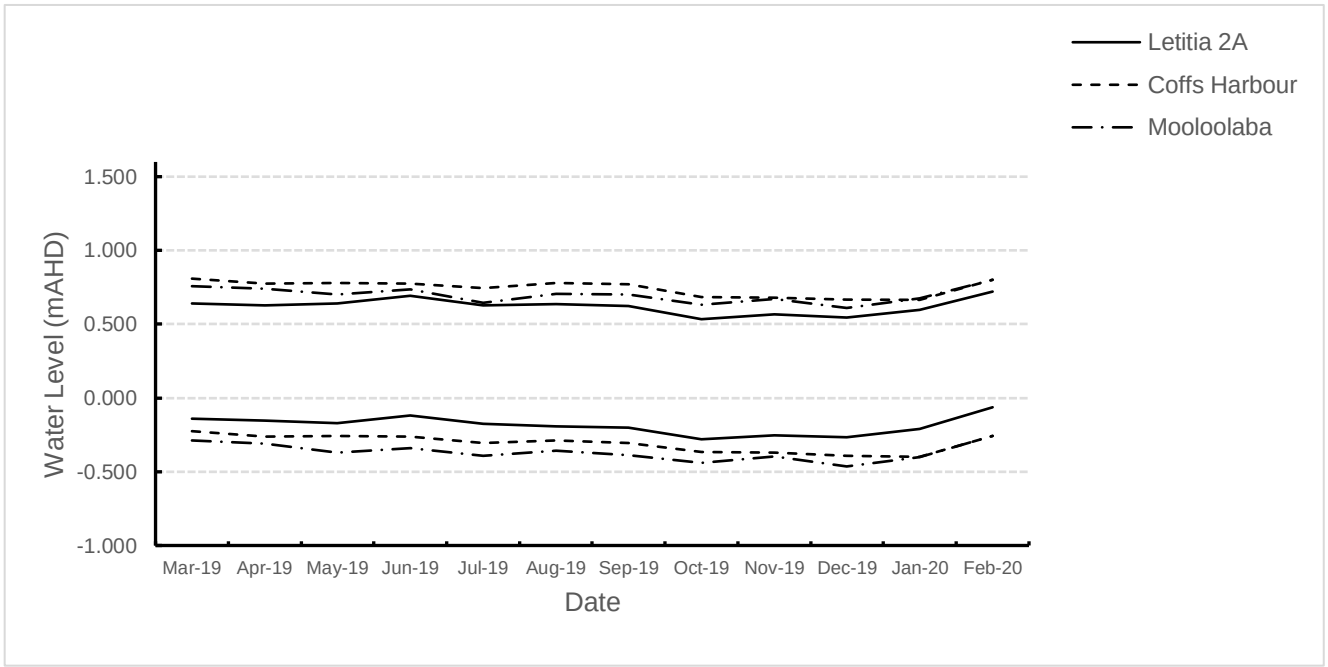


Figure 5 – Spring Tidal Planes Comparison

Table 1 – Murwillumbah recorded rainfall for the period March-2019 to February 2020 (all values in mm)

	Long Term Average	Monthly Totals	Highest Daily Recording	% Monthly Avg
Mar-18	214.3	175.8	55	82.03%
Apr-18	150.6	143.1	33	95.02%
May-18	127	62.1	16	48.90%
Jun-18	106.6	106.1	57	99.53%
Jul-18	60	39.5	14	65.83%
Aug-18	53.1	18.5	9	34.84%
Sep-18	40	5.5	2.5	13.75%
Oct-18	108	29.8	12	27.59%
Nov-18	120.7	5.8	5	4.81%
Dec-18	166.2	85	8	51.14%
Jan-19	205.3	263.9	173	128.54%
Feb-19	230.5	700.5	191	303.90%
Mean:			48	79.66%
Sum:	1571.7	1635.6		

3 Tidal Planes

Presented below are a series of monthly tidal plane tables for the five selected sites.

Key:

- **HHWS** - Highest High Water Springs
- **MHWS** - Mean High Water Springs
- **MHWN** - Mean High Water Neaps
- **MWL** - Mean Water Level
- **MLWN** - Mean Low Water Neap
- **MLWS** - Mean Low Water Springs
- **LLWS** - Lowest Low Water Springs
- **MSTR -** Mean Spring Tidal Range
- **MNTR** - Mean Neap Tidal Range
- **Residual** - Root Mean Square Residual

Table 2 – Tidal planes and ranges for March 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.034	0.850	0.996	0.874	0.781
MHWS	0.809	0.642	0.757	0.665	0.581
MHWN	0.455	0.372	0.351	0.369	0.369
MWL	0.115	0.116	0.032	0.097	0.139
MLWN	-0.579	-0.410	-0.693	-0.470	-0.302
MLWS	-0.225	-0.140	-0.287	-0.174	-0.090
LLWS	-0.804	-0.618	-0.932	-0.680	-0.502
MSTR	1.388	1.052	1.450	1.135	0.883
MNTR	0.680	0.512	0.638	0.543	0.459
Residual	0.135	0.138	0.077	*NA*	*NA*

Table 3 – Tidal planes and ranges for April 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.009	0.843	0.994	0.864	0.784
MHWS	0.776	0.627	0.739	0.647	0.574
MHWN	0.432	0.371	0.355	0.368	0.372
MWL	0.086	0.108	0.023	0.092	0.138
MLWN	-0.604	-0.411	-0.693	-0.463	-0.299
MLWS	-0.260	-0.155	-0.309	-0.184	-0.097
LLWS	-0.837	-0.627	-0.948	-0.680	-0.508
MSTR	1.380	1.038	1.432	1.109	0.873
MNTR	0.692	0.526	0.664	0.552	0.469
Residual	0.090	0.114	0.069	*NA*	*NA*

Table 4 – Tidal planes and ranges for May 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.064	0.905	1.010	0.921	0.830
MHWS	0.781	0.641	0.701	0.655	0.576
MHWN	0.507	0.427	0.387	0.422	0.407
MWL	0.125	0.129	0.009	0.106	0.147
MLWN	-0.531	-0.383	-0.683	-0.443	-0.283
MLWS	-0.257	-0.169	-0.369	-0.210	-0.114
LLWS	-0.814	-0.647	-0.992	-0.709	-0.537
MSTR	1.312	1.024	1.384	1.098	0.859
MNTR	0.764	0.596	0.756	0.631	0.522
Residual	0.088	0.089	0.069	*NA*	*NA*

Table 5 – Tidal planes and ranges for June 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.086	0.976	1.079	0.983	0.905
MHWS	0.776	0.692	0.735	0.697	0.629
MHWN	0.576	0.538	0.495	0.529	0.502
MWL	0.156	0.209	0.078	0.180	0.221
MLWN	-0.464	-0.274	-0.579	-0.336	-0.186
MLWS	-0.264	-0.120	-0.339	-0.168	-0.059
LLWS	-0.774	-0.558	-0.923	-0.622	-0.462
MSTR	1.240	0.966	1.314	1.033	0.816
MNTR	0.840	0.658	0.834	0.697	0.560
Residual	0.120	0.105	0.095	*NA*	*NA*

Table 6 – Tidal planes and ranges for July 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.059	0.911	0.994	0.913	0.831
MHWS	0.745	0.626	0.647	0.628	0.558
MHWN	0.507	0.464	0.405	0.451	0.428
MWL	0.101	0.144	0.006	0.117	0.154
MLWN	-0.543	-0.338	-0.635	-0.395	-0.250
MLWS	-0.305	-0.176	-0.393	-0.218	-0.120
LLWS	-0.857	-0.623	-0.982	-0.679	-0.522
MSTR	1.288	0.964	1.282	1.023	0.808
MNTR	0.812	0.640	0.798	0.669	0.548
Residual	0.102	0.068	0.048	*NA*	*NA*

Table 7 – Tidal planes and ranges for August 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.060	0.904	1.022	0.919	0.830
MHWS	0.778	0.637	0.706	0.653	0.573
MHWN	0.480	0.399	0.364	0.394	0.392
MWL	0.096	0.104	0.003	0.085	0.136
MLWN	-0.586	-0.429	-0.700	-0.482	-0.301
MLWS	-0.288	-0.191	-0.358	-0.224	-0.120
LLWS	-0.868	-0.696	-1.016	-0.749	-0.558
MSTR	1.364	1.066	1.406	1.135	0.875
MNTR	0.768	0.590	0.722	0.619	0.513
Residual	0.124	0.059	0.050	*NA*	*NA*

Table 8 – Tidal planes and ranges for September 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.996	0.841	0.958	0.859	0.763
MHWS	0.769	0.624	0.701	0.644	0.555
MHWN	0.403	0.336	0.293	0.331	0.330
MWL	0.049	0.068	-0.047	0.049	0.097
MLWN	-0.711	-0.546	-0.842	-0.613	-0.431
MLWS	-0.305	-0.200	-0.387	-0.233	-0.136
LLWS	-0.898	-0.705	-1.052	-0.762	-0.568
MSTR	1.440	1.112	1.496	1.190	0.916
MNTR	0.708	0.536	0.680	0.564	0.466
Residual	0.131	0.110	0.087	*NA*	*NA*

Table 9 – Tidal planes and ranges for October 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.919	0.743	0.881	0.767	0.664
MHWS	0.683	0.534	0.634	0.557	0.465
MHWN	0.337	0.268	0.234	0.264	0.256
MWL	-0.014	-0.006	-0.104	-0.028	0.017
MLWN	-0.671	-0.488	-0.795	-0.546	-0.361
MLWS	-0.365	-0.280	-0.442	-0.320	-0.222
LLWS	-0.947	-0.755	-1.089	-0.823	-0.631
MSTR	1.394	1.080	1.476	1.170	0.896
MNTR	0.702	0.548	0.676	0.584	0.478
Residual	0.063	0.097	0.065	*NA*	*NA*

Table 10 – Tidal planes and ranges for November 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.957	0.822	0.973	0.835	0.747
MHWS	0.679	0.568	0.669	0.581	0.504
MHWN	0.387	0.348	0.331	0.340	0.328
MWL	0.008	0.048	-0.033	0.020	0.066
MLWN	-0.663	-0.472	-0.735	-0.541	-0.371
MLWS	-0.371	-0.252	-0.397	-0.300	-0.195
LLWS	-0.941	-0.726	-1.039	-0.796	-0.614
MSTR	1.342	1.040	1.404	1.121	0.875
MNTR	0.758	0.600	0.728	0.639	0.523
Residual	0.097	0.077	0.064	*NA*	*NA*

Table 11 – Tidal planes and ranges for December 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.987	0.836	0.949	0.843	0.747
MHWS	0.668	0.546	0.610	0.551	0.469
MHWN	0.444	0.378	0.356	0.366	0.336
MWL	0.026	0.055	-0.054	0.021	0.054
MLWN	-0.616	-0.436	-0.718	-0.510	-0.361
MLWS	-0.392	-0.268	-0.464	-0.324	-0.228
LLWS	-0.935	-0.726	-1.057	-0.801	-0.638
MSTR	1.284	0.982	1.328	1.061	0.830
MNTR	0.836	0.646	0.820	0.690	0.564
Residual	0.138	0.080	0.078	*NA*	*NA*

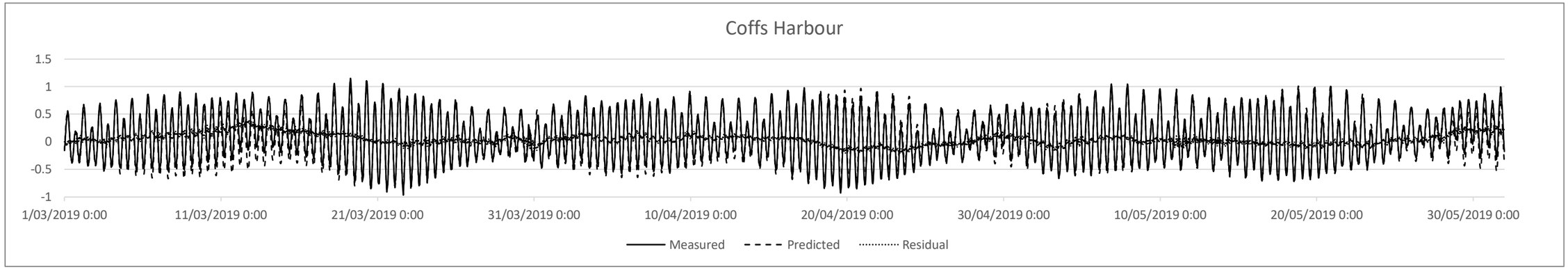
Table 12 – Tidal planes and ranges for January 2020

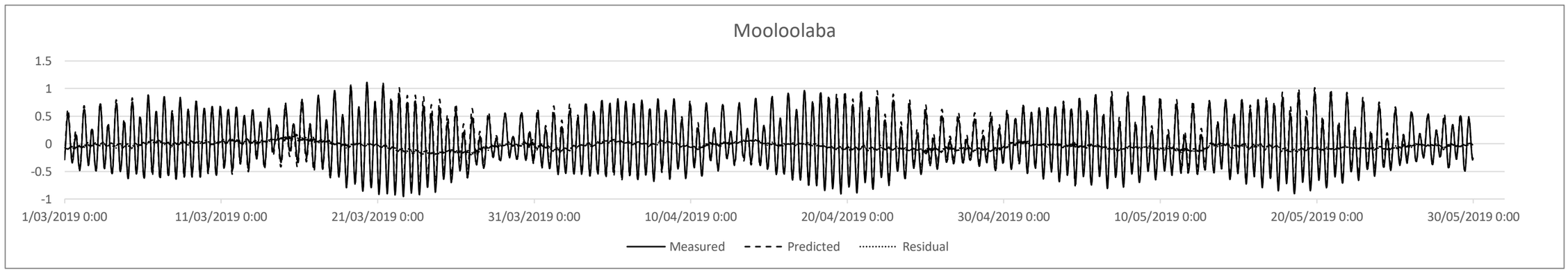
	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.978	0.886	1.009	0.889	0.797
MHWS	0.665	0.599	0.675	0.602	0.523
MHWN	0.433	0.419	0.411	0.403	0.378
MWL	0.017	0.104	0.005	0.067	0.103
MLWN	-0.631	-0.391	-0.665	-0.467	-0.318
MLWS	-0.399	-0.211	-0.401	-0.268	-0.173
LLWS	-0.944	-0.678	-0.999	-0.754	-0.592
MSTR	1.296	0.990	1.340	1.068	0.841
MNTR	0.832	0.630	0.812	0.671	0.551
Residual	0.063	0.129	0.075	*NA*	*NA*

Table 13 – Tidal planes and ranges for February 2020

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.071	0.969	1.092	0.977	0.915
MHWS	0.801	0.721	0.801	0.731	0.687
MHWN	0.479	0.475	0.449	0.460	0.497
MWL	0.111	0.206	0.096	0.177	0.263
MLWN	-0.579	-0.309	-0.609	-0.376	-0.162
MLWS	-0.257	-0.063	-0.257	-0.105	0.029
LLWS	-0.849	-0.557	-0.900	-0.623	-0.389
MSTR	1.380	1.030	1.410	1.107	0.849
MNTR	0.736	0.538	0.706	0.565	0.468
Residual	0.127	0.225	0.077	*NA*	*NA*

4 Residual Plots





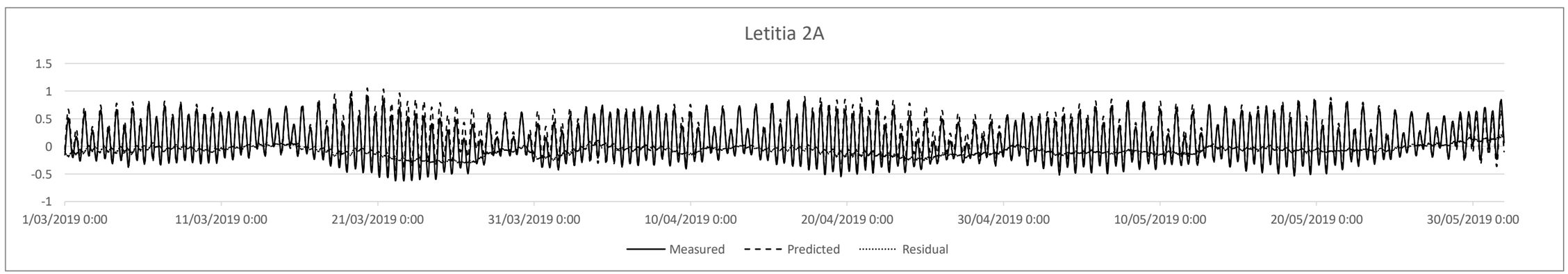
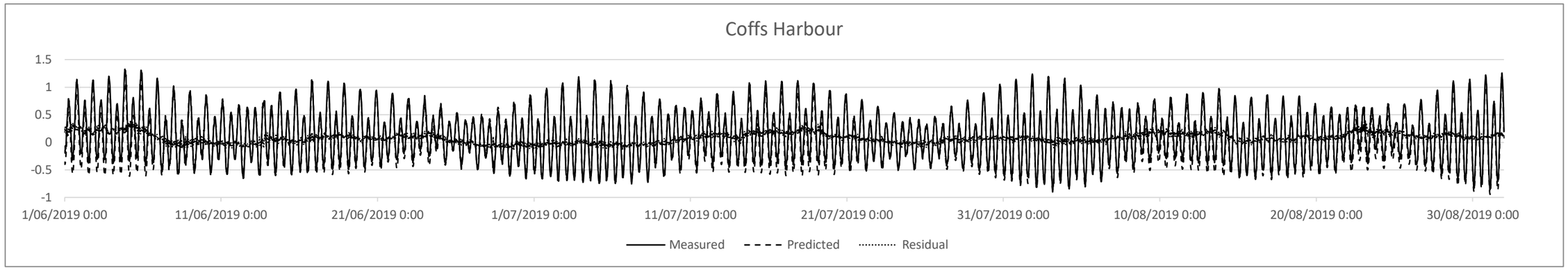
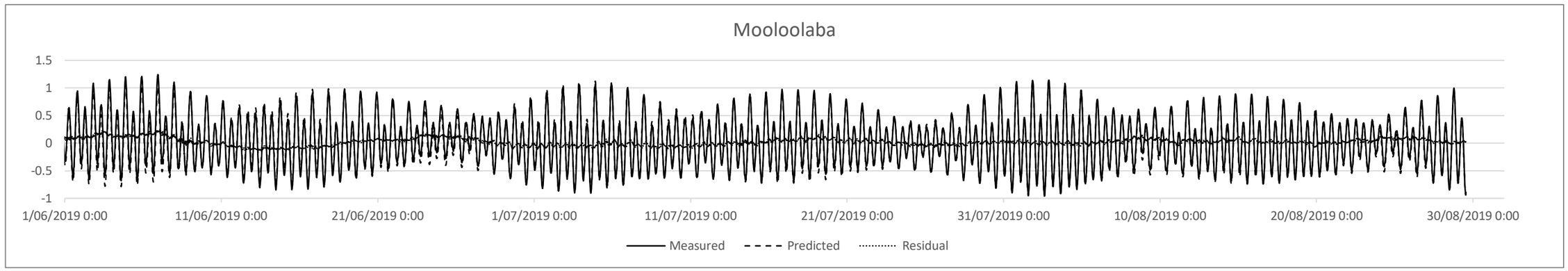


Figure 6 – March 2019 to May 2019 Water Levels





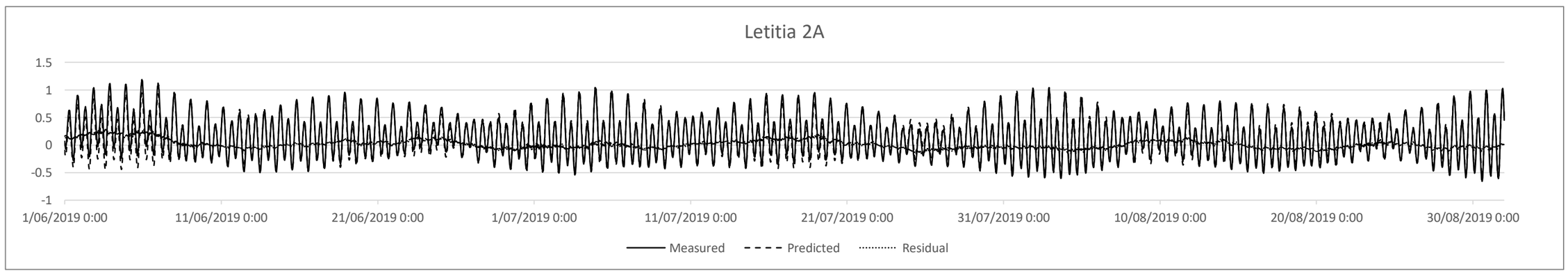
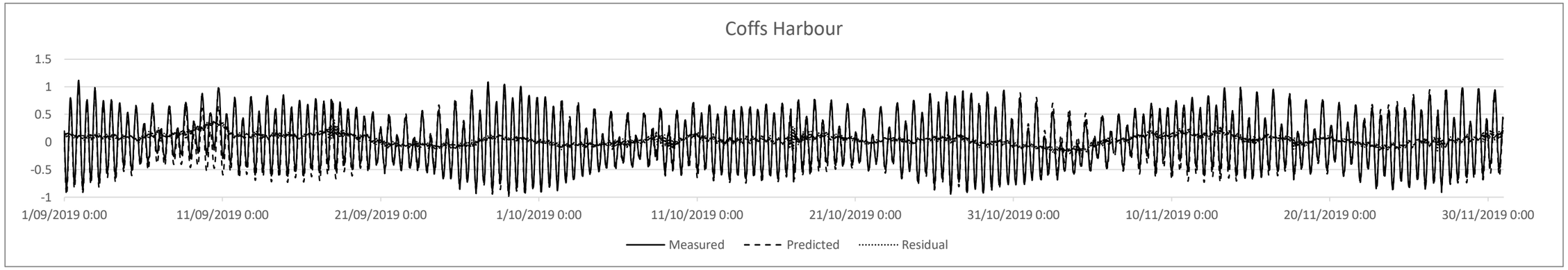
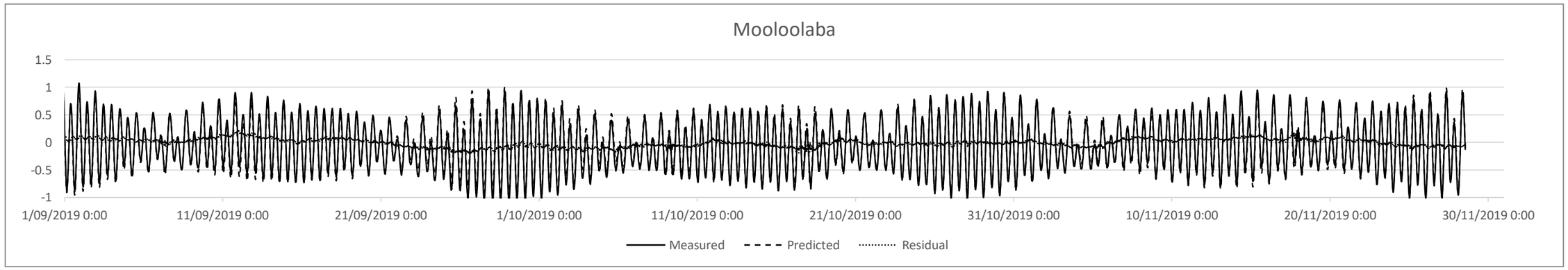


Figure 7 – June 2019 to August 2019 Water Levels





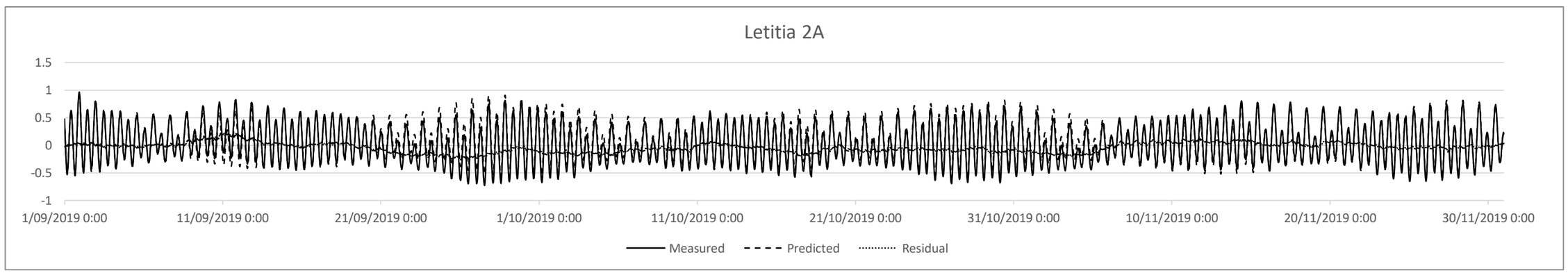


Figure 8 – September 2019 to November 2019 Water Levels

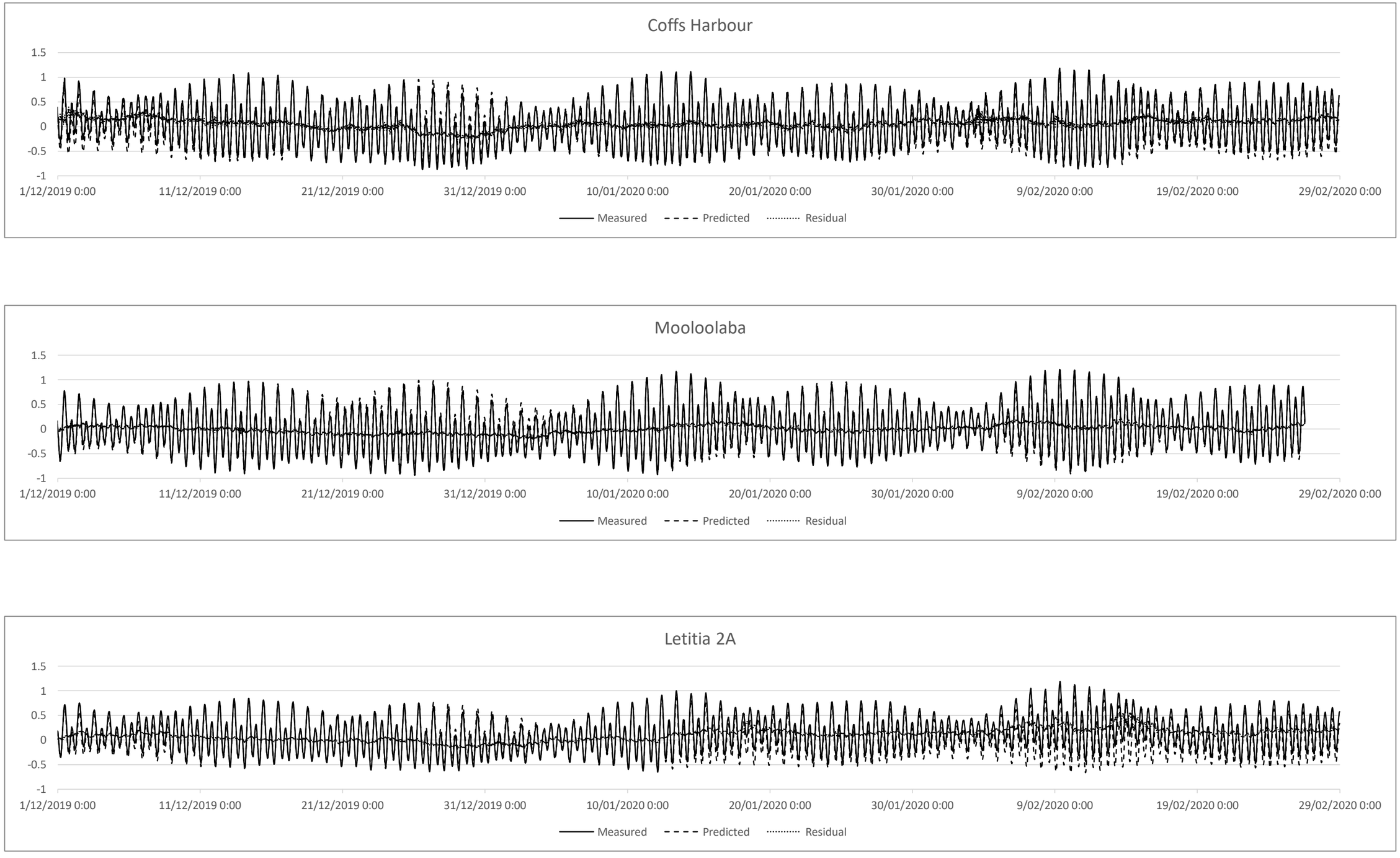


Figure 9 – December 2019 to February 2020 Water Levels

5 Conclusions

Based on the analysis presented above it is unlikely that the Tweed entrance has experienced any significant morphological changes in the preceeding 12-months which would manifest in changes to the astronomical tidal response.

Should you require further information please contact **Bronson McPherson** on (02) 9949 0244 or by email at Bronson.Mcpherson@mhl.nsw.gov.au

Yours sincerely

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Document Control

Issue/ Revision	Author	Reviewer	Approved for Issue	
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