# Tidal Reference Frame For Queensland


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## Abstract

The objective of all tidal calculation is to provide the best (most accurate, closest to the truth) estimate of the tidal height and or time.

In order to achieve this objective, tidal calculations are based upon the longest available period of recorded tidal times and heights. Reliance is placed on the statistical process of averaging the readings over a long time span in order to minimize the effect of the unpredictable components of the tidal records, sea level variations due to weather etc., to produce the best estimate.

The tidal reference frame consists of those tidal stations for which a long series of readings are available and for which a primary determination of the tidal parameters has been completed. These stations provide the long term tidal parameters for use:-

1. in study of the mean sea level surface (and of any other tidal plane);
2. as the basis of the mid term review of the mean tidal planes for Queensland waters for the present tidal datum epoch;
3. in the study of the relationship between the sea level and Australian Height Datum;
4. in seasonal variation adjustment for tidal harmonic analysis at other tidal stations;
5. as base line harmonic constituent constants for storm surge study;
6. in inference of tidal constituent constants for tidal harmonic analysis; and,
7. in the establishment of the AUSHYDROID.



**KEYWORDS:** tidal observations, tidal predictions, tidal datum determination, tidal datum epoch, mean sea level, sea level rise, tidal reference frame, AUSHYDROID


**Introduction** Tidal readings are used in association with a number of human activities along our coasts and for a wide range of purposes typically:-

1. prediction of future tidal heights for all who use and enjoy our coastal environment;
2. determination of statistical elevations for datum determination (mean tidal planes such as - mean sea level, lowest astronomical tide, high water mark) for use in:-
   a. geodesy;
   b. hydrography;
   c. cadastral surveying for the proposed marine cadastre and the freehold/leasehold cadastre;
3. coastal engineering;
4. hydrodynamic modeling;
5. foreshore erosion monitoring and control;
6. marine infrastructure development (boat ramp, jetty, wharf design, dredging, etc.); and,
7. research into many other subjects.

To improve the accuracy, tidal calculations are based upon the longest available period of recorded tidal times and heights. The effects of the unpredictable components of the tidal records are minimised by averaging these readings over a long time span.

Like every thing on this planet, the sea levels are not static. Waves, daily tides, weather, and climate induce sea level change. It is the latter, slow and small change in sea level, that resulted in the development and employment of the concept of the tidal datum epoch (Hicks, 1986). The geodetic surveying community use the epoch concept to monitor tectonic movement etc.

The tides that we experience daily include a number of cyclical variations that have periods extending from a month to many years. Because of the cyclical nature of the tides, it is necessary to base the calculations on a complete tidal cycle so that the average is not biased. In order to deal with tidal readings that do not span the necessary complete cycle, the concept of a tidal reference frame has been developed.

**The Tidal Reference Frame Project** The reference frame is essentially a control mechanism, the time element of which is the tidal datum epoch. The frame consists of the tidal stations for which a long series of readings is available. The stations are situated along the Queensland coast from Karumba to the Gold Coast. Because it is intended that the frame provides a snapshot of the tidal conditions at a point in time, the readings should, as far as is practicable, extend over the same date span.

**The Tidal Parameters** The tidal parameters of the stations in the reference frame include:-

- the datum of the station (with the associated navigation chart datum and the AUSHYDROID);
- the elevations of the following mean tidal planes:-
  - highest astronomical tide;
  - mean higher high water;
  - mean high water spring tide (semidiurnal waters only);
  - mean high water;
  - mean high water neap tide (semidiurnal waters only);
  - mean lower high water;
  - mean sea level;
  - mean higher low water;
  - mean low water neap tide (semidiurnal waters only);
  - mean low water;
  - meal low water spring tide (semidiurnal waters only);
  - mean lower low water; and,
  - lowest astronomical tide.
- the tidal constituent constants (as well as the seasonal constituents Sa and Ssa); and,
- the allowance for sea level rise.

With the exception of highest astronomical tide and lowest astronomical tide which are defined in terms of predicted tides, these elevations will be calculated from observed sea levels. Table 1 provides the values of the parameters calculated thus far. Calculation of the mean tidal planes is in progress.

**Height Reference Datum** All elevations within the reference frame are relative to the Lowest Astronomical Tide (LAT). The elevation of this datum was calculated from tidal predictions, in accordance with its definition, in the mid 1980's. Because the LAT is the navigation chart datum for Australian waters, it will be incorporated into the reference frame at its present elevation.

Maritime Safety Queensland is moving slowly toward implementing the AUSHYDROID. Future hydrographic surveys will be measured by global positioning system technology in X, Y, Z terms - thereby eliminating the need to measure tidal height and vessel motion. The charted depth will be simply Z (ellipsoidal height) less the AUSHYDROID.

**Mean Tidal Planes** Historically, many of the tidal parameters (principally the mean tidal planes) were calculated by formula or from predicted tidal heights. These processes provide approximations which are becoming less acceptable. As a second but related project, it is intended that, from 1 January 2003 onwards, all future tidal parameters for Queensland waters would be:-

1. calculated strictly in accordance with their definition; and,
2. based on observed tidal readings (except where the definition specifically refers to predictions).

The definitions to be used are those published in Queensland's "Official Tide Table and Boating Safety Guide". If a particular definition does not appear in the guide then the definition in the Australian National Tide Table is to be used. In other cases, the accepted international definition will be used.

In considering what period of readings is required in order to achieve our objective, the Queensland definitions of mean sea level and the other tidal planes specify "long term". For example, high water mark for the purposes of the Queensland Land Act (1994) means "....... the ordinary high water mark at spring tides". The courts have recently interpreted this definition to mean the "Long term average of the heights of two successive high waters during those periods of 24 hours (approximately once a fortnight) when the range of tide is greatest, at full and new moon". (Svensden, 1999) The court's interpretation corresponds to the definition of the tidal plane "mean high water spring tide" published in Queensland's "Official Tide Table and Boating Safety Guide".

**What is a "Long Term"** Waves, daily tides, weather and climate all induce sea level change. The period over which each factor operates extends from waves with period of a few seconds and an amplitude of potentially many metres, to the infinitely long period, but very small amplitude, sea level rise attributed to the "greenhouse effect". The daily tides and weather effects fall between these extremes.

**The Principal Cyclicities** The tides are the response of the oceans to the gravitational forces maintaining the earth, sun, and moon in their respective orbits. The gravitational forces fluctuate as the result of:-

1. the elliptical path of the body in its orbit;
2. the rotation of the solar and lunar perigee; and,
3. the rotation of the orbital plane in space.

The resulting principal tidal cyclicities are:-

| Orbital Element | | Approximate Tidal Period |
|---|---|---|
| | one tidal day | approximately 25 hours |
| s | mean longitude * of the moon | a lunar month |
| h | mean longitude * of the sun | a calendar year |
| p | mean longitude * of the lunar perigee | 8.8 years |
| N | negative of the mean longitude * of the lunar ascending node | 18.6 years |
| p' | mean longitude * of the solar perigee (perihelion) | 21,000 years |
| | (Doodson, 1980) (also called astronomical arguments - Foreman 1979) | |

The mean longitude * of the perihelion has a period that is too long to have any observable effect on the tidal times and heights. This element is omitted from future consideration within the tidal reference frame for Queensland.

* "The position of any heavenly body is defined by its "longitude", which is the angular distance eastward along the ecliptic, measured from the vernal equinox, and (2) by its latitude .......". (Doodson 1980).

Historically when readings were hard to obtain and to process, we based our tidal height calculations on a lunar month of 28 days, the second cyclicity in the tides. As data became more readily available and digital processing became the norm the period that could be considered as "long term" was extended to one year, the third major cyclicity.

Readings extending over approximately 18.6 years, (the lunar nodal cycle) are available at a number of places along the coast of Queensland. It is now practicable and logical to extend the concept of "long term" to the nodal period, the fifth principal cyclicity in the tides.

**Primary Determination of the Elevation of the Mean Tidal Planes** In considering mean sea level, Marmer in his book "Tidal Datum Planes" states:-

> A period of 19 years is generally considered as constituting a full tidal cycle, for during this time the more important of the tidal variations will have gone through complete cycles. It is therefore customary to regard results derived from 19 years of tide observations as constituting mean values. Hence sea level derived from 19 years of observations may be taken to constitute a primary determination and as giving accurately the datum of mean sea level.
>
> (Marmer 1951)

The tidal datum epoch which has been proposed for Australia as the 20 years - 1992 to 2011 inclusive, is broadly in concordance with the above. The initial selection of the 20 year period for the epoch was made with Marmer's statement in mind.

It is proposed to extend Marmer's reasoning to the primary determination of all of the mean tidal planes including the highest and lowest astronomical tide. The definition of these latter tidal planes refers to "any combination of astronomical conditions". It is accepted that for practical purposes that Marmer's 19 year nodal period satisfies this condition.

In order for the tidal reference frame to be finalized at the present time (2003) those places with 15 years of more of readings are considered to be equivalent to those places with 19 years available. Tidal readings for 22 stations along the Queensland coast commence during the years 1985/86/87 and continue through to the present.. It is proposed to accept that these readings, which are less than the ideal 19 year data span, will provide a practical primary determination of the sea level parameters.

The Table 1 details the first primary determination of the value of the mean sea level and the harmonic tidal constituent constants for those stations selected for inclusion in the tidal frame. For convenience the seasonal constituents Sa and Ssa and the AHD connection are also listed in the table.

Commencing on 1 January 2003:-

1. the 22 stations listed in the Table 1 form the Tidal Reference Frame for Queensland;
2. the mean sea level, seasonal constituents, and the constituents of the inference file are the primary determination of the particular parameter for the tidal station concerned;
3. If 19 years or more of tidal recordings are available, then tidal calculations will be primary determinations of the parameters being deduced; and,
4. When less than 19 years of tidal readings are available, then tidal calculations will be secondary or tertiary determinations of the parameters being deduced. These determinations are to be referred to the appropriate station of the Tidal Reference Frame.

Unfortunately it is not possible at the present time to align the datum epoch and the observation period on which the primary determinations are being made. Further because the amount of weather induced variation in the sea levels, 19 years of readings is not sufficient to determine a reasonable estimate of the very slowly changing sea level rise. Accordingly it has been necessary to make an adjustment for sea level change occurring between the central date of the observations and of the tidal datum epoch.

**Sea Level Rise** Because the sea level rise is very low, averaging 0.0003 metres per annum for the Australian continent (Mitchell, 2002), the 15 to 19 years of readings available from Queensland tidal stations is not sufficient to calculate a reasonable estimate of sea level change. Accordingly an adjustment of 0.0003 metres per annum is made to the mean sea level within the tidal reference frame. The allowance is been calculated from the central date of the observation period at each station to the central date of the tidal datum epoch (31 December 2001).

In time, it is expected that there will a sufficiently long span of readings and that it will be possible to obtain a refined estimate of the sea level rise at individual stations. The sea level change observed at each place can be incorporated into future primary determinations in lieu of the Australia wide rise incorporated at present.

**Secondary Determination of the Tidal Parameters for Queensland** Marmer provides a process whereby estimates of the long term tidal parameters can be made for those places where less than 19 years of readings are available. He calls these estimates secondary determinations.

> At all other places a satisfactory secondary determination of this datum plane *(mean sea level)* can be made by means of observations covering much shorter periods if the results are corrected to a mean value by comparison with the primary determination at some suitably located tide station.
>
> . (Marmer 1951)

Essentially the process provides that a mean value of the height of the required mean tidal planes at each of the secondary and primary reference stations is obtained by simultaneous observations. The height difference between the observed mean tidal plane and the primary determination of it at the reference station is applied to the observed height at the secondary place.

Because it is necessary to adjust the mean sea level to the equivalent 19 year elevation, the harmonic analysis for tidal constituent constants based on readings spanning 1 to 19 years is regarded as being a secondary level determination of them.

Using Marmer's reasoning, one may expect that a secondary determination of all of the mean tidal planes and the tidal constituent constants would achieve a satisfactory estimate of the long term values for them.

**The effect of Changing Tidal Range Along the Coast** It is clear that the range of tide changes from place to place along the coast. The tidal ranges at the reference and secondary stations are generally not the same.

By judicious selection of the tidal frame reference station, the tidal range difference between it and the secondary station is minimized. Accordingly it is customary to omit any allowance for range difference between the stations when calculating secondary determinations.

**Other Considerations** It would seem to be unwise to blindly follow the process for secondary determinations of the tidal parameters. Clearly secondary determinations depend upon:-

1. the coherence of the tide at the tidal frame reference station and at the station for which the secondary determination is being made; and,
2. minimisation of local casual variations in the mean tidal plane under consideration.

**Tidal Coherence** Experience within Maritime Safety Queensland indicates that, regionally, the tides in Queensland waters are generally highly coherent. The selected regions are:-

- The ocean south from the Great Barrier Reef , excluding the Burnett River and Hervey Bay;
- Bundaberg and the Hervey Bay;
- Bundaberg to Whitsunday Passage;
- Whitsunday Passage north to Bowen;
- Bowen to Torres Strait;
- Torres Strait; and,
- Gulf of Carpentaria.

This recognizable regional coherence supports Marmer's proposition and dictates the choice of tidal frame reference station associated with each other station.

**Minimization of Casual Variations** It is implicit that casual variations are small and random such that we may rely on averaging over the length of the observations in order to minimize the effect the variation.

The most striking example of a casual variation is the storm tide. Such tides may be above (or below) the normal tidal level for some considerable time (many days) and may for some storms achieve extreme elevations. Storm tides are highly site specific and are unlikely to be experienced at each of the reference and secondary stations to the same degree. The requirements of coherence and minimization of casual variations are clearly violated. A secondary determination should not be undertaken in these circumstances unless the:-

- storm tide readings are excluded from the readings being used in the determination; or,
- data length is such that the non-tidal residuals associated with the storm surge have no perceptible effect on the mean value of the height being calculated.

Because we are relying on averaging to minimize casual variations, the number of readings that are included in the calculation of the mean is important. For example the height of a mean high water spring tide (MHWS) can only be determined twice from a lunar month of tidal readings. As a result the precision would not be very high. In such cases, other processes, such as those described for tertiary determinations, are required in order to improve the precision of the estimate of the tidal planes of MHWS and the like where the readings to be included in the mean are few in number.

**Tertiary Determination of the Tidal Parameters for Queensland** As is apparent from the above, the level at which the determination of tidal parameters can be made is dependent on:-

- the coherence of the tide at both the reference station and the secondary stations; and,
- the length of simultaneously observed readings at the reference and secondary stations.

Except for the permanent standard port tidal stations where ongoing readings are available and at a few other places at which there are readings spanning one year or more, the most usual length of readings available for tidal calculations is approximately one lunar month

As in the case of secondary stations, because the primary determination is referred to the tidal datum epoch then the tertiary determination will automatically be referred to the same epoch.

Because of the limited span of readings, the process used in a secondary determination may only be applied to the mean higher high water, mean high water, mean lower high water, mean sea level, mean higher low water, mean low water, and mean lower low water planes. Accordingly, in order to progress the determination of the mean high water spring tide, mean high water neap tide, mean low water neap tide, meal low water spring tide mean tidal planes, it is necessary to classify the tidal heights at the reference and tertiary stations into semidiurnal or diurnal form.

**Tidal Form** In Queensland waters, some places have tides that are clearly semidiurnal in form, others are clearly diurnal in form. Tidal stations situated north from Townsville, and including the Torres Strait have tides that are mixed in form, that is there are generally two high and low tides each day but the diurnal inequality is large. At these stations the classification is not particularly clear. The criteria for assigning the tides at such places to the diurnal or semidiurnal class has not yet been determined.

The tides at all of the stations within a region must be assigned to the same form as the tidal reference frame station in the region.

**Semidiurnal Tides** In those regions where the semidiurnal components of the tide dominate, it is proposed to rely on correlation and regression analysis to deduce the tidal "rise ratio and constant" or the related "amplitude ratio and constant" for the high and low tide heights at the secondary station and the relevant reference station. The elevations of the semidiurnal mean tidal plane are then estimated by applying the ratio and constant to the elevations of the tidal planes at the reference station. This is regarded as a tertiary determination.

As in the case of the secondary determination, selection of the appropriate reference station is to be made from those within the region to which the primary and secondary stations belong.

Many of these tertiary determinations are made for stations with significant shallow water restriction. This restriction may preclude the use of a single "ratio and constant". In such cases it is appropriate to use a ratio for high tides and a ratio for low tides. Tides falling to or below the height of the low water restriction are to be excluded from the calculation of the "ratio and constant". If two ratios are calculated no ratio and constant is published.

**Diurnal Tides** Even in those regions where the diurnal component of the tide dominates, and the form of the tide is clearly diurnal, the degree of diurnality changes significantly over relatively short distances. As a result the correlation is generally poorer than in the case of semidiurnal tides.

In limited circumstances (very small distance between the reference and tertiary stations such that the degree of diurnality differs little between them) it is possible to use either of the ratio and constant processes.

At other places with diurnal tides, it is proposed to use the process used for the secondary determination. This tertiary determination will be less precise than the secondary counterpart.

The problems of shallow water restrictions described for semidiurnal tides also applies to diurnal tides.

**Final Comments** This paper is reporting work in progress. Accordingly there are number of issues remaining to be tested and finalised, such as:-

1. the criteria for classifying the form of tide into semidiurnal or diurnal; and;
2. the number of readings required to make a secondary and tertiary determination of the semidiurnal tidal planes.

Issues related to the shallow water restriction remain unresolved.

The tidal stations comprising the frame have been selected and are listed in Table 1. Those parameters that are finalised for each tidal reference frame station are:-

1. the mean sea level applicable to the year 1992 - 2011 tidal datum epoch (including the associated rate of change of sea level); and.
2. the tidal constituent constants that are to be used for:-
   a. seasonal variation adjustment;
   b. use in the tidal constituent inference process associated with the tertiary level determination of tidal constituent constants; and,
   c. the base line harmonic constituent constants for storm surge study.

**The Expected Benefits** For the first time in Queensland, each tidal plane will have been calculated according to its definition and based on observed tidal heights. All height determinations will be relative to the tidal datum epoch and all heights will be referred to the station datum. This will improve the long term precision of tidal predictions and of the tidal information in general.

Within the tidal community, the tidal datum epoch and reference frame is used to:-

1. monitor the long period sea level changes relative to the land (i.e. the climate induced and so called greenhouse sea level rise). The geodetic community is monitoring the height component of the tectonic movement so that the sea level and ground movement can be separated to provide absolute sea level change;
2. provide stability to the published height of the mean tidal planes which will be held fixed for the duration of the epoch unless significant change occurs; and,
3. Control the orderly change to the published tidal information as sea level rise impacts on the tidal predictions and on the height of the mean tidal planes.

The mean sea level elevation is available as an input to any future modernisation of the Australian Height Datum.

The mean tidal planes (high water mark and highest astronomical tide particularly) are assuming heightened importance to the cadastral surveyors of Queensland when they are determining or re-instating littoral boundaries.  Similarly the tidal planes are important to the delineation of the Australian maritime boundaries.

The economic value of tidal recording and prediction should not be under estimated nor even taken for granted. Every improvement of the tidal predictions (either to improve accuracy or increase precision) has a dollar return. For example, better management of the tidal heights at the port of Hay Point resulted in an increase of 0.07m in export ship draft.  The productivity boost that resulted amounts to tens of millions of dollars per year.

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**Glossary**

| | |
|---|---|
| AUSHYDROID | "L" the height separation between the Geodetic Datum Australia ellipsoid and chart datum, analogous to "N" the geoidal separation. |
| Constituent constant | See Tidal harmonic analysis |
| Diurnal tide | A tide with one cycle per day, one high and one low per day. |
| Diurnal inequality | Diurnal inequality is the difference in height between successive high tides. It is related to the amplitude of the diurnal tidal constituent constants. |
| Inferencing | A process used to estimate the value of the constants for those constituents which cannot be deduced directly by tidal harmonic analysis. |
| Mean tidal planes | The datum planes of semidiurnal tides:-<br>mean high water spring tide, mean high water neap tide, mean low water spring tide, mean low water neap tide.<br>The datum planes of diurnal tides:-<br>mean higher high water, mean lower high water, mean higher low water, mean lower low water.<br>The datum planes unrelated to the form of the tide:-<br>highest astronomical tide, mean high water, mean sea level, mean low water, lowest astronomical tide. |
| Primary station | A tidal station for which a primary determination of the tidal parameters has been made. |
| Primary determination | The determination of the tidal parameters for a tidal station based on 19 years of tidal readings. |
| Reference station | A reference station is a tidal station that is used as a standard for the comparison of simultaneous observations at a second station i.e. a station at which a primary determination of the elevation of the mean tidal planes and tidal constituent constants has been made. |
| Seasonal constituents | These are the tidal constituents, Sa and Ssa, that are used to represent the annual variation in the mean sea level. |
| Seasonal variation | The seasonal variation is the changing component of the mean sea level, the phase of which corresponds to the annual cycle of the summer/winter seasons. It represented by the solar annual and semi-annual constituent constants, Sa and Ssa. |
| Secondary determination | The determination of the tidal parameters for a tidal station based on less than 19 years but 1 year or more of tidal readings. |
| Secondary station | A tidal station for which a secondary determination of the tidal parameters has been made. |
| Semidiurnal tide | A tide with two cycles per day, two high and two low tides each tidal day with a small diurnal inequality. |
| Shallow water restriction | In tidal streams, the ebb and flow of the tide is restricted by the effect of friction. In shallow streams this effect becomes significant – The lower tidal levels are impeded to such an extent that the low tides cannot fall to the level that they would fall if the stream were deeper. There are no simple processes that can be used to allow for this "shallow water restriction". |
| Tertiary determination | The determination of the tidal parameters for a tidal station based on less than 1 year of tidal readings. |
| Tertiary station | A tidal station for which a tertiary determination of the tidal parameters has been made. |
| Tidal constituent | See Tidal harmonic analysis |
| Tidal datum epoch | The 20 year period over which tidal observations are averaged to establish the various mean tidal planes. |
| Tidal harmonic analysis | Tidal harmonic analysis is the process of decomposing the tidal height time series into a polynomial comprising simple harmonic terms of the form Acos(B) (the constituents), the coefficients of which are the tidal constituent constants (where A is the amplitude constant and B is the phase angle constant relative to the time origin). |
| Tidal parameters | For each tidal station, these consist of the elevation of the mean tidal planes relative to the station datum, the tidal constituent constants, and the rate of sea level rise. |
| Z00 | Long term mean sea level. Once the tidal frame is fully established this will be the value for the tidal datum epoch or the equivalent value from a secondary or tertiary level determination |

| Table 1- Primary Determinations<br>Datum is Lowest Astronomical Tide | | Reference Port Details for use in the Queensland Tidal Reference Frame<br>Allowance for sea level rise is 0.0003 metres per annum | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Port** | **Z00** | **Observation Epoch<br>Central Date** | **Sea Level Rise** | **Z00 Epoch 1992- 2012** | **AHD** | **Seasonal Constituents** | | | **Inference File Name** |
| Gold Coast Seaway<br>045044A | 0.735 | 01/01/1987 to 18/02/1999<br>24/01/1993 | 0.003 | 0.738 | 0.760 | SA<br>SSA | 0.0546<br>0.0055 | 43.66<br>142.22 | C045044A.99 |
| Brisbane Bar<br>046046A | 1.244 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 1.247 | 1.243 | SA<br>SSA | 0.0503<br>0.0087 | 12.27<br>162.97 | C046046A.00 |
| Mooloolaba<br>011008A | 0.944 | 01/01/1987 to 31/12/2000<br>31/12/1993 | 0.002 | 0.947 | 0.990 | SA<br>SSA | 0.0599<br>0.0052 | 26.09<br>164.79 | C011008A.00 |
| Urangan<br>058009B | 2.076 | 01/01/1986 to 31/12/2000<br>02/07/1993 | 0.003 | 2.079 | 2.040 | SA<br>SSA | 0.0481<br>0.0070 | 345.47<br>13.67 | C058009B.00 |
| Bundaberg (Burnett Heads) 051011A | 1.705 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 1.708 | 1.693 | SA<br>SSA | 0.0767<br>0.0037 | 344.47<br>259.87 | C051011A.00 |
| Gladstone Auckland Pt<br>052027A | 2.319 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 2.322 | 2.268 | SA<br>SSA | 0.0937<br>0.0081 | 348.60<br>319.66 | C052027A.00 |
| Port Alma<br>050008A | 2.886 | 01/01/1986 to 31/12/2000<br>02/07/1993 | 0.003 | 2.889 | 2.854 | SA<br>SSA | 0.0862<br>0.0113 | 346.93<br>21.20 | C050008A.00 |
| Hay Point<br>060008A | 3.353 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 3.356 | 3.340 | SA<br>SSA | 0.0975<br>0.0092 | 353.40<br>335.95 | C060008A.00 |
| Mackay 054004A<br>Z00 not yet finalized | 2.996 | 01/01/1988 to 31/12/2000<br>02/07/1994 | 0.003 | | 2.941 | SA<br>SSA | 0.1050<br>0.0095 | 350.37<br>3.19 | C054004A.00 |
| Shute Harbour<br>030003A | 1.900 | 01/01/1987 to 31/12/2000<br>31/12/1993 | 0.002 | 1.903 | 1.907 | SA<br>SSA | 0.0969<br>0.0101 | 354.78<br>348.21 | C030003A.00 |
| Bowen<br>061007A | 1.742 | 19/11/1986 to 31/01/2002<br>26/06/1994 | 0.002 | 1.744 | 1.776 | SA | 0.0990<br>0.0192 | 356.56<br>355.22 | C061007A.02 |
| Cape Ferguson Storm Surge 033007A | 1.776 | 13/04/1984 to 31/01/2002<br>08/03/1993 | 0.003 | 1.779 | 1.693 | SA<br>SSA | 0.1042<br>0.0166 | 352.83<br>8.88 | C033007A.02 |
| Townsville<br>055003A | 1.928 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 1.931 | 1.856 | SA<br>SSA | 0.0974<br>0.0173 | 349.93<br>351.98 | C055003A.00 |
| Lucinda Offshore<br>062006A | 1.869 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 1.872 | 1.844 | SA<br>SSA | 0.1032<br>0.0152 | 355.47<br>1.11 | C062006a.00 |
| Cardwell Storm Surge<br>035012A | 1.944 | 17/12/1985 to 31/01/2002<br>08/01/1994 | 0.002 | 1.946 | 1.863 | SA<br>SSA | 0.0976<br>0.0237 | 352.86<br>349.05 | C035012A.02 |
| Clump Point Storm Surge 035002B | 1.735 | 17/12/1985 to 31/01/2002<br>08/01/1994 | 0.002 | 1.737 | 1.678 | SA<br>SSA | 0.1039<br>0.0189 | 356.65<br>4.52 | C035002B.02 |

| Table 1- Primary Determinations<br>Datum is Lowest Astronomical Tide | | Reference Port Details for use in the Queensland Tidal Reference Frame<br>Allowance for sea level rise is 0.0003 metres per annum | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Port** | **Z00** | **Observation Epoch<br>Central Date** | **Sea Level Rise** | **Z00 Epoch 1992- 2012** | **AHD** | **Seasonal Constituents** | | | **Inference File Name** |
| Mourilyan<br>063012A | 1.722 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 1.725 | 1.729 | SA<br>SSA | 0.1012<br>0.0175 | 358.59<br>356.47 | C063012A.00 |
| Cairns<br>056012A | 1.680 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 1.683 | 1.643 | SA<br>SSA | 0.0938<br>0.0174 | 358.41<br>12.96 | C056012A.00 |
| Cooktown<br>066003A | 1.527 | 01/01/1983 to 28/02/2002<br>31/07/1992 | 0.003 | 1.530 | 1.480 | SA<br>SSA | 0.0844<br>0.0168 | 4.69<br>29.11 | C066003A.02 |
| Thursday Island<br>057022B | 1.851 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 1.854 | 1.769 | SA<br>SSA | 0.1103<br>0.0100 | 321.98<br>25.22 | C057022B.00 |
| Weipa<br>070021A | 1.812 | 01/01/1985 to 31/12/2000<br>31/12/1992 | 0.003 | 1.815 | 1.752 | SA<br>SSA | 0.3152<br>0.0529 | 307.42<br>303.37 | C070021A.00 |
| Karumba<br>071004A | 2.083 | 01/01/1985 to 31/12/2001<br>02/07/1993 | 0.003 | 2.086 | 2.184 | SA<br>SSA | 0.3920<br>0.0433 | 302.60<br>317.76 | C071004A.00 |