Guidelines

Concerning the Reduction of Soundings to Chart Datum

Objective
All tidal height readings are measured vertically in standard metric units relative to the chart datum at a tidal station.

To achieve this:-
Tidal stations should be:-

- established, documented and operated using the agency's own work instructions;

or

- established and documented using the "Tide Gauge Survey Instructions"; and,
- operated in accordance with the "Recommended Operating Procedures for Tide Gauges on the National Network".

The latter were prepared by the Permanent Committee on Tides and Mean Sea Level (PCTMSL) on behalf of the Intergovernmental Committee on Surveying and Mapping.

These guidelines should be read in conjunction with the attached "Notes Concerning the Reduction of Soundings to Chart Datum".

Sources of additional information
The PCTMSL "Recommended Operating Procedures for Tide Gauges on the National Network" and "Tide Gauge Survey Instructions" provide appropriate processes and documentation to confirm the continued accuracy of the tidal recordings.

Processes
Several processes are required in order to ensure that tidal readings are accurate and that their variability is assessable.

1 Pre-deployment of the Instrument Package

1. **The Span** Standardisation of the span of height measurement system, (including the sensor and the data logger system as a single unit) under laboratory conditions using equipment and techniques that are one order of magnitude better than the required output of the tidal recording system.
2. **Linearity** Linearity of the sensor and digitizing unit tested as a single unit, by sampling the height measurement at a number of points distributed along the measurement range, using the same equipment and techniques as for the span.
3. **Time** Standardisation of the system clock rate against the Australian time standard.
4. **Confirmation of the TGBM Elevation.** The elevation of the TGBM will be confirmed by independent and redundant measurements to at least three benchmarks. In the case of marks on structures (particularly offshore structures), at least two of the marks will be on independent structures.
5. **Setting the tide board (or other tidal height checking mechanism)** Set the tide board to the specified distance above or below the TGBM and confirm its elevation using any standard surveying technique that is one order of magnitude better than the required output of the tidal recording system. The accuracy of the tide board markings should be confirmed, particularly if the board is installed as a number of sections. Refer to the PCTMSL "Tide Gauge Survey Instructions"-
    a. Section 4. Bench Marking,
    b. Section 5. Levelling to the Zero of tide staffs, and
    c. Section 6. Connection to the National Levelling Survey.

Tidal recorders may be checked using other tidal height checking mechanisms - "dip tapes", portable stilling wells, and the like. Such equipment and the reference marks used with it must be set and confirmed in the same manner as for the tide board. Refer to the PCTMSL "Tide Gauge Survey Instructions" Section 5. Levelling to the Zero of tide staffs.

2 During Deployment of the Instrument Package
The PCTMSL "Tide Gauge Survey Instructions" provide an appropriate process and documentation to confirm the continued accuracy of the tidal recordings. Refer to Section 2. Calibration of Automatic Recorders

Guidelines

Concerning the Reduction of Soundings to Chart Datum

Day to day checking

It is prudent practice to check the recordings both height and time (the so called water level check) at the beginning and end of any day for which tidal recordings are required. Refer to the "Recommended Operating Procedures for Gauges on the National Network", Section 6. Operating Procedures which details procedures suitable for both analogue and digital recording instruments.

For additional information, refer to the PCTMSL "Tide Gauge Survey Instructions" subsections 2.4 and 2.6 of Section 2. Calibration of Automatic Recorders.

Ongoing Calibration Check

Refer to the PCTMSL "Tide Gauge Survey Instructions" for an appropriate method by which a tidal height station may be calibrated in-situ, Section 2.2 of the Calibration of Automatic Recorders. Ainscow et al. also provides comprehensive information on the operation and ongoing testing (Van de Casteele test) of tidal recording equipment.

Provided that it is possible to synchronise the readings from the recorder and the water level checks accurately, it is possible is possible to monitor the ongoing calibration (span and zero setting) using the water level checks. Perform a linear regression using the tide board readings and the recorded readings. The slope should be 1.000 and the offset 0.000.

Notes Concerning the Reduction of Soundings to Chart Datum

1.0 Introduction

The tidal heights are a variation in the sea level that is associated with the gravitational forces maintaining the sun, moon, and the earth in their orbits. Because the orbits of the bodies are precisely known, the variations in the gravitational forces can be used as a basis for predicting the tidal heights (the gravitational tide).

The reduction of soundings from floating platforms is traditionally based on the observed the tidal time and height at one or more tidal stations and some interpolating techniques together with the associated assumptions to obtain tidal height relative to chart datum at other places.

However, with the advent of the Global Positioning System (GPS) and the development of the real time kinematic (RTK) mode of operation, the height of the surveying platform can be measured directly as an ellipsoidal height relative to the survey mark at the RTK reference control station.

1.1 Chart Datum

The International Hydrographic Conference of 1926 agreed that "Chart datum....... a plane so low that the tide will but seldom fall below it." Cited in Doodson.

Accordingly chart datum is selected according to some arbitrary rule which is related to the tidal heights. Lowest Astronomical Tide (LAT) datum has been selected by the Hydrographic Service of the Royal Australian Navy as the chart datum of Australian waters.

Once selected and in accordance with the concept of a "datum" chart datum is held at a fixed physical height. Because chart datum is usually below the water, its elevation is defined at each tidal station as being a specified distance above or below the Tide Gauge Benchmark (TGBM). Each TGBM should be:-

1. A permanent survey mark registered with the state mapping agency; and,
2. Established in accordance with Section 4. Bench Marking PCTMSL "Tide Gauge Survey Instructions".

It is prudent surveying practice to support each TGBM by a number of "recovery" or witness marks.

In order to remove any impression that it is a geometric plane, chart datum is hereafter referred to as a surface. Because the range of tide varies from place to place, chart datum is not necessarily planar, horizontal, nor parallel to the geoid, ellipsoid, mean sea level or Australian Height Datum.

2.0 Sounding Reduction

During the hydrographic survey, the soundings are measured relative to the vessel's water line in the absence of vessel motion or waves i.e. the still water line. In tidal waters, the elevation of the water surface in the absence of waves (still water) is measured relative to chart datum. Soundings, relative to chart datum, are simply the surveyed depth less the height of the vessel relative to chart datum. Because the tides are not the same everywhere and because neither the water surface nor the vessel is still it is necessary to compensate for these variations in the water surface elevation.

2.1 Sounding Reduction by Tidal Heights

In this technique, it is assumed that the vessel's water line and the still water surface are co-incident. The soundings relative to chart datum is simply the surveyed depth less the height of the tide at the point of sounding.

Because the tidal times and heights are not the same every where, i.e., tidal times and heights are site specific - they apply only at the place where they were recorded. Accordingly it is usual to observe the tide at one place (at least) and to make an assumption about the times and heights at other places nearby. There are two usual assumptions made:-

1. Accept that the tide is the same at all places in the immediate vicinity of the tidal observation station; or,
2. Interpolate the tidal time and height from observations at a number of stations.

Maritime Safety Queensland prefers to use the latter (incorporating two stations) for surveys requiring the highest precision.

A scheme dividing the ship channels and coastal waters into a number of segments "co-tidal zones" has been established. Each "co-tidal zone" details the tidal stations to be used and the assumptions to be used when reducing soundings. Typically the "co-tidal zone" (in this case East Channel, Moreton Bay) information has the form:-

> Linearly interpolate the tidal readings between the Brisbane Bar tidal station 046046A Latitude 27 Deg 22' S Longitude 153 Deg 10' E & the East Channel Beacon, station 046208B Latitude 27 Deg 14' S Longitude 153 Deg 20' E
> Datum is LAT

There are two commonly accepted interpolation techniques. They are:-

- Linear; and,
- Planar.

2.1.1 Linear Technique

The tidal height at a point along the line joining the tidal stations is interpolated by distance from simultaneous readings from each station – the linear technique. All points on a line at right angles to this point are assumed to have the same tidal height.

2.1.2 Planar Technique

The planar interpolation technique assumes that the water surface is a geometric plane between three tidal stations. In this way any cross slope incorporated into the interpolation.

2.1.3 Uncertainty in the elevation of Chart Datum

Refer to section 3.2 Uncertainty in the Elevation of Chart Datum for further details.

In the event that neither the precision requirement nor cost justify the observation of the tides, then estimates of the tidal times and heights may be used in lieu. The following processes are usually employed to make these estimates:-

1. Harmonic tidal prediction;
2. Enhanced harmonic tidal prediction; (Tidal observations and predictions for some nearby place are necessary if this process is used.)
3. Rise ratio, constant and time difference; (This process may be based on either predicted or observed tidal times and heights from some nearby place.)

2.2 Sounding Reduction by AUSHYDROID

The height of the sounding platform may be measured directly as an ellipsoidal height using the Global Positioning System (GPS).

As already noted, chart datum is not necessarily planar (flat) or a surface parallel to the ellipsoid through the RTK reference height control mark. Accordingly it is necessary to apply the AUSHYDROID in order to obtain the soundings relative to chart datum.

At the present time the AUSHYDROID can only be obtained at the tidal stations where the LAT and ellipsoidal heights are both known. As in the case of tidal reductions is necessary to make the same assumptions in order to interpolate the AUSHYDROID at places in between. When known the AUSHYDROID values are noted in the "co-tidal zone" details.

3.0 Variations in the Parameters Used to Reduce Soundings to Chart Datum.

All measurements are subject to variability. The objective is to minimize the variability and to understand the quantum of it. Each component of the sounding reduction process, i.e. datum, observed height, predicted height, and interpolation technique, has its own uncertainty estimate.

3.1 Sources of Tidally Related Uncertainties in Sounding Reductions.

There are six elements to the uncertainties.

1. Instrumental calibration (Span, linearity of the sensor and digitizing unit, time [clock rate]);
2. Setting of the elevation of the tidal station tide board (or other tidal height checking mechanism) relative to the tide gauge benchmark;
3. Determination of the elevation of zero of the recorded tidal readings relative to the tide gauge benchmark;

4. The variability in the recorded tidal heights due to wave and water flow conditions at the station;
5. Variability due to the assumptions made when interpolating tidal heights between tide stations; and,
6. Instrumental errors (unstable calibration parameters [span, linearity and height zero], and clock time & rate).

Refer to the "Recommended Operating Procedures for Tide Gauges on the National Network",
Section 3. Importance of Accuracy, Section 4. Height Errors, and Section 5. Time Errors.

It is important to test the entire tidal height measuring system as a whole, i.e. the sensor and data logger / digitizing unit, of the tide gauge. We are concerned about the accuracy of the recorded reading - not the accuracy of the component parts. Any precision statement emanating from tests and calibrations should refer to the recorded readings.

3.1.1 Instrumental calibration Span, linearity of the sensor and digitizing unit, time [clock rate].

These tests (and subsequent adjustment of the recording equipment) ensures that the tidal recordings are measured in standard metric units of length and time.

Prudent practice dictates that instrumental calibrations are undertaken before and after the deployment to confirm the accuracy of the readings as well as at any time there is reason to suspect that the readings are not accurate.

3.1.2 Elevation of the tidal station tide board. Setting the elevation of the tidal station tide board (or other tidal height checking mechanism) relative to the tide gauge benchmark.

It is necessary that the zero of the tide board be set exactly to the elevation of the chart datum.

The water level checks taken using the tide board are the primary means of confirming the ongoing accuracy of the recorded tidal heights. All tidal readings depend upon the accuracy of the setting of the tide board.

Because of its importance in establishing the elevation of the recorded tidal readings, it is prudent to check the length of the tide board once in situ.

3.1.3 Elevation of zero of the recorded tidal readings. Determination of the elevation of zero of the recorded tidal readings relative to the tide gauge benchmark.

The water level checks taken using the tide board are the primary means of establishing the elevation of the zero point of the recorded tidal heights, relative to both the TGBM and the tide board.

The check comprises the simultaneous observation of:-

1. the tide board reading and the water level actually recorded by tide gauge. Do not use the tide gauge display as the recorded and displayed readings are not always the same; and,
2. the local standard time (e.g. AEST - 10 hours east) of the recorded water level by means of an independent time piece. The PCTMSL Recommended Operating Procedures for Tide Gauges on the National Network Tide Gauge Survey Instructions Special Publication No. 9 provides further guidance and a pro forma suitable for recording the checks.

The average value for the difference between the board reading and the recorded reading is the elevation of the zero of the recorded tidal readings relative to the tide gauge benchmark.

Over time, the results of the water level check confirm the ongoing accuracy of the recorded readings. If there are sufficient checks covering the full range of tide experienced at the station, the checks provide a means of testing the recorder calibration (span, linearity, and clock rate).

3.1.4 Variability in the recorded tidal heights due to wave and water flow conditions
The weather systems experienced on an ongoing basis impart variations in the sea level. These variations experienced in Queensland waters are unpredictable and are regarded as normal and as such a part of the daily tides. Extreme weather events may generate larger variations resulting in the phenomena known as storm tide.

Waves within the marine environment may range in period:-

1.	less than 10 seconds - wind waves -	short period;
2.	10 to 60 seconds - swell and vessel wash -	short period;
3.	60 seconds to tidal periods, seiche -	long period;
4.	12 hours in semidiurnal waters and 24 hours in diurnal waters - tides -	macro period.
5.	Greater than 24 hours - storm tide	Storm tide

The waves 1, and 2 are regarded as a random variation in the elevation of the water surface relative to its undisturbed (still water) state.

The effect of Waves and Water Flow on Recorded Tidal Height Readings The objective of tidal recording is to obtain a time series of the elevation of the still water level in order to obtain the tidal height component.

Because the short period waves (less than 60 second period) are filtered (averaged or integrated), either mechanically (e.g. stilling well) or numerically, tidal stations measure total still water level. This is made up of:-

1. Draw down (due to the Bernoulli effect of water flowing past the water level sensor);
2. Wave pumping (associated with imperfect filtering of waves);
3. Wave setup (related to dissipation of wave energy on a shoreline i.e. breaking waves);
4. Seiche;
5. Gravitational (astronomical) tide; and,
6. Storm surge (related to the effects of wind stress and regional barometric pressure differential on the water level).

Effects 1, 2, and 3 are minimized by careful site selection for the tidal station, avoiding places with exposure to:-

1. waves; and,
2. strong currents and streams.

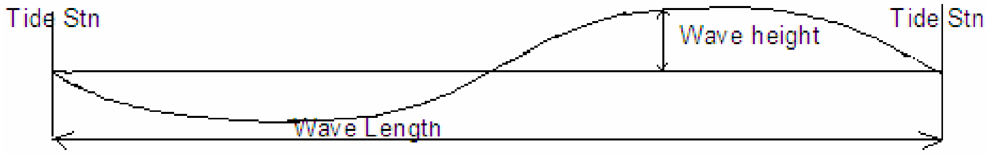
Some assessment of all of the waves present at a tide station is necessary, in order to design the measurement system and process. Clearly it is impractical to log all of the readings for 5 second period waves and the like. Consequently it is necessary to employ some form of mechanical filtering and/or, in combination with signal processing, numerical filtering to attenuate the wave action within the tide gauge in order to produce a reasonable estimate of the undisturbed water level.

It is clearly undesirable to filter out all water level variations. The long period, macro period, waves and the storm tides (effects 4, 5, and 6) remain in the tidal record.

At this point it is necessary to be aware of aliasing within digitally recorded tidal readings. Appendix A of the "Recommended Operating Procedures for Tide Gauges on the National Network" provides a discussion on aliasing and it also provides a means of detecting and dealing with the phenomenon. In order to avoid aliasing, it is necessary to sample at a rate of not less than 2 samples per wave, and preferably more.

3.1.4.1. The effect of Waves on the Reduction of Soundings.

Short period waves These waves manifest themselves as vessel motion, heave, roll, pitch, yaw which is necessarily measured on site and related to the elevation of the undisturbed water. However the measurement of vessel motion has technical limitations, principally related to the encounter frequency of the wave relative to the platform. Present inertial based technology is limited to relatively high encounter frequencies. Not withstanding the inertial technology limitations, soundings are referred to the undisturbed water level, as are the tidal readings.



In the case of the storm tide and macro period waves and where the distance between the tidal stations is very much shorter than the wavelength, it is reasonable assume that any slope of the water surface due to these waves is linear in the direction of flow. Accordingly the linear interpolation between stations provides a reasonable estimate of the tidal height.

Long period waves Dealing with the long period waves (60 sec to 12 hours) is not simple however they can be divided into further frequency bands in order to establish a means of dealing with them.

The following table provides guide to the wave length for various wave periods on the proviso that the wave height is a very small part of the total water depth.

Wave period	Approximate wave length (10m average depth)	Approximate wave length (20 m average depth)
12 hours	430 km	600 km
6 hours	215 km	300 km
2 hours	70 km	100 km
1 hour	36 km	50 km
30 minutes	18 km	25 km
15 minutes	9 km	13 km
10 minutes	6 km	8 km
5 minutes	3 km	4 km
2 minutes	1 km	1.7 km
1 minutes	0.6 km	0.8 km

Tidal reduction of soundings in the presence of waves requires a knowledge of:-
1. the wave length,
2. the phase of the wave at the tidal station and
3. The phase of the wave at the sounding vessel.

In general it is not possible to know any of these with certainty. Clearly wave lengths that are equal to or less than the distance between the tide stations cannot be dealt with by tidal measurement alone. Longer waves may also give unacceptable water level variations up until the distance between the tidal stations is such that curvature of the wave may be accepted as approximately linear at which time interpolation between stations provides a reasonably small variability.

For example:**-** The tidal stations are one wavelength apart (9 km which applies to a 15 minute period seiche wave in 10 metres average depth) and the wave height is 0.1m.

Because the stations are one wave length apart they will always be at the same relative phase and as a result both will always read the same height. At one point between the stations the water will be 0.1m below the undisturbed elevation and at a second (1/2 wave length away) the water will be 0.1m above the undisturbed elevation. Such an variation will be virtually undetectable at the survey vessel.

Other combinations of wave length and tidal station separation result in a more complex situation than in the example.

In a general example, the maximum difference in height between the curve and the chord of any segment of the wave which is 10 percent of the wave length long is about 5% of the wave amplitude. The maximum difference is about 19% of the amplitude for a chord which is 20% of the wavelength.

When surveying in the presence of a seiche with significant amplitude, there seems to be only three options:-
1. Accept the seiche amplitude as part of the error budget for the soundings;
2. Reduce the distance between tidal stations so that it becomes a small part of the wave length at which time the linear interpolation results in no significant error; or,
3. Use RTG survey techniques and the AUSHYDROID.

3.1.5 Variability due to interpolating tidal heights

Refer to Section 3.2 Uncertainty in the Elevation of Chart Datum for discussion on the interpolation of chart datum (and thus tidal heights) between tidal stations.

3.1.6 Instrumental errors

Unstable calibration parameters (span, linearity, and height zero), clock time and clock rate. Refer to the PCTMSL "Tide Gauge Survey Instructions" for an appropriate method by which a tidal height station may be calibrated in-situ, Section 2.2 of the Calibration of Automatic Recorders. Ainscow et al. also provides comprehensive information on the operation and ongoing testing (Van de Casteele test) of tidal recording equipment.

Provided that it is possible to synchronize the readings from the recorder and the water level checks accurately, it is possible is possible to monitor the ongoing calibration (span, linearity, and zero setting) using the water level checks. Perform a linear regression using the tide board readings and the recorded readings. The slope should be 1.000 and the offset 0.000. Any clock rate and clock offset will become apparent over time, both of which may be determined by means of a linear regression.

3.2 Uncertainty in the Elevation of Chart Datum

At Tidal Stations Chart datum is selected according to some arbitrary rule that is related to the tidal heights. Once selected and in accordance with the concept of a "datum" chart datum is held at a fixed physical height.

Because its height is arbitrarily selected, the datum itself has no error. However the realization of the datum (by setting tide boards and stability of the TGBM etc.) is subject to variation associated with the measurement processes used.

At Other Places Unfortunately the tide does not occur at the same time nor height everywhere.

1. The height of chart datum is known only at the tidal stations used to define it; and,
2. Chart datum is a surface which is not parallel to the geoid, ellipsoid, mean sea level, or AHD.

Accordingly it is necessary to interpolate the tidal height and as a result to interpolate the height of the datum. As a consequence, the tidal interpolation process becomes part of the realisation of chart datum.

The "co-tidal zone" details provide all of the necessary information to realise the chart datum:-

1. Tidal station or stations, including position;
2. The chart datum required;
3. The AUSHYDROID "L" value when known; and,
4. The interpolating technique to be used.

In general little is known about the interpolation of chart datum between tidal stations. However a careful selection of the siting of tidal stations (mainly distance apart) and the shape and size of the "co-tidal zones" should minimize the variation. On the basis that the water will flow down slope, the present thinking is that:-

1. the tidal stations should be situated so that the flow is along the line between two stations; and,
2. that there should be minimal cross flow.

This should ensure that any height difference will be along the axis of the interpolation. In the case of the two station interpolation technique any cross slope is minimal. If the planar interpolation is used, then any cross slope will be included.

3.3 Ellipsoidal Datum

At the Primary Tidal Stations Generally ellipsoidal datum is not the responsibility of the hydrographic surveyors. It is provided by the state mapping agency and disseminated as an elevation of the state survey control marks which include the TGBMs for the tidal stations. At present in Queensland the ellipsoidal elevations of the benchmarks are not published. As a result the ellipsoidal height is inferred as being the sum of the AHD elevation of the TGBM plus the AUSGeoid value. Once selected and in accordance with the concept of a "datum" the ellipsoidal datum is held at a fixed physical height relative to the TGBM.

Because its height is essentially arbitrarily selected, the datum itself at the TGBM has no error. However the realization of the datum is subject to variation associated with the measurement processes used. Refer to the "Tidal Reference Frame For Queensland" for further details of the tidal station classification and the adopted ellipsoidal heights.

At other Places These are the tertiary level stations of the reference frame. They are project oriented and the ellipsoidal datum connection is the responsibility of the hydrographers.

The ellipsoidal heights are surveyed by means of the global positioning system survey of a network of four or more stations (including the subject tertiary station). The heights are based on an minimally constrained network adjustment holding the adopted ellipsoidal height at the adjacent primary tidal station fixed. Martin 2001

Note:- This procedure provides two advantages over a fully constrained adjustment of the control network:-

1. The survey is internally consistent and the geometry of the survey measurements is maintained. Any uncertainties in the control network are not propagated to the subject tidal station; and,
2. Because the RTK system operates in a purely geometric sense, any of the network control marks (necessarily using the minimally constrained height) may be used as the base station.

Fundamentally the minimally constrained network adjustment provides a strictly geometric local co-ordinate frame (heights) relative to the TGBM. The reinstatement of the datum of offshore tidal stations is made using this local frame and the AUSGeoid also employs it.

3.4 TGBM Stability

In general little is known about the stability of the elevation of the TGBM - every benchmark and its placement is different. However adherence to good surveying practice will minimise the risk of undetected instability of the TGBM. Each TGBM should be supported by a number of subsidiary marks, and have connection to the national height network. In the case of marks on offshore tidal stations, at least two, and preferably three or more, subsidiary marks should be on independent structures.

The ICSM Special Publication 1 "Standards and Practices for Control Surveys" Version 1.5 of May 2002 and Hicks et al., provides guidance in the establishment of stable marks.

3.5 Recorded tides

The only uncertainty assessment I have is in the calm conditions at Brisbane Bar. The daily water level check readings have a spread of 4 centimetres relative to the recorder reading. The recorder's mean offset from chart datum (also called the elevation of the chart zero of the recorder) has a span of 2 centimetres. Clearly at exposed sites the variation will be larger.

3.6 Harmonic predictions

The uncertainty of tidal predictions is routinely assessed as a part of the harmonic tidal analysis process. Two typical analyses from stations in Moreton Bay result in non-tidal residuals which are summarised as below:-

Data span	30 days resulting in 39 constituent constants.
Mean	0.000
Variance	0.0048
Std Dev.	0.069

Data span	365 days resulting in 68 constituent constants.
Mean	0.000
Variance	0.0079
Std Dev.	0.089

Data span	17 years resulting in 111 constituent constants.
Mean	0.000
Variance	0.0116
Std Dev.	0.1078

Because this variance is of non-tidal residuals resulting from the self prediction of the readings analysed, one may expect slightly larger variations at other times.

The variance includes a component related to storm surges (any sea level disturbance that can be attributed to the weather). Accordingly the variance will vary from year to year and place to place.

3.7 Enhanced predictions

Attached is a copy of chapter 10.0 B Enhancement of Tidal Predictions from the operating manual for the Tidal Unit of Maritime Safety Queensland. The results of the study reported in the manual are accepted as being typical.

3.8 Rise ratio, constant and time difference

Chapter 10.0 B also illustrates the effectiveness of the rise ratio, constant and time difference.

3.9 Other considerations

The precision of all subsidiary methods depends upon the precision of the observed readings used to generate the necessary harmonic constituent constants and the rise ratio, constant and time difference.

3.10 AUSHYDROID and Global Positioning System - RTK

I have little experience with RTK readings but have processed about two hours of elevations from a survey using a 5m dingy in sheltered waters off Palm Island. The distance between the RTK base station and the boat is less than 0.5 km. The sea conditions were calm.

The raw readings were obtained at a rate of about every one second. They were averaged over 5 minutes (the average is centred on the time tag) with obviously spurious readings rejected. The resulting readings are:-
30 07 2003 08:40 2.179
30 07 2003 08:45 2.178
30 07 2003 08:50 2.189
30 07 2003 08:55 2.202
30 07 2003 09:00 2.198
30 07 2003 09:05 2.187
30 07 2003 09:10 2.213
30 07 2003 09:15 2.223
30 07 2003 09:20 2.203
30 07 2003 09:25 2.219
30 07 2003 09:30 2.209
30 07 2003 09:35 2.201
30 07 2003 09:40 2.180
30 07 2003 09:45 2.165
30 07 2003 09:50 2.174
30 07 2003 09:55 2.162
30 07 2003 10:00 2.141
30 07 2003 10:05 2.130
30 07 2003 10:10 2.134
30 07 2003 10:15 2.127
30 07 2003 10:20 2.110
30 07 2003 10:25 2.111
30 07 2003 10:30 2.112
As expected they show a high tide pattern with minimal variation.

The Future It is possible in the future that GPS RTK technology and vessel navigation software will develop to the point where the vessel motion can be measured in three dimensions and applied to the soundings without reference to the water surface and the variability associated with it. This can be achieved at present in calm waters but is felt that issues with the on the fly lane ambiguity are such that the heights are not yet sufficiently reliable for special order surveys.

Glossary

AUSHYDROID — "L", or height separation between the chart datum and the WGS84 ellipsoid.

Chart Datum — The International Hydrographic Conference of 1926 agreed that "Chart datum....... a plane so low that the tide will but seldom fall below it." Cited in Doodson.

Charted Depth — The depth of water depicted on a chart. It is measured below chart datum.

Chart Zero — An elevation which is the recorder's mean offset relative to chart datum. Not to be confused with chart datum.

Lowest Astronomical Tide (LAT) datum — .... the lowest level which can be predicted to occur under average meteorological conditions and any combination of astronomical conditions.

RTK — The real time kinematic mode of obtaining the position and height of a survey point using the global positioning system. The position of the point is measured differentially between a GPS base station at a survey control mark and the point.

As the name suggests, the point is on a surveying platform which is moving (in this case the sounding vessel).

The position is usually expressed as X, Y, Z coordinates referred to the WGS84 geodetic datum.

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Appendix 1 Enhancement of Tidal Predictions

Enhancement of Tidal Predictions by inclusion of observed short term Mean Sea Level Variations

Introduction
Short term mean sea level (MSL) variations (caused by meteorological or other factors) limit the accuracy of tidal predictions by the harmonic method.

Mean sea level variations are generally regarded as being coherent regionally and therefore a MSL variation observed at a reference port (usually a standard port) may be expected to occur at secondary places within the region. Short term MSL variations are detected by comparing the harmonically predicted tide to the observed tide at a reference station.

Procedure
In this method the tidal predictions for the secondary place are adjusted by the addition of the observed regional MSL variation. The observed MSL variation may be an average variation for the data period under consideration (such as is done in the seasonal MSL variation calculation).

Care should be taken when determining an average MSL variation to apply in predictions as the magnitude of the variation can change rapidly in a short time period. Alternatively, subject to the variation being sufficiently coherent regionally, a moving MSL such as the output of a low pass tidal filter, could be used to deduce the variation.

It is preferable to use more than one reference station in order to confirm the regional relationship.

Testing the Procedure
A period of data was chosen when observations and predictions were available for both Caloundra Head (010003A) and Waddy Point (014002B).

The predictions and observations were compared for a 5 day period to determine the average MSL variation at both Caloundra Head and Waddy Point. The observed MSL variations were as follows:

Caloundra Head	0.13 m (observed lower than predicted)
Waddy Point	0.12 m (observed lower than predicted)

The regional relationship is confirmed in this case. See appendix 1 for the details.

Tides for Waddy Point have been estimated by 3 methods:
I. Harmonic predictions with regional MSL variation applied.
II. Rise Ratio and average time difference applied to observed tides from Caloundra Head.
III. Rise Ratio and average time difference applied to predicted tides from Caloundra Head with regional MSL variation applied.

These estimated tides are similar to the observed tides. See Appendix 2 for the details.
The ratio and constants for Waddy Point are detailed in Appendix 3.

Enhancement of Tidal Predictions Appendix 1 Determination of MSL Variations

Predicted MSL Caloundra Head (010003A)	1 - 5 April 1977	= 1.015 m LWD
Observed MSL Caloundra Head (010003A)	1 - 5 April 1977	= 0.883 m LWD
Caloundra MSL Variation		= 0.132 m
Predicted MSL Waddy Point (014002B)	1 - 5 April 1977	= 0.880 m LWD
Observed MSL Waddy Point (014002B)	1 - 5 April 1977	= 0.756 m LWD
Waddy Point MSL Variation		= 0.124 m

Notes Concerning the Reduction of Soundings to Chart Datum

Appendix 1 Enhancement of Tidal Predictions

Enhancement of Tidal Predictions Appendix 2 Tidal Height Comparison

Ratio & Constants: Caloundra (LWD) * 0.91 - 0.01 = Waddy Point (LWD)
Caloundra HW Time + 03 mins = Waddy Point HW Time Caloundra LW Time + 04 mins = Waddy Point LW Time

Caloundra Tides - LWD						Waddy Point Tides - LWD							
1.00		2.00		3.00		Using Ratio & Constants				Harmonic Predictions with MSL Var. Adj.		Actuals	
Caloundra Harmonic Prediction		Caloundra Preds. Adj. for MSL Var.		Caloundra Obs.		On Caloundra Preds. Adj. for MSL Var.		On Caloundra Observations					
01/04/77													
05:47	1.73	05:47	1.60	05:57	1.57	05:50	1.44	06:00	1.42	05:40	1.43	05:47	1.40
12:13	0.36	12:13	0.23	12:14	0.20	12:09	0.20	12:10	0.17	12:14	0.07	12:14	0.03
18:17	1.55	18:17	1.42	18:22	1.37	18:20	1.28	18:25	1.23	18:21	1.20	18:48	1.20
02/04/77													
00:17	0.31	00:17	0.18	00:21	0.19	00:13	0.15	00:17	0.16	00:09	0.11	00:24	0.14
06:32	1.81	06:32	1.68	06:42	1.62	06:35	1.52	06:45	1.46	06:22	1.49	06:13	1.46
12:53	0.25	12:53	0.12	12:55	0.11	12:49	0.10	12:51	0.09	12:48	-0.03	12:45	-0.03
19:02	1.68	19:02	1.55	19:08	1.53	19:05	1.40	19:11	1.38	19:01	1.34	18:53	1.39
03/04/77													
01:04	0.23	01:04	0.10	01:07	0.11	01:00	0.08	01:03	0.09	00:54	0.04	00:56	0.01
07:15	1.84	07:15	1.71	07:19	1.67	07:18	1.54	07:22	1.51	07:04	1.52	07:03	1.52
13:31	0.17	13:31	0.04	13:24	0.03	13:27	0.03	13:20	0.02	13:22	-0.11	13:09	-0.12
19:45	1.80	19:45	1.67	19:49	1.64	19:48	1.51	19:52	1.48	19:42	1.48	19:39	1.44
04/04/77													
01:50	0.19	01:50	0.06	01:52	0.08	01:46	0.04	01:48	0.06	01:39	0.00	01:36	-0.01
07:57	1.83	07:57	1.70	07:58	1.70	08:00	1.53	08:01	1.53	07:47	1.51	07:50	1.55
14:08	0.12	14:08	-0.01	14:09	0.00	14:04	-0.02	14:05	-0.01	13:58	-0.14	14:01	-0.09
20:28	1.88	20:28	1.75	20:32	1.76	20:31	1.58	20:35	1.59	20:24	1.59	20:32	1.58
05/04/77													
02:37	0.19	02:37	0.06	02:35	0.09	02:34	0.04	02:31	0.07	02:26	0.01	02:16	0.00
08:39	1.77	08:39	1.64	08:41	1.67	08:42	1.48	08:44	1.51	08:30	1.46	08:37	1.43
14:46	0.11	14:46	-0.02	14:49	0.00	14:42	-0.03	14:45	-0.01	14:35	-0.12	14:32	-0.08
21:12	1.92	21:12	1.79	21:15	1.88	21:15	1.62	21:18	1.70	21:08	1.66	21:13	1.69

Appendix 1 Enhancement of Tidal Predictions

Enhancement of Tidal Predictions Appendix 3 Ratio and Constants Determination for Waddy Point

LWD for Waddy Point was established as being -0.81 m AHD from Bundaberg vs Waddy Point transfers using observed heights. (24 September 1983 to 16 October 1983 and 28 August 1983 to 2 September 1983).

Range Ratios and Constants where established for Transfers for period 21 March 1977 to 28 April 1977 as follows:

Bundaberg (LWD) Predictions	* 0.563	+ 0.07	= Waddy Point (LWD)
Caloundra (LWD) Actual	* 0.909	- 0.01	= Waddy Point (LWD)
Brisbane (LWD) Actual	* 0.683	+ 0.03	= Waddy Point (LWD)

Note: Waddy Point LWD established in 1983.

Average Time Differences:

Bundaberg (Pred)	HW Time	-0 hr 36 mins	= Waddy Pt HW Time
Bundaberg (Pred)	LW Time	-0 hr 54 mins	= Waddy Pt LW Time
Caloundra Hd (Obs)	HW Time	+0 hr 03 mins	= Waddy Pt HW Time
Caloundra HD (Obs)	LW Time	+0 hr 03 mins	= Waddy Pt LW Time
Brisbane Bar (Obs)	HW Time	-1 hr 25 mins	= Waddy Pt HW Time
Brisbane Bar (Obs)	LW Time	-1 hr 39 mins	= Waddy Pt LW Time

Tidal Planes Waddy Point

Datum Plane Waddy Pt (LWD)	Calculated from Constants	Transferred from Bundaberg	Transferred from Caloundra	Transferred from WIB
HAT	1.88	1.89	1.95	
MHWS	1.48	1.44	1.42	1.50
MHWN	0.17	1.14	1.14	1.24
ML	0.85	0.82	0.80	0.88
MLWN	0.52	0.51	0.46	0.50
MLWS	0.22	0.21	0.20	0.24
LAT	-0.02	-0.14	-0.01	