Tide Gauges

Contents

To comply with regulatory or other requirements, tide gauges on the national network (in particular those used as "standard ports" in the ANTT) must meet with certain standards for accuracy and reliability, as well as being subjected to regular maintenance schedules. This ensures the integrity of the database on which the tidal predictions are based.

Description

A standard tide gauge installation consists of the following.

1. A data recording (short term storage) device. All Australian primary ports (and virtually all secondary sites) now use a digital recording device.
2. At least one water level sensor.
3. A means of communicating the readings to users - a direct connection to the recorder, a broadcast, polled or on-demand interrogation device. Traditionally, a chart was posted to head office.
4. Some means of independently checking the height and time recorded (e.g. a tide staff, the operator to maintain a clock set to standard time.)
5. A station height datum above/below which heights are measured, recorded, and stored.
6. A TGBM (tide gauge benchmark) of known elevation relative to the station height datum.
7. Several recovery benchmarks in the event the TGBM is damaged.
8. A standard time zone for recording.
9. Performance specifications: station to comply with a given set of requirements, e.g. the GLOSS (Global Sea Level Observing System) requirements found in IOC Training Manual I Appendix 1, or the Queensland requirements, documented in MSQ specifications.
10. Documentation in accordance with levelling procedures outlined in Section 3 below.

Tide gauge at Hillarys, Western Australia. This is a "SEAFRAME" station, one of thirteen installed by NTC to monitor long-term sea level changes around Australia. The water level is measured by sending an acoustic pulse down a small pipe within the environmental tube.

Types of Water Level Sensors

The main types of water level sensors in use in standard ports in Australia are the float gauge and acoustic sensor. Also used, but less common are radar, pressure gauge, and bubbler systems. The IOC Training Volumes provide a very comprehensive source of information on tide gauge types (see links below). Bear in mind that there are substantial gaps in time between the three manuals, published in 1985, 1994, 2002 and 2006 so that the latest manual is far more up to date than the original.

The pros and cons of the main types are given in IOC Vol. III, Table 2.1.

Descriptions of float gauges are given in IOC Training Manual Vol. I Section 3.2, Vol. II Section 2.1, and Vol. III Section 2.3. The Queensland EPA website has a description of the float gauges used in their “storm tide” network, primarily used to detect storm surges.

The radar instrument is a freestanding, portable unit which sends a microwave pulse downward through free air and measures the return time.

Descriptions of pressure-type tide gauges (including bubbler systems) are given in SP9 1984, IOC Training Manual Vol. I Section 2.4 and Vol. III Section 2.2.

Descriptions of acoustic tide gauges are given in IOC Vol. II and IOC Vol. III.

These instruments measure return time, sending an acoustic pulse down a 13 mm (internal diameter) ABS sounding tube. The return travel time through the air between a transmitter/receiver and the water surface below is converted to sea level. A calibration hole, drilled into the tube at a set distance from the transmitter, causes a secondary reflection which is used to correct the sound velocity (which changes with temperature and other factors). Most acoustic instruments are very lightly damped in comparison to the 1:10 ratio of float gauges. For example, the acoustic instruments of the Australian Baseline are damped only 1:3. The mechanical damping is replaced by digital filtering of the return signals. A pulse is sent down the tube every second for three minutes. The arithmetic mean of the return times is then recorded. The standard deviation of the levels is also recorded, as it is used to eliminate outliers and can be related to the significant wave height (swh), both of which can be of significant advantage.

Manly Hydraulics Laboratory (MHL), in NSW, has successfully used an (Electromagnetic Tide and Wave Monitoring System) "EWS" since the early 1980s to collect tide and wave data at over 20 sites along the New South Wales coast. Data has been collected for both site-specific studies and ongoing tide and wave data collection programs. At present EWS capture tide data at ten sites and wave data at five sites in New South Wales. In addition, in recent years, MHL has commissioned twelve EWS at five Australian ports to collect real-time wave and tide data for input to Dynamic Underkeel Clearance Systems.

Recording Devices

Modern tide gauge installations automatically record the water level data. For a mechanical system such as a float device, the distance travelled by the float was, until recently, usually recorded directly on a chart recorder, but nowadays more commonly is converted to an electrical pulse for recording on a digital medium. Acoustic systems use a transducer to convert the acoustic wave to an electrical signal.

Chart recorder operating procedures

As chart recorders are nearly obsolete at Australian ports, we refer the reader, if necessary, to Vol. 1 of the IOC training manuals, and SP9 1984, which contains a check sheet for operational water level checks to the tide staff.

A chart recorder

Digital recorder operating procedures

Chart recorders are gradually being replaced by some form of shaft encoder coupled with a digital recording device. A pulley attached to the float (see diagram below) causes the encoder shaft to rotate in response to vertical motion of the float.

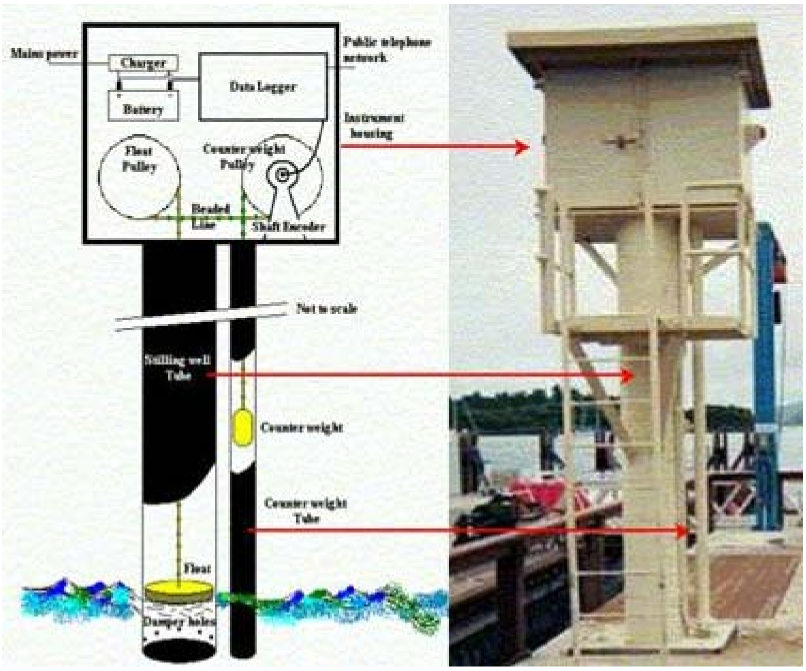

Diagram of tide gauge with shaft encoder and data logger, from the Queensland EPA website.

There are many types of shaft encoder, however they all convert the vertical displacement of the float to a digital or analog electrical signal. Some employ a quadrature device that picks up the motion of a rotating disk and sends out two digital pulses, out of phase by 90°. This requires a second device to interpret the edges of the pulses “increase or decrease of voltage” as either upwards or downwards motion. Another type uses a transducer to send out a 16 bit parallel code which again requires interpretation by an electrical sensor. Other types include potentiometers “voltage level output” and counters “these send out a “motion” pulse plus an “up/down” signal”.

An incremental shaft encoder.

The operating procedures for digital recording devices are outlined in SP9 1984, in which may be found a check sheet for operational water level checks to the tide staff.

Tide Gauge Specification

Precision, accuracy and resoloution

Accuracy and precision are frequently confused, despite having quite distinct technical definitions. A simple way to think of the difference is in terms of a target. Consider a cluster of five arrows shot into a small area above and to the right of the bulls-eye. The archer's accuracy would be measured by the distance from the bulls-eye to the centre of the cluster, while his or her precision would be measured by the tightness of the cluster. Precision is a measure of repeatability, or how closely repeated measurements of the same quantity agree with each other. Accuracy is a measure of reliability - how close are the measured values, as a whole, to the true or accepted value?

Resolution is usually defined as the smallest interval of change that can be measured by a particular instrument.

Requirements for accuracy and placement

Tide gauges used for standard port predictions in Australia have the same requirement for accuracy as tide gauges on the GLOSS network, i.e., one centimetre accuracy in all weather (see IOC Vol. III Section 1.3). Likewise, it is important that should an instrument be replaced, there should be a period of overlap in which the two operate in parallel to ensure accuracy and to pinpoint the mean level. The GLOSS implementation plan suggests that the period be one decade, but acknowledges that this will be impractical.

Many tide gauges, such as the SEAFRAME instruments operated as part of the Australian Baseline Array, are intended to monitor sea level trends over the least possible period of time. Compared to the port and storm surge gauges, these are subject to more rigorous requirements in accuracy and precision, as well as datum control.

Measurement System Defects

A discussion of the errors common to stilling wells and chart recorders is given in IOC Training Manual Vol. I (see Section 4.2), and a diagram of the amplitude attenuation as a function of wave height is shown in Figure 3.3 of the same volume.

A summary of possible systematic errors in the acoustic measurement system can be found in Section 2.1.1 of IOC Vol. III. The most serious problem commonly cited is with temperature gradients along the flight path of the acoustic pulse, as can happen, for example, when the sun shines only on the part of the “environmental tube” which encloses the inner sounding tube. Such errors can be quite substantial. These can be avoided to a large extent by providing even solar exposure of the environmental tube to the direct rays of the sun.

Section 2.2 of IOC Vol. III discusses possible sources of systematic errors in pressure gauges. One of these is barometric pressure, which can be avoided either by simultaneous air pressure monitoring, or by using a gauge vented to the atmosphere. With pressure gauges in deep water, changes in water temperature or salinity may need to be considered. Another problem discussed on Section 2.2 is that of datum control with pressure gauges, particularly in light of the general tendency of the transducers to drift. A means of overcoming this is given, by use of a second pressure gauge at approximate mean sea level.

Calibration

From the 1984 Special Publication 9 on tide gauges:

Many tide records show unexplained jumps in datum, bad overlaps on charts, time errors, and other discrepancies which have no connection with the tidal movement which the gauge is required to *monitor.*

The fact that a gauge is in error is not necessarily a reflection on the attention of the operator. No gauge is perfect or trouble-free and errors are to be expected from time to time. Our main concern is that the user of the records should be able to see at once whether any correction to the records is necessary.

Perhaps the main requirement to enable the tide gauge records to be correctly processed is the availability of independent checks. From these checks the performance of the gauge can be assessed and any necessary corrections made before putting the records into the national data base. It is therefore most essential that accurate and true comparisons be made between the gauge time and a standard clock and also between the recorded height and the height as read from the tide staff.

The preceding words from SP9 1984 are still true, except that the independent checks now often take the form of a second instrument, either temporarily or permanently installed alongside the primary gauge.

Calibrating an Aquatrak sensor in a calibration rig.

A description of stilling well test calibration and maintenance may be found in IOC Training Manual Vol. 1 Section 3. A description of the Van de Casteele test may also be found in the IOC Training Manual Vol. I Section 3.2. These checks should be carried out yearly or more often if biological fouling of the sensors is a problem, and always after a change of any of the components of the system.

Biological fouling is a real problem, especially in nearshore tropical waters. The picture shows a side view of the circular copper plates normally bolted to the bottom of the acoustic sensor, and the brass damping cone that sits just above them inside the environmental tube. The tide gauge is located in Kiribati, and shows the accumulation of about five years' growth. Photo credit: Allan Suskin.

There must be frequent independent water level checks, with time and height recorded.

The tide staff and TGBM, and its supporting marks must be re-surveyed at least yearly and at any change to the board.

Precise datum control for pressure gauges is outlined in IOC Vol. II