

number of switchings and it is usually necessary to protect the switch within its own small stilling enclosure. Careful design of this enclosure should minimise any errors introduced, particularly if use is only made of sea level crossings in calm conditions giving rise to only single switchings. An acoustic type of switch has been found to be robust, reliable and to have small hysteresis (e.g. Bestobell Mobrey, [Appendix 1](#)).

2.3 ACOUSTIC TIDE GAUGES

A number of acoustic tide gauges have been developed which depend on measuring the travel time of acoustic pulses reflected vertically from the air/sea interface. This type of measurement can be made in the open with the acoustic transducer mounted vertically above the sea surface, but in certain conditions the reflected signals may be lost. To ensure continuous, reliable operation the acoustic pulses are generally contained within a vertical tube or well which can provide some degree of surface stilling. Averaging of a number of measurements will also have a stilling effect and give improved accuracy.

To accurately convert the time of travel of the acoustic pulses to sea level requires a knowledge of the velocity of sound between the acoustic transducer and the sea surface. The velocity of sound can vary significantly with changes in temperature and humidity (about 0.17%/°C) and some form of compensation is necessary for accurate sea level measurements. The simplest method is to continuously measure the air temperature at a point in the air column and use this to calculate the sound velocity to be used. To account for temperature gradients in the air column temperature sensors may be required at a number of different levels.

A more accurate method of compensation is by use of an acoustic reflector at a fixed level in the air column. By relating the reflection from the sea surface to that from the fixed reflector, direct compensation for variations in sound velocity between the acoustic transducer and the fixed reflector can be achieved. However this still does not account for any variations in sound velocity between the fixed reflector and the sea surface. To achieve full compensation would require a number of fixed reflectors covering the full tidal range.

2.3.1 ACOUSTIC GAUGES WITH SOUNDING TUBES

The National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS) - (USA), has been involved in a multi-year implementation of a Next Generation Water Level Measurement System (NGWLMS) within the US national tide gauge network and at selected global sites. At the present time (October 1992), 110 of the 189 stations of the national network have these new systems, as do 22 NOAA Global Sea Level sites around the world (Gill et al., 1992). The new systems are being operated alongside the present analogue-to-digital (ADR) gauges at all stations for a minimum period of one year to provide datum ties to and data continuity with the historical time series. Dual systems will be maintained at a few stations for several years to provide long term comparison information. The same technology gauges have also been deployed in several other countries (e.g. Australia, see Lennon et al., 1992).

The NGWLMS tide gauge uses an Aquatrak water level sensor (Dartex Inc.) with a Sutron data processing and transmission system. The Aquatrak sensor sends a shock wave of

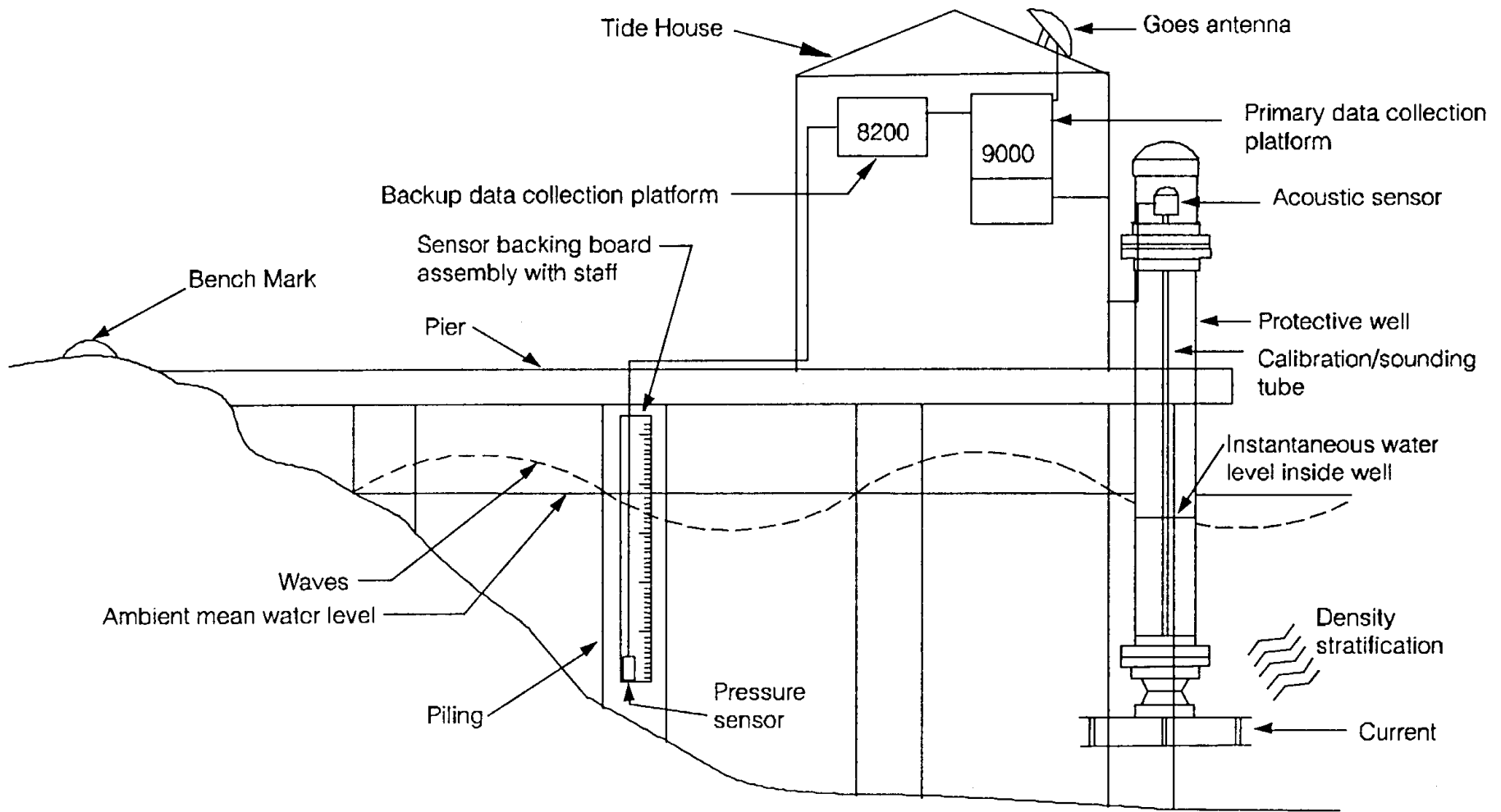


Figure 2.1

Next Generation Water Level measurement System

acoustic energy down a 1/2-inch diameter PVC sounding tube and measures the travel time for the reflected signals from a calibration reference point and from the water surface. Two temperature sensors give an indication of temperature gradients down the tube. The calibration reference allows the controller to adjust the measurements for variations in sound velocity due to changes in temperature and humidity. The sensor controller performs the necessary calculations to determine the distance to the water surface. The sounding tube is mounted inside a 6-inch diameter PVC protective well which has a symmetrical 2-inch diameter double cone orifice. The protective well is more open to the local dynamics than the traditional stilling well and does not filter much of the wind waves and chop. In areas of high velocity tidal currents and high energy sea swell and waves, parallel plates are mounted below the orifice to reduce the pull down effects (Shih and Baer, 1991). **Figure 2.1** is a schematic of a typical NGWLMS installation. To obtain the best accuracy the acoustic sensor is calibrated by reference to a stainless steel tube of certified length, and the zero offset is determined.

The NGWLMS also has the capability of handling up to 11 different ancillary oceanographic and meteorological sensors. The field units are programmed to take measurements at 6-minute intervals with each measurement consisting of 181 one-second interval water level samples centred on each tenth of an hour. Software rejects outliers etc. and measurements have typically 0.01 foot resolution. Data are transmitted via telephone or satellite connections.

Papers by Gill and Mero (1990a, 1990b) and Gill et al. (1992) describe the acoustic sensor calibration methods and temperature gradient induced errors, while Gill et al. (1992), Lennon et al. (1992) and Vassie et al. (1992) present comparisons between NGWLMS and conventional (stilling well or bubbler) systems in the USA, Australia and the UK. For example, US comparisons (Gill et al., 1992) between NGWLMS and ADR data have shown small differences, on the order of millimetres, for the various tidal and datum parameters, which are generally within the uncertainty of the instrumentation. Such differences are very small when compared to typical tidal ranges and even seasonal and interannual sea level variations. The differences in mean sea level from the two systems are being looked at more closely in order to ensure no long term bias. Much work remains to be done on the long term intercomparisons between technologies.

2.3.2 ACOUSTIC GAUGES WITHOUT SOUNDING TUBES

An instrument manufactured by MORS Environment uses a 41.5 KHz transducer with a beam width of 5° which can be operated in an existing stilling well or in the open. A temperature sensor in the air column is used to compensate for variations in the velocity of sound, and the measurement range is between 0.6 and 15 metres.

A similar instrument by Sonar Research and Development has been developed which operates at 50 KHz with a beamwidth of 4°. It can be operated in the open or in a plastic tube of about 25cm diameter. Compensation for variation in the velocity of sound is achieved by use of a bar reflector mounted 75cm from the acoustic transducer. An accuracy of 0.05% is claimed over a range of 15 metres.

For both these systems, datum control needs to be verified externally e.g. by long periodic tide pole checks.