Notes about the Port Taranaki Annual Mean Sea Level Data

Last updated 18 November 2022

1. **Tide Gauge History.** This information has been obtained from archived correspondence files held by Toitū Te Whenua Land Information New Zealand (LINZ). These files, first created by the Department of Lands & Survey (Lands & Survey, dis-established in 1987) were maintained by the Department of Survey and Land Information (dis-established in 1996).

Figure 1. Diagram of Port Taranaki

(a) A tide gauge operated at Moturoa Wharf from 1917 until about 1922. Sea level data was collected for the years 1918 – 1921. Lands & Survey used all four years of data to calculate a reference value for MSL.

(b) An unreliable Foxboro gauge was installed on Newton King Wharf in 1955 and was in operation from December 1955 - June 1966 when it was replaced with a new Evershed & Vignoles (E&V) gauge. The new gauge commenced operation on 17 April 1966.

(c) Prior to 1966 another gauge may have operated on the Newton King Wharf with the files making reference to a standard (float) gauge also producing data. The readings from this standard gauge were 1.5 ft lower than those from the new automatic gauge.

(d) About 1978 the harbour board moved the automatic tide gauge back to Moturoa Wharf. Two new standard gauges (tide poles) were installed at that time with care being taken to ensure that continuity of datum was maintained.

(e) In early 1984 a new automatic tide gauge (a piezoresistive bridge type gauge) was installed at Newton King Wharf. Levelling was undertaken to ensure continuity of datum between local bench marks (BMs), the old Moturoa Wharf gauge, the new gauge, and the standard gauge.

(f) The Newton King Wharf gauge was repositioned on 8 June 2021, at which time gauge zero was returned to chart datum to offset the 12mm subsidence caused by the 2016 Kaikōura earthquake.

2. **Data History**. Where available, historic data has been collected as hourly point values. From 1955 – 1984 these were obtained by digitising (or reading) the hard copy tide gauge charts. In more detail:

(a) The earliest records (1918 – 1921) were never found – the only information available being a single MSL calculated by Lands & Survey for the four years. There is a high level of confidence in the accuracy of this value.

(b) The data from 2 December 1955 – 26 April 1966 were on circular paper charts, 280 mm in diameter. Each chart contained at least one week of data although some charts had been used for two consecutive weeks. The hourly data values were painstakingly extracted by manual measurement. Reliance has been placed on comments made in the old correspondence files combined with notes written on the tide charts. It is clear that the gauge zero was subject to a number of changes. As a best guess, the following corrections have been made to the raw digitised data:

- 1.0 ft has been subtracted from the December 1955 data. The gauge appears then to have been out of operation until October 1956.
- All data from 3 October 1956 – 10 December 1956 were corrected by (-1.0 + 0.21) ft in accordance with the results from a tide gauge calibration performed on 10 December 1956.
- 1.0 ft was subtracted from all the data from 10 December 1956 to 7 March 1957. Following this the gauge then appears to have been out of operation until May 1957.
- All data from May 1957 – August 1965 has been corrected by -2.0 ft. While this is consistent with notes found on tide charts and with the correspondence record, there were almost three months of data over this period that were quite anomalous and for which datum problems could not be resolved. These data were discarded. Additionally, within this period (from 17 February 1963 – 22 March 1963), an additional, spurious datum shift of +1.0 ft appears to have been introduced.
- Following a two month break in the record, the raw data from October 1965 to 5 January 1966 has been corrected by -1.5 ft on the basis of the difference between the zero of the Foxboro gauge and the new E&V gauge. The correspondence file indicates that this problem was rectified in early January 1966.

(c) The data from 17 April 1966 – 11 April 1983 were on long roll paper charts, each roll covering a period of approximately 2 months. With the 1966 installation of the new E&V gauge, the datum for the raw sea level data became far more stable. Six different types of roll chart were used. Each of these chart types had different vertical graduations. Some were used for two consecutive two-month periods by overprinting one tidal record upon another. In addition, and shortly after New Zealand adopted a metric measurement system in 1972, the charts changed from imperial measurement (feet) to metric measurement (metres).

(d) From May 1984 (corresponding to the installation of a new automatic gauge) all data are available as hourly point values.

3. **Datum History**

(a) Various levelings performed in 1966, 1969, 1970, 1979 and then more regularly after 1982 show no evidence of any vertical movement at any of the BMs established in the vicinity of the gauge, nor on any of the wharf structures. Thus, while not absolutely conclusive, all evidence supports the hypothesis that there has been no significant vertical movement to any of the wharf structures to which the various tide gauges have been attached.

(b) The tide gauge used to produce the 1918-1921 data was positioned such that MSL, as determined from the 1918 data alone, was a defined height (12.44 ft) below a specified local BM. The zero of the gauge was 0.24 ft (0.073m) below the post-1973 datum.

(c) When tide gauge operations recommenced late 1955, the zero of the Foxboro gauge was set 1.65 ft (0.503m) lower than the previous gauge.

(d) The tide gauge zero, as established for the 1966 E&V gauge, was raised 2 ft above that of the Foxboro gauge until 1 January 1973 when zero was lowered by 0.11 ft (0.034m) where it has remained.

(e) All data prior to 1 January 1973 has been corrected such that it refers to the post-1973 datum, being 16.185 metres below New Plymouth Fundamental No. 3 B.M. (LINZ code EE9M).

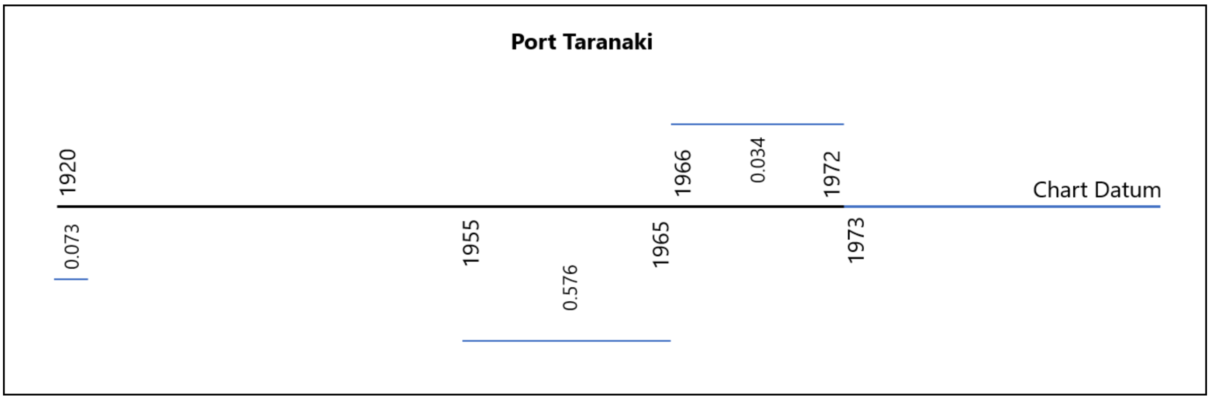
4. All data has been quality assured, as best as possible, using the University of Hawaii sea level processing software (Caldwell, 1998)

5. The daily raw data (as recorded by the tide gauge) has been corrected for the regional tectonic movement caused by the 2016 Kaikōura earthquake. Between 00:00 hours on 14 November 2016 and 8 June 2021, 12 mm has been deducted from the recorded data. The daily data files during this period were thus already free of this datum inconsistency, as are the monthly and annual means. Since the gauge reset that took place on 8 June 2021, the 12mm adjustment has no longer been necessary.

6. Each annual MSL value has been assigned a standard deviation as described in the accompanying notes regarding current international data standards.

7. Corrections applied to original data (refer also to the following diagram):

1920	-0.073 metres
1955 – 1965	-0.576
1966 – 1972	+0.034
1973 –	0.000



Offsets (decimal numbers in metres) between gauge zero (blue lines) and chart datum as defined since 1973

Reference

Caldwell, P., (1998). Sea level data processing on IBM-PC compatible computers, Version 3.0. JMAR Contribution No. 98-319, University of Hawaii at Monoa, School of Ocean and Earth Science Technology, Honolulu, Hawaii. (2014: Updated to v4.0 – SLP64, available from http://ilikai.soest.hawaii.edu/UHSLC/jasl/slp64/slp64.html).

Current International Data Standards

J. Hannah, April 2022

The current international standards for data sets associated with climate change/sea level studies are not fully consistent – particularly in their completeness of data criteria. The WMO standard for surface meteorological observations (WMO, 2017) assume that daily mean values for sea level pressure are calculated from either eight evenly spaced 3-hourly observations or six evenly spaced 4-hourly observation. It is accepted that the calculation of daily mean temperatures may differ, dependent upon country. However, they do recommend that where a monthly value is the mean of that month's daily values, it should not be calculated if either of the following criteria are satisfied:
– Observations are missing for 11 or more days during the month;
– Observations are missing for a period of 5 or more consecutive days during the month.

Standards governing sea level data are different. Daily MSLs are calculated from hourly means by passing them through a filter such as the 39-hour Doodson filter, a 71-hour Demerliac filter, or some other appropriate filter. This filter removes the tidal energy at diurnal and higher frequencies (UNESCO/IOC, 2020). The resulting data are then quality assured against a predicted tide.

A simple arithmetic monthly mean is calculated from the daily means. The PSMSL recommends discarding the month if over 15 days are missing. Some software, however, such as the University of Hawaii software (Caldwell, 1998), will only calculate a monthly mean automatically if seven or fewer days of data are missing. The PSMSL calculates annual means as a weighted mean of the monthly values, with each month weighted by the number of days present. If over one month is missing, the annual mean is not calculated.

Much of the early work on the New Zealand data sets was undertaken prior to the development of the above international data standards. Fortuitously, the processes used largely meet the PSMSL standard. The fact that the hourly data has been filtered using the University of Hawaii software generally results in a monthly mean being calculated when only seven or fewer daily means are missing.

The one major point of difference in the existing datasets with respect to the PSMSL standards, relates to the annual MSLs. Wherever at least one month of data is available a MSL is recorded. However, it has been assigned a standard deviation derived as follows:

a) Where the data record is based upon very reliable and well-maintained tide gauges with few outages, the associated standard deviation is calculated from the equation:

$$\sigma_{MSL} = \frac{0.09\,m}{\sqrt{n}} \qquad \text{where n = number of months of data.}$$

In other words, an annual mean with one month of good, consistent data will have a standard deviation of 0.09 metres, whilst an annual mean with 12 months of data will have a standard deviation of 0.025 m. The standard deviations have all been rounded down to the nearest 0.005 m. This weighting system was determined by a posteriori variance analysis and is documented in Hannah (2004).

b) Where the tide gauge has a poor maintenance history or over periods when the data record seems less reliable, the 0.09 m in the above equation is replaced by 0.11 m. Conversely, when the digitised record has shown good consistency, even if the overall gauge maintenance has not been good, the 0.011 m has been replaced by 0.09 m.

c) Due to its derivation process, a MSL derived from a Mean Tide Level is considered even less reliable again.

This weighting procedure was chosen so that all the annual MSL data could be used in a weighted least squares estimation process from which the linear sea level trends could be calculated. Standard deviations for each annual MSL are shown in the data files.

References

Caldwell, P., (1998). Sea level data processing on IBM-PC compatible computers, Version 3.0. JMAR Contribution No. 98-319, University of Hawaii at Monoa, School of Ocean and Earth Science Technology, Honolulu, Hawaii. (2014: Updated to v4.0 – SLP64, available from http://ilikai.soest.hawaii.edu/UHSLC/jasl/slp64/slp64.html).

Hannah, J., (2004). An Updated Analysis of Long-Term Sea Level Change in New Zealand. Geophysical Research Letters, 31, L03307, 4 pp.

UNESCO/IOC, (2020). Quality Control of in-situ Sea Level Observations: A Review and Progress towards Automated Quality Control, Vol. 1. Paris. UNESCO. IOC Manuals and Guides No. 83. (IOC/2020/MG/83 Vol. 1)

WMO, (2017). WMO Guidelines for the Calculation of Climate Normals. WMO-No. 1203, available from https://library.wmo.int/doc_num.php?explnum_id=4166.