# Calibration

Before the wave loggers can be used for measuring the wave heights, the wave loggers need to be calibrated. The output of the wave loggers is a pressure in voltage. The relation between pressure and the water depth is linear and needs to be found during the calibration.

## Method

To calibrate the loggers, we needed a controlled experiment where the water depth, and therefore the output, was human-controlled. Another requirement was that enough data had to be retrieved, to make the experiment valid and accurate. To control the water pressure recorded by the sensor, we choose for a fixed water depth, but a variable position of the device.

For the calibration, the wave logger was set up to record for a short time interval. The sample interval is set to 15 minutes and the burst to 5 minutes, which means that the logger starts recording for 5 minutes at every quarter of an hour. For this to work, the clock of the device is set to the local time. Before doing the calibration it is important to make sure that the wave logger is measuring and the data is saved on the SD card. The logger records with a frequency of 5 Hz, or an interval of 0.2 seconds.



Figure 1: Device with taped rope and ballast

To lower the device, we taped a rope to the non-sensor side of the device. The rope is taped at every 50 cm and the device is sunk due to a ballast. The device is lowered every 30 seconds during one burst of 5 minutes. This time interval is chosen so that we can retrieve a maximum of 10 different water levels, or a maximum water depth of 5 meters. We choose to do the experiment inside the marina at a very calm spot with sufficient depth. This had mainly two reasons: first of all, the depth at the pool was not sufficient and secondly the salinity of the pool differs from the marina, where the loggers will be deployed eventually. The salinity influences the density of the water, which in turn influences the total water pressure. At the day of the experiment the weather was very calm and there were very little waves visible. These are good circumstances: the results are very little influenced by the waves, because of the water level being constant in time. Also the wave induced pressure is therefore neglectable.

The output of the wave logger is a .txt file with the voltage per measurement linked to the time. The data is copied to an excel file. The data is linked to the water pressure using Excel. Taking the mean of the data per water depth (0, 50, 100, 150, 200, 250 cm) the average voltage per depth was determined. Because of the linear relation between depth and voltage the two coefficients for the transformation formula are derived. Using linear formula y=Ax+b, the coefficients for the wave loggers are found.

### TU Delft Loggers

Figure 2: Output of the calibration of TU Wave logger 3

Figure 3: Output of the calibration of TU Wave logger 2

A2=3,8964  
B2=499,00  
A3=3,0567  
B3=-368,17

Giving the following formulas:

d2=3,8964 P2-499,00

d3=3,0567 P3-368,17

Where d is the water depth in cm and P is the pressure in Voltage.

Figure 4: Calibration of TU Wave logger 3

Figure 5: Calibration of TU Wave logger 2

After the calibration along the coast the calibration is checked in the swimming pool. The wave logger is placed on the bottom of the swimming pool at a water depth of 160 cm. The difference of water density between the pool and the sea is taken into account. The coefficients from the tests at the sea are used to determine the water depth in the swimming pool. The measured water depth is compared with the real water depth. A difference of approximately 20 cm between the results from the sea and the pool is found and can be explained by the orientation of the device and the angle between the rope and the device. In the pool the device is situated on the bottom and during the tests in the sea the device was hanging on the rope. This gives a constant height difference of the device of approximately 20 cm. The coefficient B is corrected for this constant error by adding 20 cm to this coefficient.

### Boyans Loggers

After being deployed, the last day the second pair of loggers was calibrated. The same method as above was used, except that due to technical problems the burst rate and time interval were unable to be adapted to the correct settings. Which led to empty data files.

After departure, Boyan used a similar method to retrieve yet the following figures with calibration formulas.

Figure 6: Output of the calibration of Boyans Wave logger 1

Figure 7: Calibration of Boyans Wave logger 1

Figure 8: Output of calibration of Boyans Wave logger 2

Figure : Calibration of Boyans Wave logger 1

# Accuracy

To know how valuable the recorded data is, one must check its accuracy. The inaccuracy of the calibration consists of three parts.

## Sensitivity

The loggers all measure in integer volts, which means that its accuracy is a maximum of 1 volt. Which can be converted to a change in water depth of:

Logger 3 = 3.1cm

Logger 2 = 3.9cm

Boyan 1 = 2.6cm

Boyan 2 = 2.8cm

## Sensor error

Looking at the data file up close, we notice a constant fluctuation around its mean level. This is due to the sensors not measuring accurate. This fluctuation is also visible in the output signal when the logger was on land. Which indicates that the fluctuation is nog caused by a very fast changing water pressure. To determine accuracy, we use the standard deviation:

Logger 3 = 3.5cm

Logger 2 = 4.5cm

Boyan 1 = 5.9cm

Boyan 2 = 6.0cm

## Human error

The experiment contained some areas of uncertainty in relation to accuracy because of human error. First of all, we assumed the wave induced pressure to be neglectable, but there was a change of hydrostatic pressure due to small waves. The waves were approximately 4-5cm. The other factors of uncertainty include the connection with the rope, the logger being lowered by hand and the length indications with tape on the rope. These factors are the reason why the device is calibrated with multiple points. The value of *R*2 is influenced by amount of human errors. Looking at the values of *R*2 it can be concluded that TU Delft logger 3 has more human errors in its calibration than the other three loggers. Overall the values for *R*2 are:

Logger 3 = 0.9719

Logger 2 = 0.9992

Boyan 1 = 0.9991

Boyan 2 = 0.9929

## Total inaccuracy

For our design, the loggers are used to determine significant wave height. These significant wave heights are of such order that the deviation due to the inaccuracy of the calibration is acceptable. But, one should note that due to the difference in accuracy, comparing results between different loggers may contain small differences, which are due to inaccuracy and not due to difference in wave conditions. Also looking at all the factors above, it can be concluded that the loggers are not capable of measuring extreme low waves (<5cm).