Nanumaga Wave-Driven Inundation Assessment, Tuvalu: Physical Modelling Report

WRL TR 2021/19, August 2021

Contents

Acronyms and abbreviations

BTB	Berm Top Barrier
MSLA	Mean Sea Level Anomaly
SPC	The Pacific Community
TCAP	Tuvalu Coastal Adaptation Project
UNDP	United Nations Development Programme
WRL	Water Research Laboratory

Figure 1.2: Nanumaga Island, Tuvalu

The investigation site is located on the western side of the reef island of Nanumaga as shown in

2 Model arrangement, design and operation

2.1 Modelling objeb5( )-7(ob)4(je)-7(b5( )m)h3s2 0 r5[des)-t

Figure 2.4: Model roughness elements on reef platform (top) and upper fore-reef

2.4 Measurements and analysis

2.4.1 Wave and water level measurements

Wave conditions and water levels were measured continuously throughout all tests at several locations within the flume, namely just offshore of the reef and at six other individual locations across the reef profile. Measurements were collected using high-accuracy capacitance wave gauges sampled at a frequency of 5 Hz (real world scale). Figure 2.5 shows the layout of wave gauges within the flume. The offshore wave conditions measured at the -25 m MSL location were collected using an array of three carefully spaced wave gauges, which enabled separation of incident and reflected wave time series using the least squares method of Mansard and Funke (1980). This was particularly important during the wave climate calibration process, to ensure that the incident wave climate matched the target wave climate for each test condition, without the interference of wave reflections.

Wave data recorded at each location was analysed using both spectral and zero crossing analysis, to

2.4.2 Runup/Overtopping measurements

Runup levels were measured continuously throughout all tests using a 2D LiDAR mounted over the beach, as well as through visual analysis using an overhead camera. While the intention was to process the runup data to determine the 2% runup level, extreme wave runups exceeded the crest of the beach berm in all tests. Wave overtopping of the beach berm crest was also measured for all tests, and this parameter was used instead as the measure of inundation intensity. Figure 2.6 shows the arrangement of instrumentation for measuring runup/overtopping in the wave flume.

Average wave overtopping rates, Q_{ave} (L/s/m) were measured by recording the total volume of water to overtop the beach berm crest during a full test, then dividing this by the test duration and normalising it to the beach berm crest length of the model. Peak wave overtopping volumes, V_{max} (L/m) were also estimated by measuring the volume of water to overtop the beach berm crest during individual large wave overtopping occurrences. Both Q_{ave} and V_{max} are widely used within coastal engineering literature as a measure of wave overtopping intensity and hazard. Measured values from the Nanumaga physical model tests are discussed relative to guideline values from literature in Section 4.5 of the report.

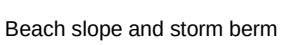

Figure 2.6: Layout of wave runup/overtopping instrumentation

Table 3.2 Target test conditions

Test Condition	H_s (offshore) (m)	H_s (@-25 m MSL)[1] (m)	T_p (s)	Water Level[2] (m MSL)
TC Pam Peak	5.3	5.1	15.6	0.39
100 Year ARI	5.5	5.2	14.3	0.67
250 Year ARI	6.0	5.7	14.8	0.65
250 Year ARI (2050)[3]	6.0	5.7	14.8	0.97
250 Year ARI (2100)[3]	6.0	5.7	14.8	1.49

1. Value determined by wave transformation calculation using SBEACH
2. Water level includes tide plus mean sea level anomaly (tide + MSLA)
3. Values for RCP8.5 adopted from SPC (2021)

All five test scenarios were calibrated in the wave flume prior to beginning the finning th68q0.000008871 0 595.32 842.0

Figure 4.1: Variation in H_s across reef profile for Stage 1 testing

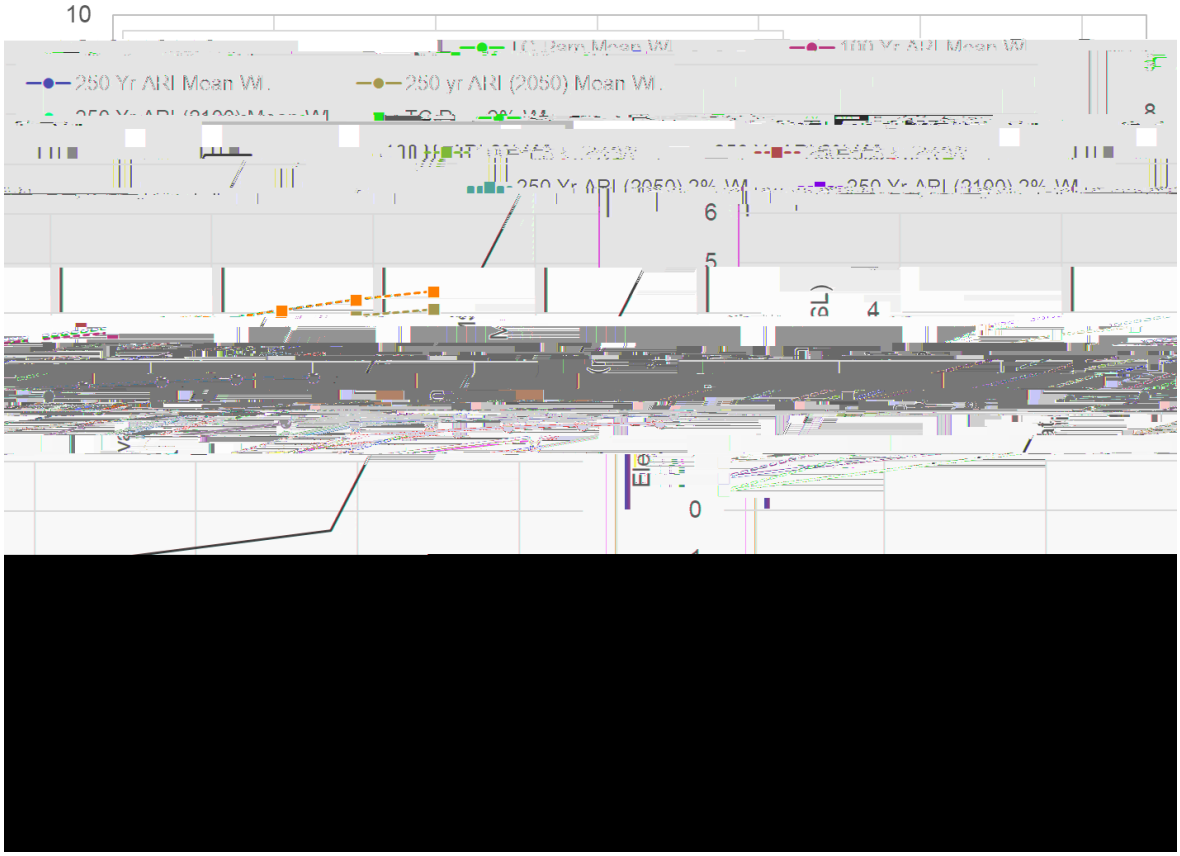

Figure 4.2: Variation in water levels across reef profile for Stage 1 testing

Figure 4.3: Wave breaking on fore-reef slope and dissipating across reef platform

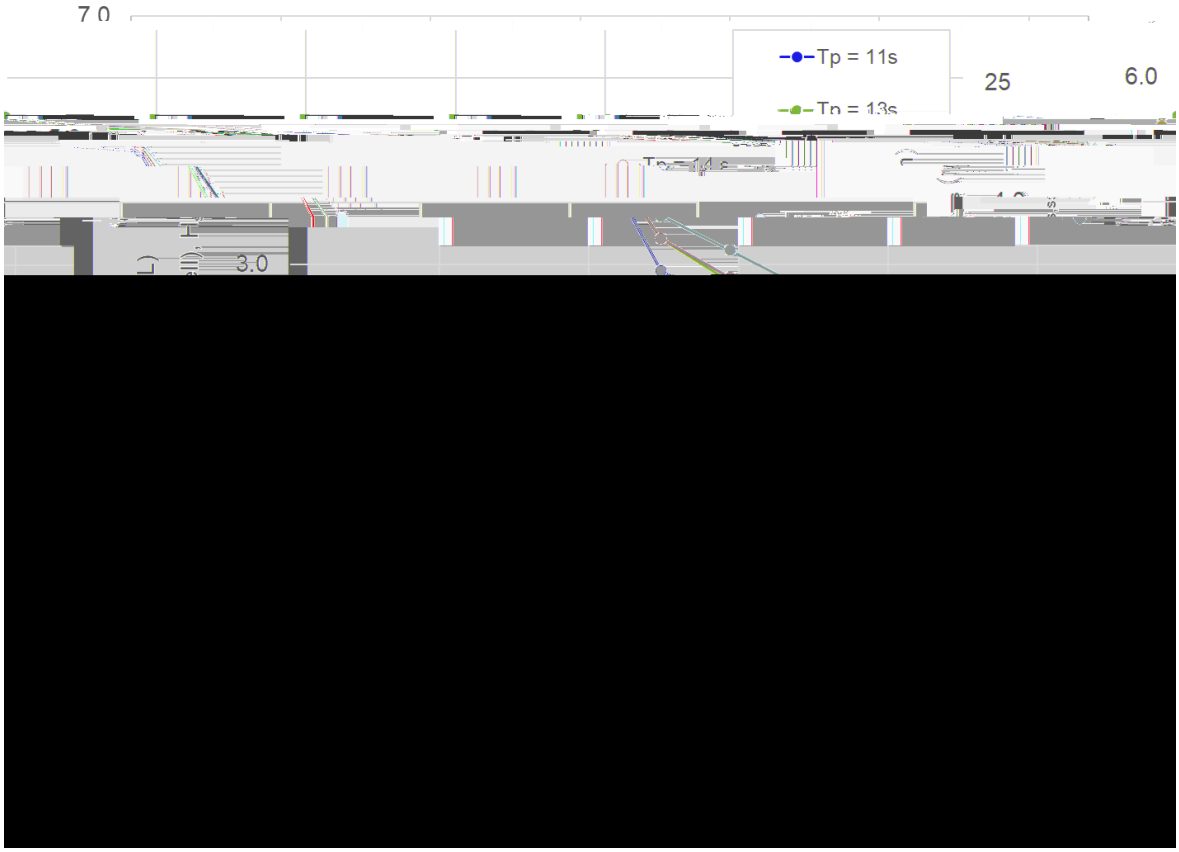

Figure 4.5: Influence of wave period on reef-top wave heights

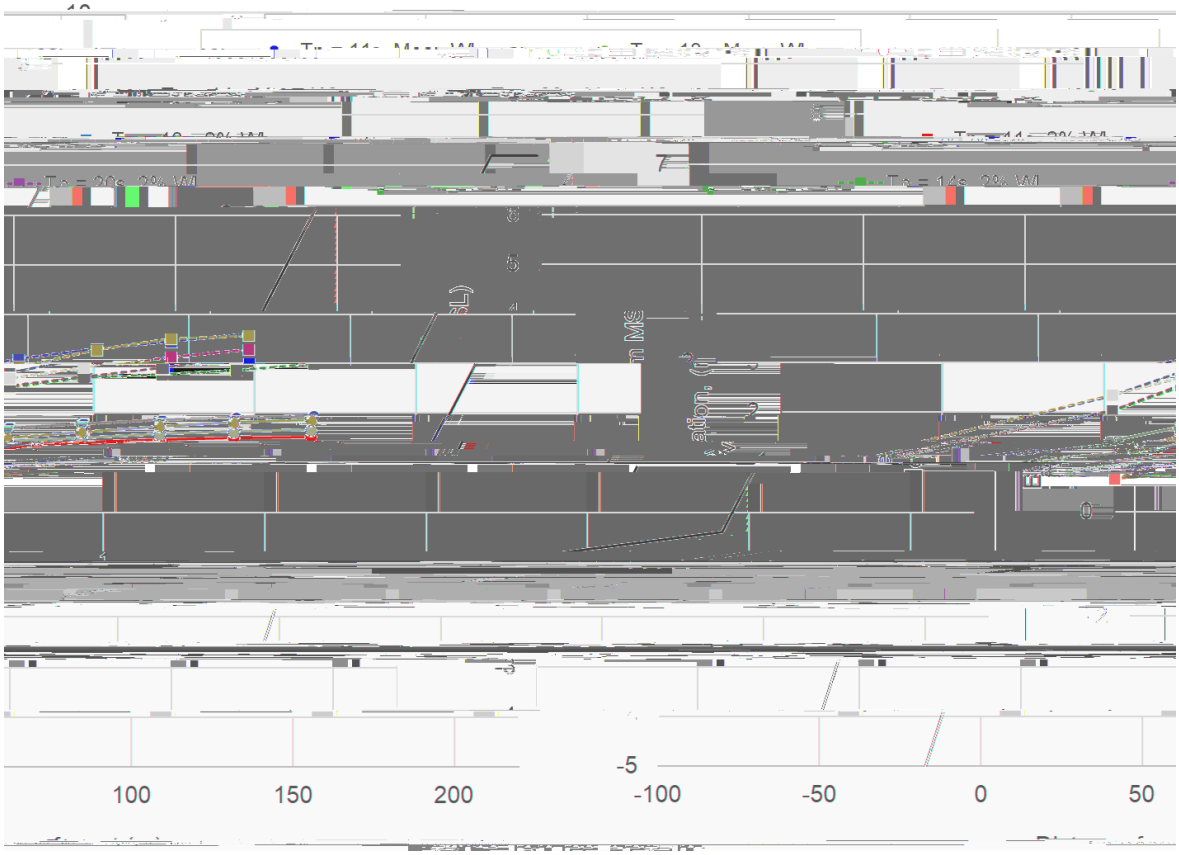

Figure 4.6: Influence of wave period on reef-top water levels

For each of the four wave period sensitivity tests, the wave height measured nearest the shoreline was found to increase with increasing wave period (Figure 4

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Table 4.4 Measured water levels, Infragravity waves and overtopping for Stage

Figure 4.12: Variation in H_s across reef profile for Stage 3 testing

4.4 Stage 4: Testing with BTB installed

Stage

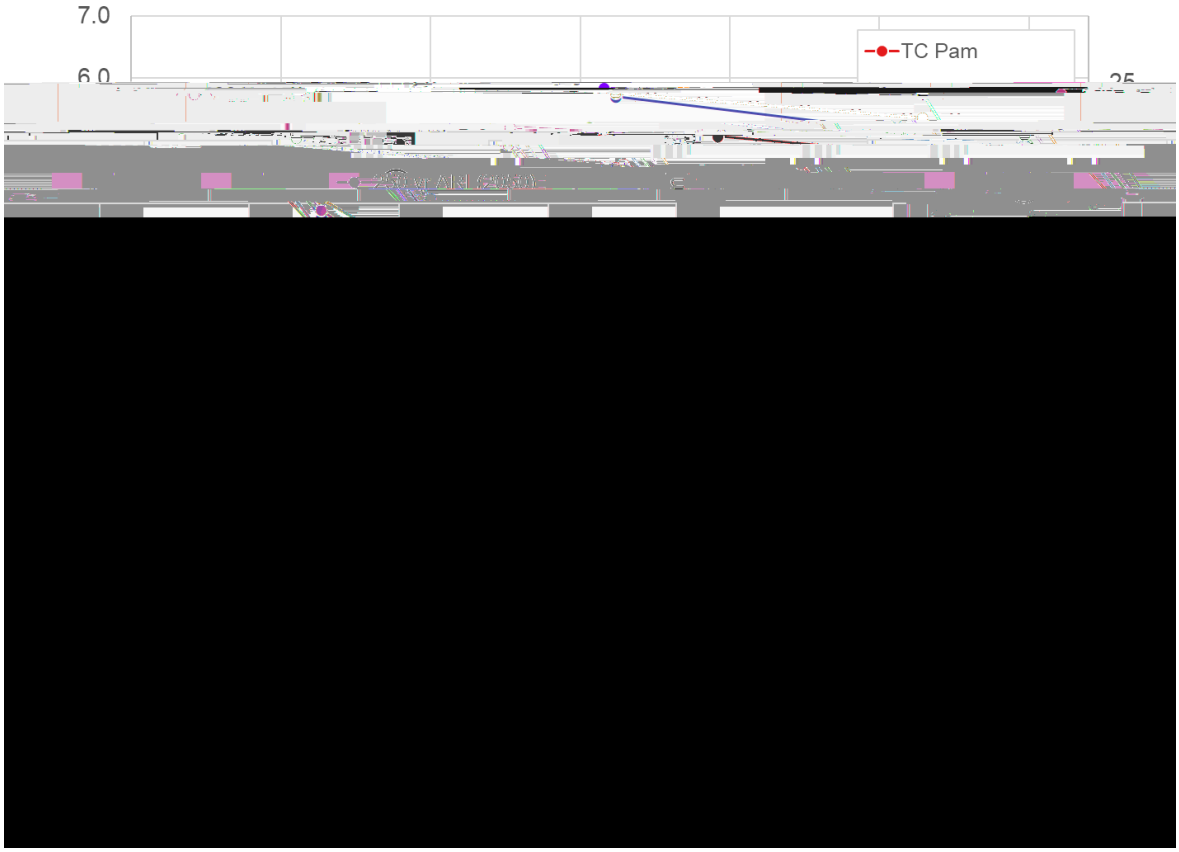

Figure 4.17: Variation in H_s across reef profile for Stage 4 testing

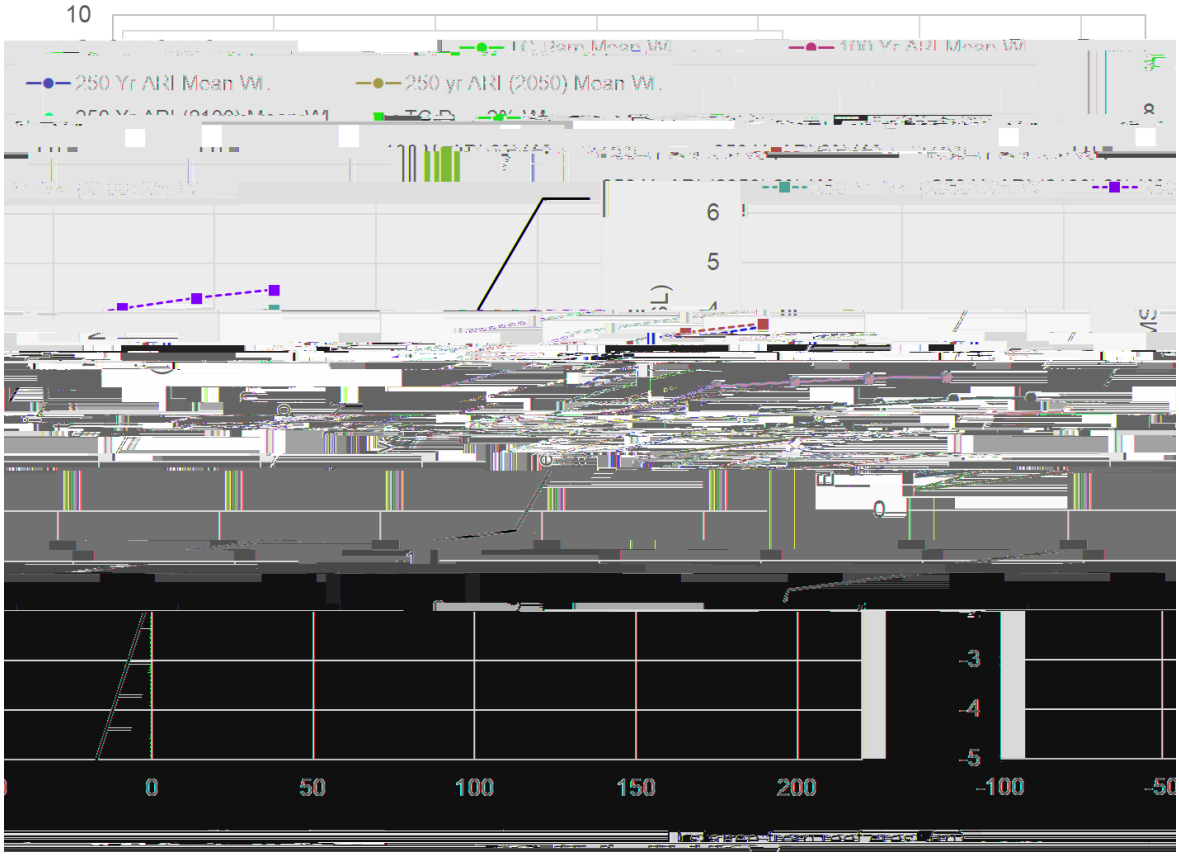

Figure 4.18: Variation in water level across reef profile for Stage 4 testing

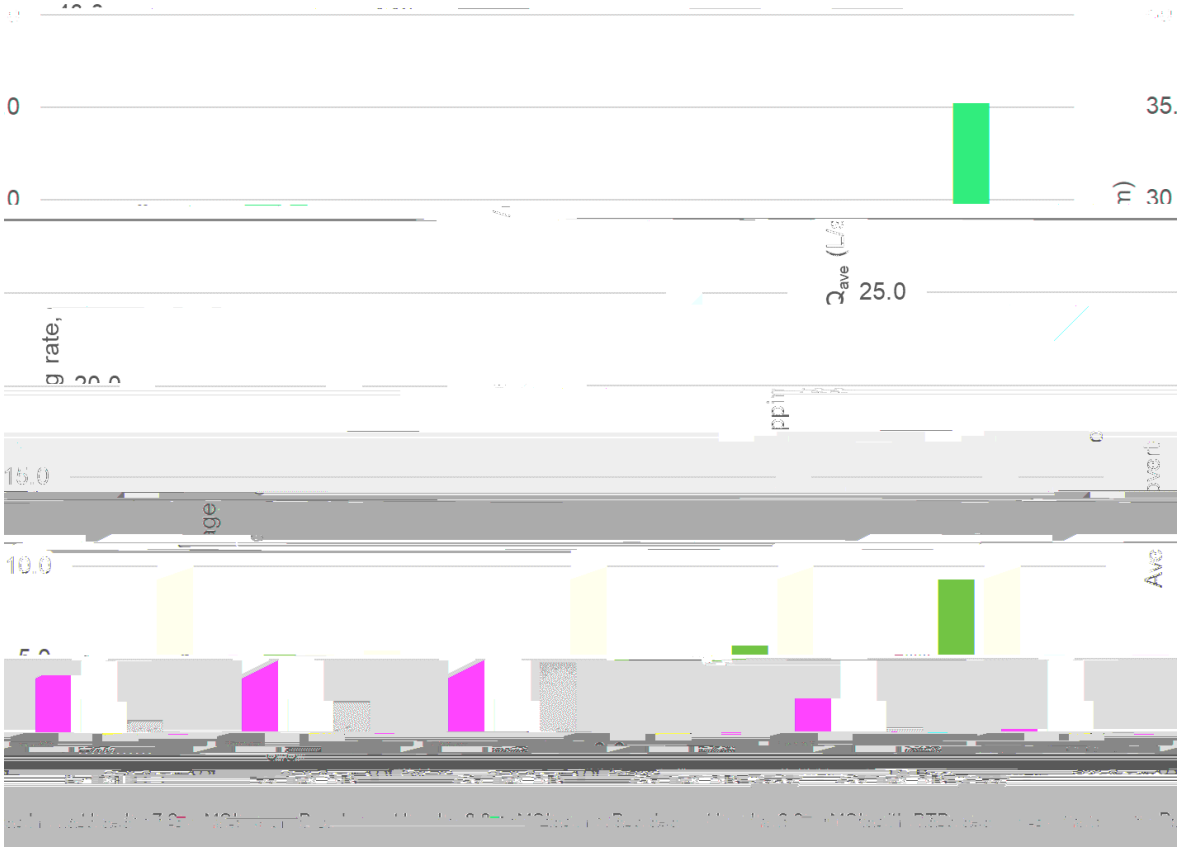

Figure 4.19: Average wave overtopping rates for Stage 4 testing (6.3 m MSL beach berm crest level, with additional BTB installed to crest level of 8.1 m MSL)

4.5

5 Conclusions

SPC is carrying out an assessment of wave-driven coastal inundation hazards for the islands of Nanumaga, Nanumea and Funafuti in Tuvalu. WRL was engaged to conduct a scale physical modelling assessment of wave processes, runup and overtopping hazards for Nanumaga island, to support SPC's investigation. The key objectives of the physical modelling study included analysis of the following parameters for a range of extreme wave and water level scenarios:

- Wave characteristics and transformation as waves cross the reef profile
- Reef-top water levels, including sustained wave setup and low frequency components
- Wave runup/inundation levels at the beach
- Reduction in wave overtopping achieved by Berm-Top-Barrier coastal protection structures

A testing program comprising 20 separate test runs was completed using a 1:25 scale, 2D cross-shore reef profile model for the western coast of Nanumaga. The tests investigated five separate wave/water level scenarios:

1. TC Pam: H_s = 5.3m, T_p = 15.6s, Tide + MSLA = 0.39m MSL
2. 100 Year ARI: H_s = 5.5m, T

overtopping rates by a factor of 7 to 14, and for present day sea levels, the resulting overtopping rates were reduced to be at the safe limit during the 100 year ARI test condition. For the TC Pam and 250 year ARI conditions with present day sea levels, overtopping rates were measured to be slightly above guideline values.

6 References

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