RPS

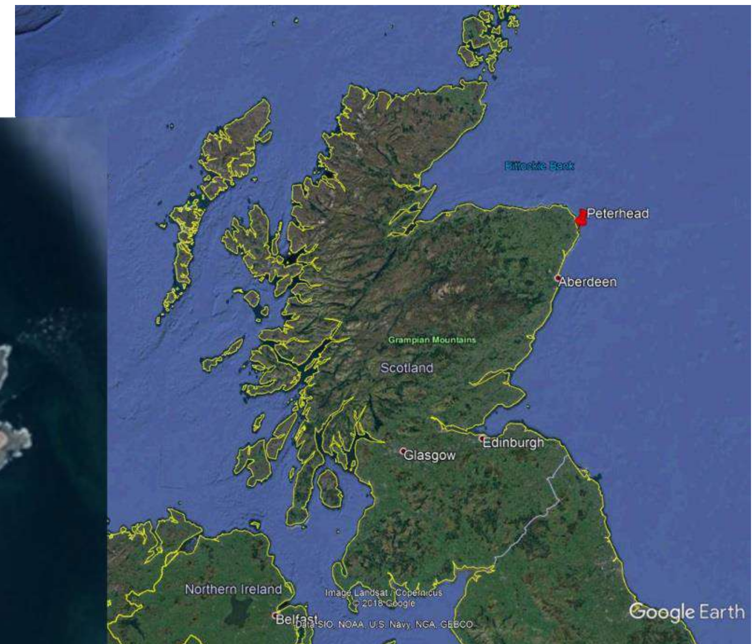
Peterhead Port Alexandra Parade Seawall

Local Knowledge
INTERNATIONAL EXPERTISE

Alexandra Parade Seawall

PETERHEAD PORT

- **Major whitefish port on the NE coast of Scotland**
- **Port has undergone a major redevelopment including the construction of a new fish market at Alexandra Parade**



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Two major issues relating to overtopping

- **Direct damage to the building which sits close behind the seawall**
- **Flooding of the market building and loading areas**

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https://www.youtube.com/watch?v=tV28SpJzVhU

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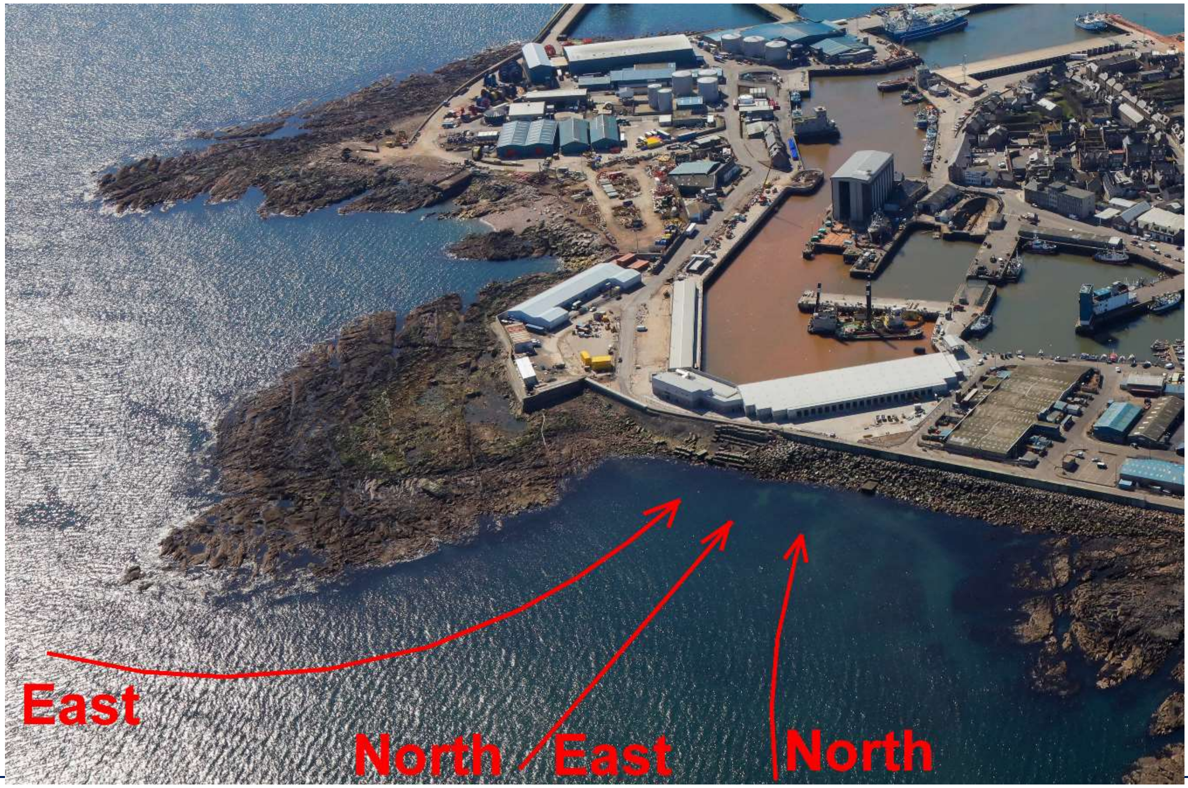
Wave Exposure

- The revetment is exposed to storms from the North to East sector
- Offshore of the revetment the storm waves can be in excess of 9 metres high but are attenuated by the sea bed bathymetry as they run in towards the revetment



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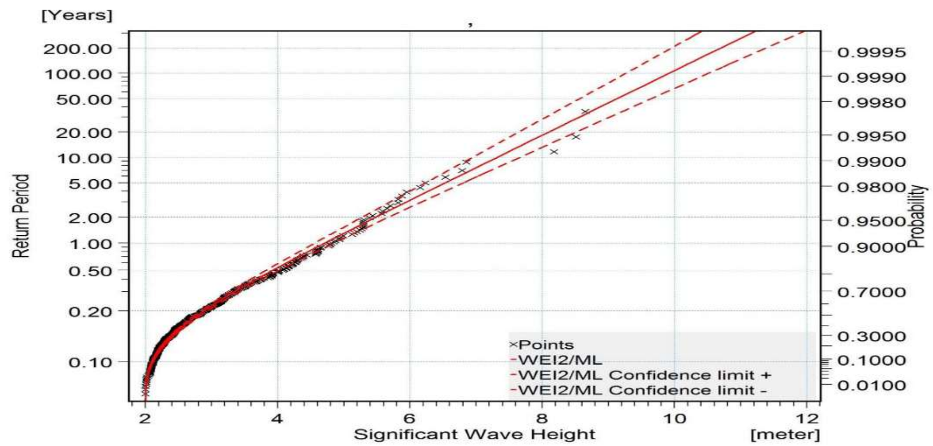
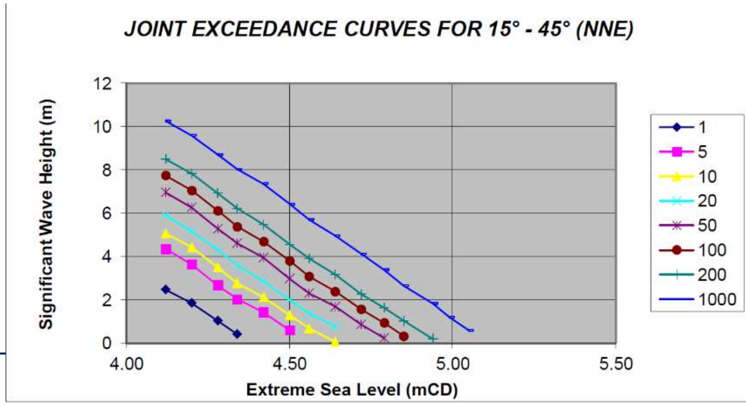
Offshore wave data

- Offshore wave climate based on 30 years of 3 hr data from UK Met Office WWIII model
- Data divided into 30º sectors and extreme value analysis undertaken using Mike EVA toolbox

Joint probability analysis

- The wave heights approaching the sea defences are restricted by water depth so the wave climate is sensitive to storm surges
- JP Analysis undertaken using SEPA extreme water levels and wave EVA based on recommendations of FD2308





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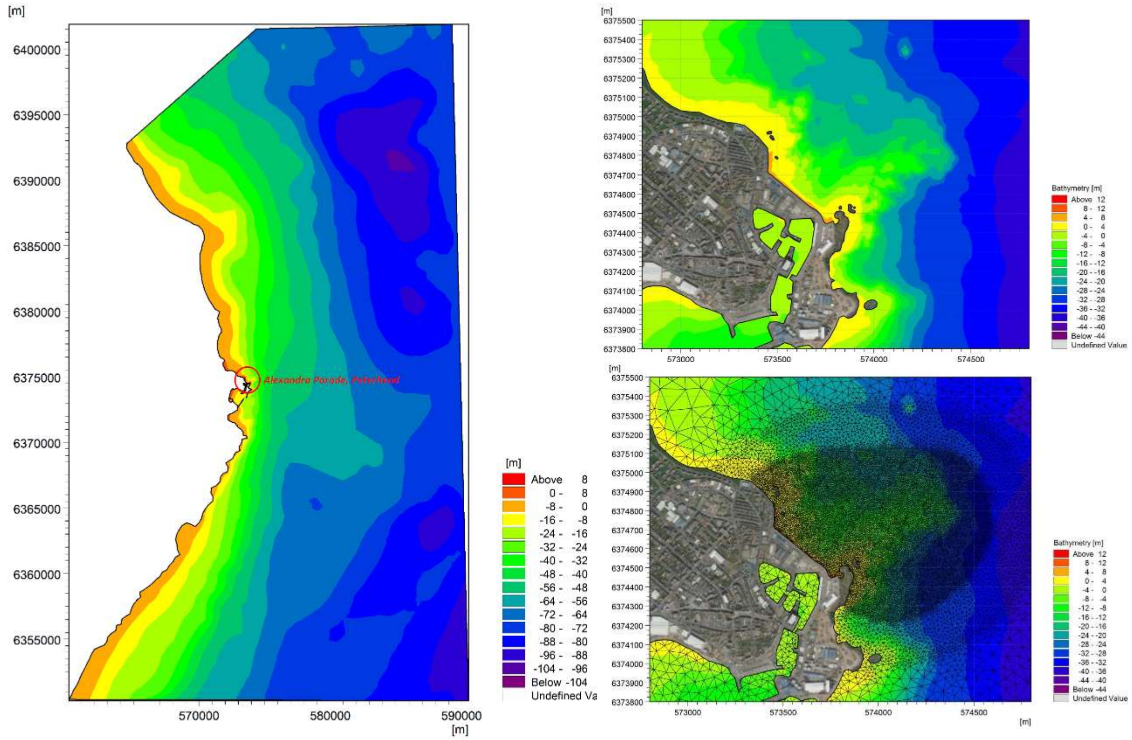
Wave transformation

- The wave climate approaching the revetment has been simulated using a coupled Mike21 SW and Mike21 FM model so that wave setup could be included
- The extent of the model was as shown with mesh sizes varying form 1 kilometre offshore to a fine 7 metres at the approaches to the seawall
- The sea bed immediately in front of the seawall is quite steep with a slope of 1 in 17



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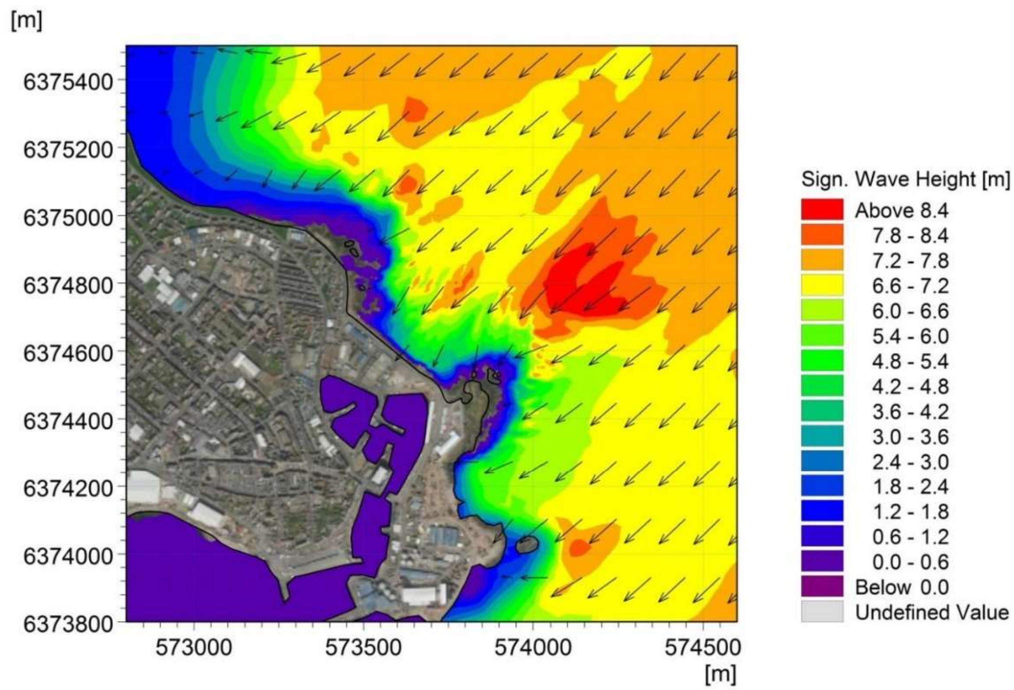
Wave transformation

- The diagram shows the significant wave height and direction of the waves in the a 1 in 200 year return period storm (the design storm)
- It will be seen that for a storm of this magnitude the waves approaching the seawall are restricted by water depth
- In the Mike 21 SW simulations the depth breaking index was set to 0.8 and to be conservative the bed roughness set to 0.01m
- The SW wave transformation simulations were run for the range of wave and water depths for directions from 330° to 90°



Hm0 and MWD – 1 in 200 storm from 30°

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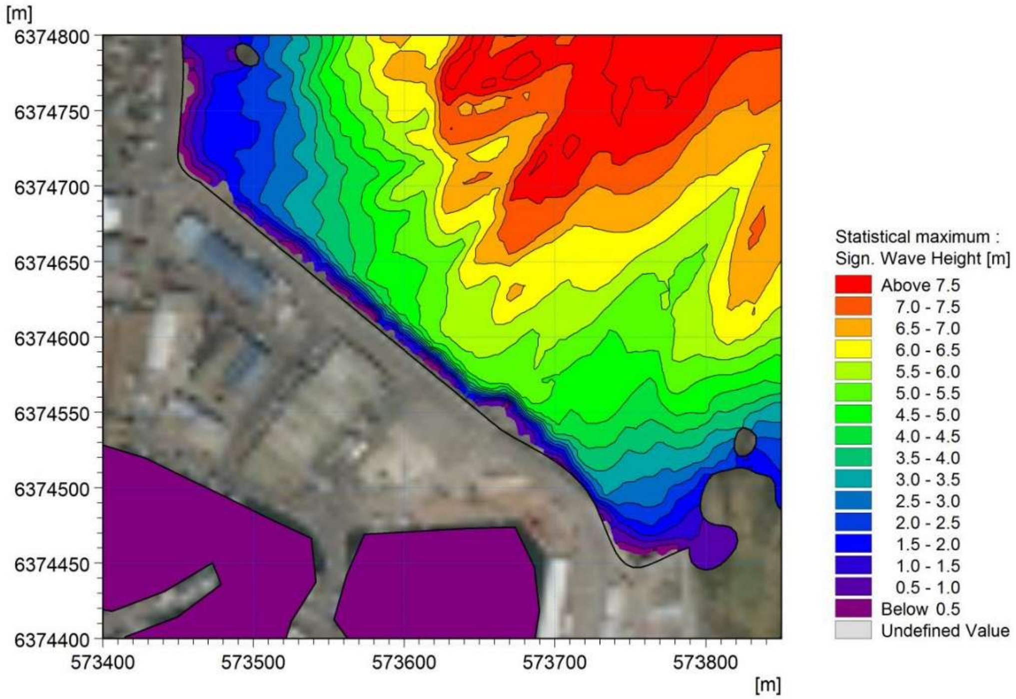
Extreme Storm Waves

- The diagram shows the envelope of the largest significant wave heights for all the directions for a 1 in 200 year return period storm (the design storm)
- It will be seen that waves of about 5.5 metres significant height can approach the seawall at Alexandra Parade during a 1 in 200 year return period event
- The greatest wave activity would appear to occur to the west of the Fish Market with wave heights of about 4.5 to 5 metres where the Fish Market is closest to the seawall



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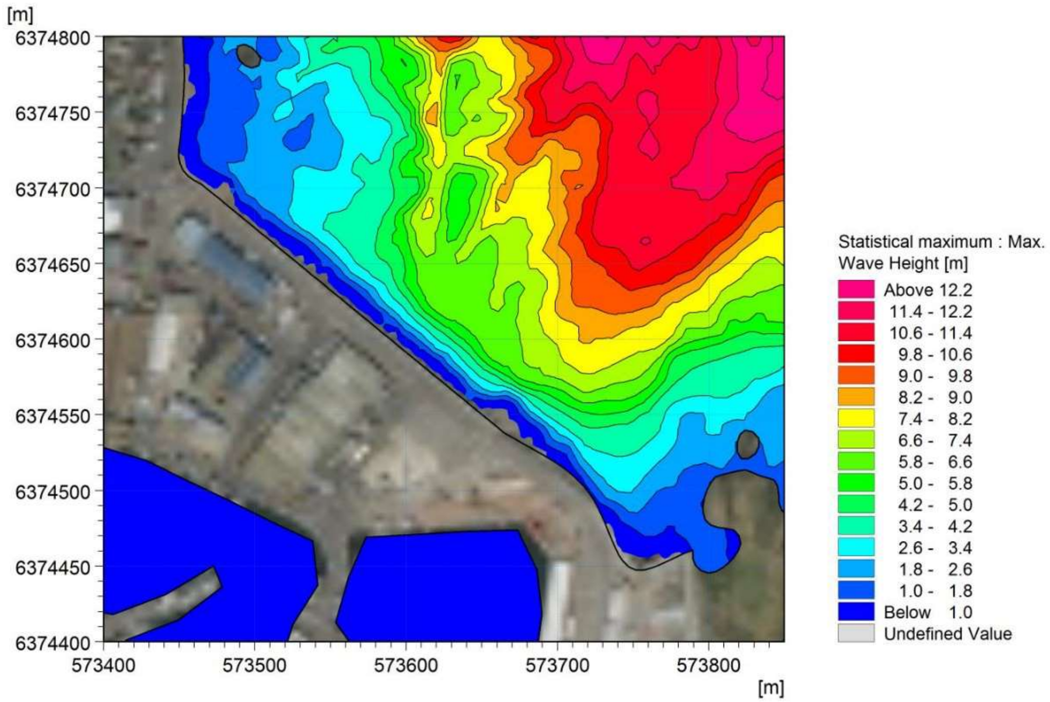
Extreme Storm Waves

- The diagram shows the envelope of the largest maximum wave heights for all the directions for a 1 in 200 year return period storm (the design storm)
- Unlike the significant wave height diagram the largest waves in the storm wave spectra would appear to occur close to the point where the Fish Market is close to the seawall
- It is these very large waves that can result in the highest rates of overtopping which can potentially damage the Fish Market building



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Existing Seawall

- The existing seawall protecting the fish market is made up of a traditional pitched stone apron and a rock armour revetment
- The rock armoured revetment was designed in about 1980 and is now showing signs of failure with some of the primary armour being removed exposing the smaller stone underlayers
- The rock armour slope was originally at a 1:3 slope with the pitched stone apron having a 1:2.7 slope

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Existing pitched stone revetment

- The performance of the existing pitched stone revetment in terms of overtopping is strongly influenced by presence of the blocks on the surface of the structure, particularly the blocks cut from the north breakwater crest sections
- However these blocks are only resting on the surface and there is no mechanism for anchoring such blocks
- We believe that while the blocks will continue to work during relatively smaller storms, such as those with a 1 in 1 year return period, more extreme events will wash the blocks away and they cannot be relied upon for protection from overtopping during major storm events

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Computational Wave Overtopping

- The wave overtopping at both the pitched stone revetment and the rock armoured wall section have been calculated using empirical and neural network formulations from EurOtop 2016 Manual
- The mean overtopping rates range from about 36 l/s/m for a 1 in 1 year storm to as high as 1691 l/s/m for the 1 in 200 year storm with allowance for sea level rise to 2080
- Safe average overtopping values for pedestrians walking on Alexandra Parade would be about 1 l/s/m and for vehicles would be less than 10-20 l/s/m

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Computational Wave Overtopping

- Two vehicles have been damaged by overtopping on Alexandra Parade during last winter
- There is a considerable spread of overtopping results using numerical design methods. For example the 1 in 200 year return period storm can have an mean value of overtopping rate of 480 l/s/m with a 95% value of 4970 l/s/m i.e. a ten fold spread in the results
- In addition, the one individual large wave in the sea state can result in a massive amount of overtopping which could very seriously damage the Fish Market

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Physical Modelling

- Due to the uncertainty in the numerical methods for calculating overtopping, particularly for the larger individual waves in the sea state, we undertook physical model studies in the large 4.5m wide wave flume at Queens University, Belfast
- A 1 in 50 scale model of the existing pitched stone revetment and the rock armoured slope and wave wall were constructed in the middle part of the width of the flume
- The base of the flume was adjusted to the nearshore bathymetry

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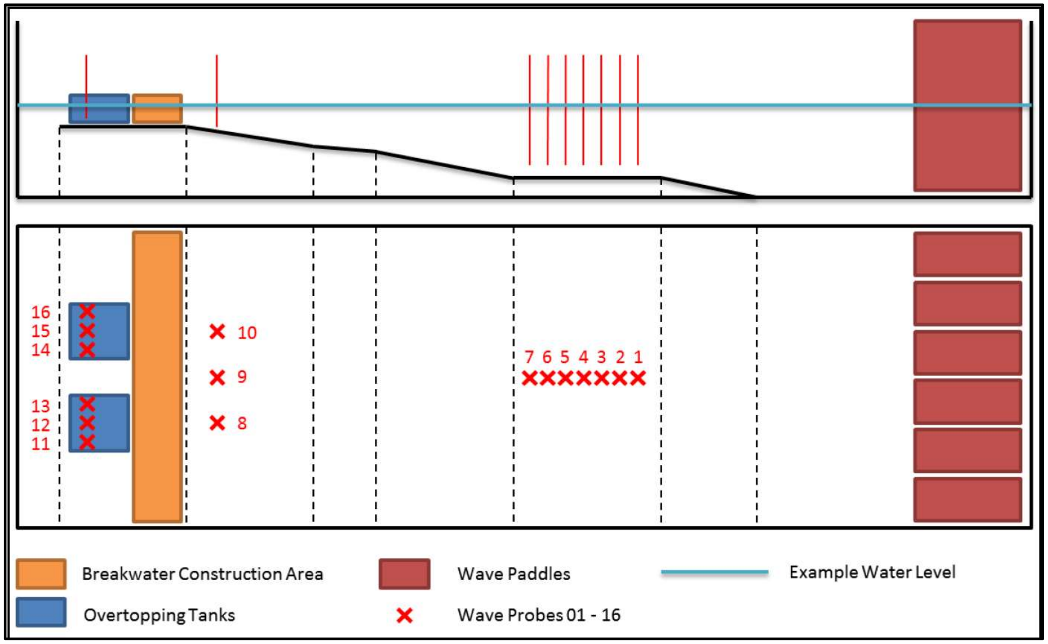
Physical Modelling – Flume setup

- The diagram shows the schematic section and plan of the wave tank used for the physical modelling with the random wave paddles at the right hand end
- Twin wire surface elevation probes were located at the nearshore wave point, at the approaches to the toe of the proposed structure and in the overtopping measuring tanks which were positioned immediately behind the sea wall
- The base of the flume was adjusted to the nearshore bathymetry



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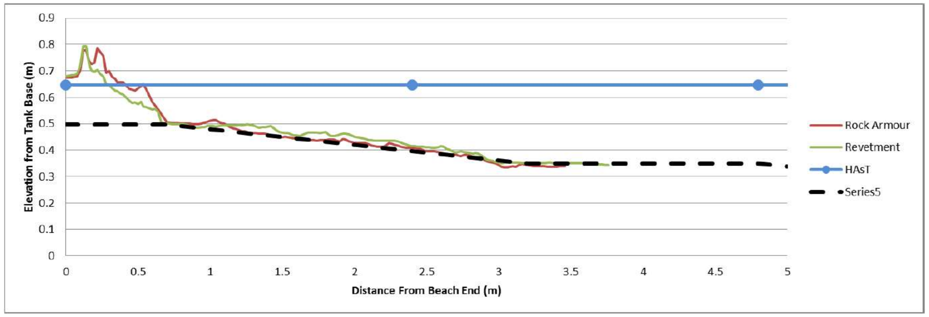
Physical Modelling – Flume setup

- The levels of the base of the tank were adjusted to match the bathymetry of the sea bed at the approaches to the seawall. The slope of the sea bed to seaward of the wall was approximately 1 in 17
- V notches were placed in the overtopping measuring tanks so that the tanks could drain back to the flume at a known rate.
- This together with the twin wire surface elevation measuring probes in these tanks allowed both the mean rates and individual wave overtopping volumes to be measured during the tests



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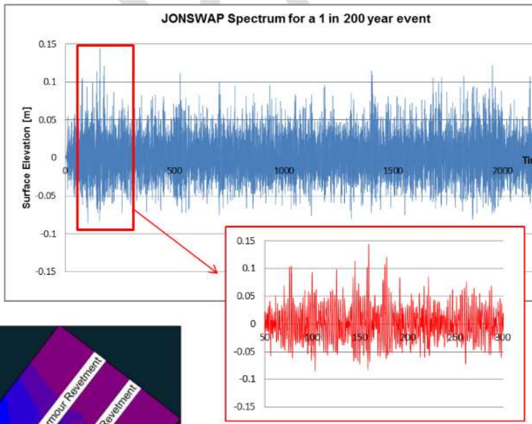
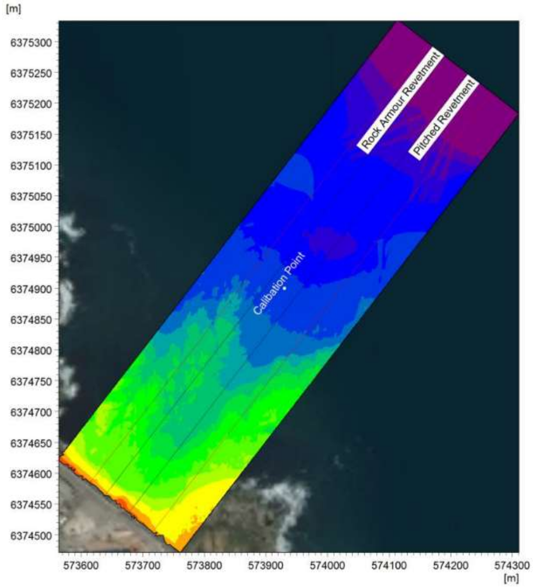
Physical Modelling

Wave Calibration

- The wave data was taken from the Mike21SW model simulations for a nearshore point where the water depth was approximately 14 metres at HAT.
- The sea state was assumed to have a JONSWAP spectral form and each test lasted the equivalent of about 4 hours in real time
- The wave paddle settings were adjusted until a good calibration was achieved at the specified wave point





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Physical Modelling

Overtopping Simulations

- The overtopping test commenced with simulations on the model of the existing seawall and revetment structure
- Simulations were run for 1 in 2, 10, 50 and 200 return period storms with water levels set to include sea level rise to 2080
- Surface elevation records from the twin wire probes were recorded at the toe and at the calibration point.
- Overtopping rates both mean and peak were also recorded.

Alexandra Parade Seawall – Physical Model

1 in 200 year storm at 2080 water levels

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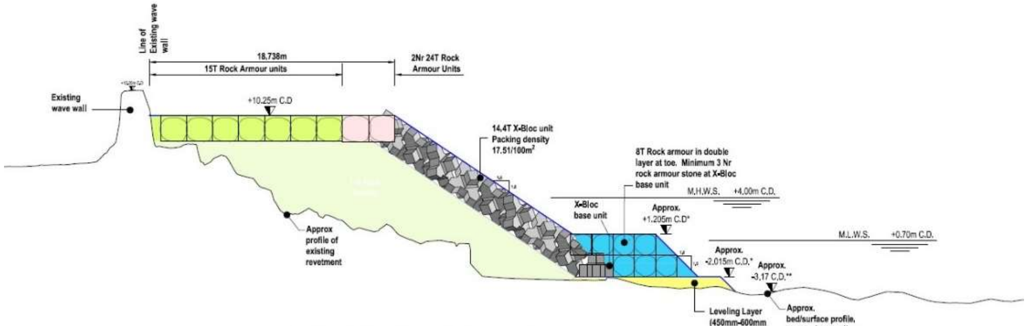
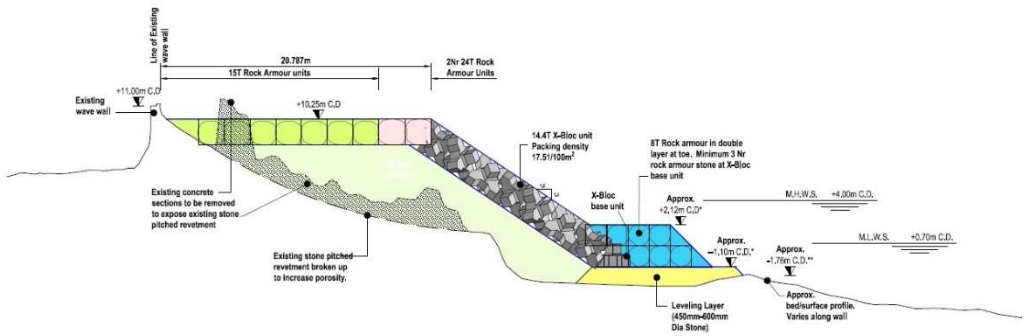
Physical Modelling

Proposed New Revetment

- As can be seen from the demonstration video the fish market is at risk from a major storm
- Several options were examined and the most feasible scheme was a new wide crested revetment built to seaward of the existing wall for the section in front of the fish market
- Computational modelling indicted that might improve mean overtopping rates by a factor of 100
- Test were undertaken using a 5m^3 x-bloc model armour units



Typical Section A through Existing Rock Revetment



Typical Section B through Existing Pitch Stone Revetment

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Physical Modelling
Overtopping Simulations

- The overtopping test were undertaken on the proposed revetment structures
- Simulations were run for 1 in 2, 10, 50 and 200 return period storms with water levels set to include sea level rise to 2080 as previously
- The results indicated that the crest level need to be increased by about 1.5 metres to reduce the peak rates of overtopping
- Rocking of the 5m^3 x-bloc units was noted which could result in armour unit breakages in real life

Alexandra Parade Seawall – Physical Model

1 in 200 year storm at 2080 water levels

Alexandra Parade Seawall – Physical Model

Rocking $5m^3$ x-bloc armour units

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Physical Modelling

Revised design

- The Client asked for the revetment to be redesigned for todays water levels with the opportunity to raise the crest at a later date
- The opportunity was taken to retest the design with $8m^3$ x-bloc units with a lower crest
- Simulations were run for both today water levels and for the projected water level for 2080
- The larger units were completely stable with no rocking observed throughout any of the simulation runs

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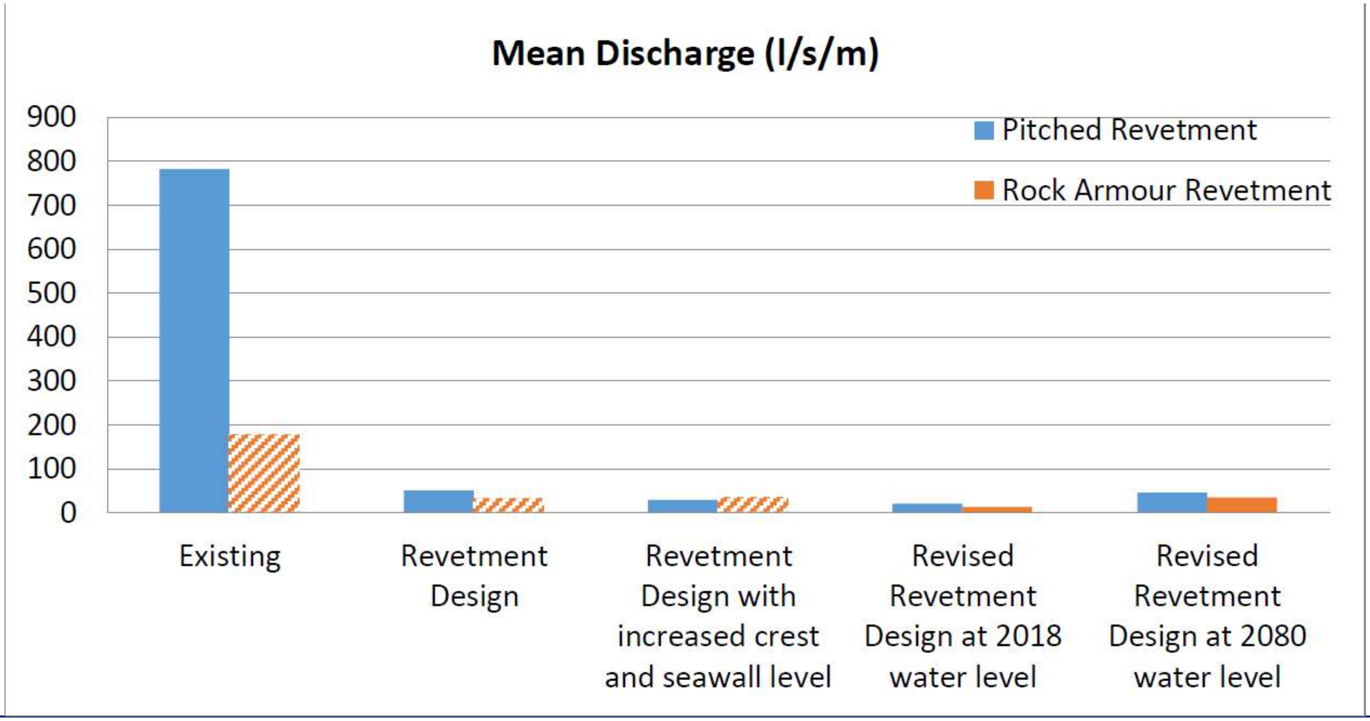
Physical Modelling – Overtopping results



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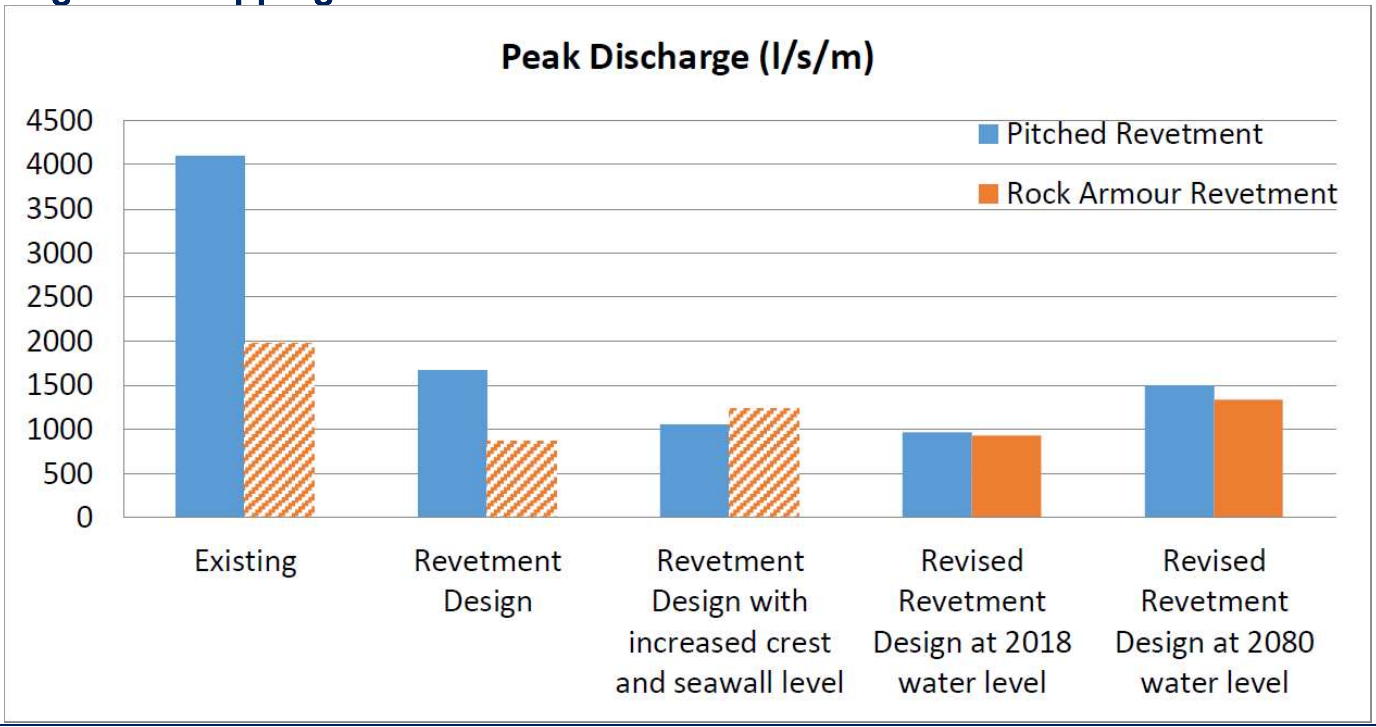
Physical Modelling – Overtopping results



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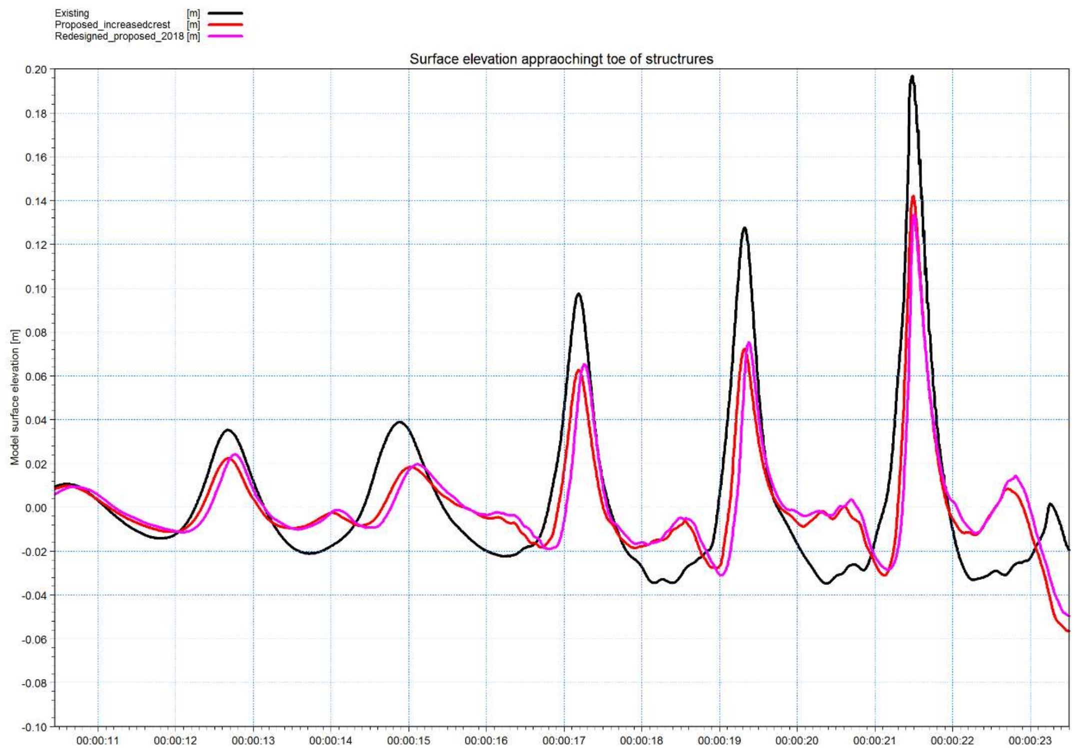
Physical / Computational modelling - issues

- This is the trace of the water surface elevation from the probes near the toe of the structure during the start of the 1 in 200 year storm simulation
- The wave shape appears highly conoidal and away above the breaking limit (14m height on a 9m water depth!)
- The wave height is much larger for the existing seawall than for the proposed revetment but nearshore wave heights are the same. This is due to wave reflections being higher from the existing structures



Peterhead PORT AUTHORITY

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Physical / Computational modelling - issues

- Analysis using the Mike Zero WS Linear Spectral Analysis Tool gives the values in the table. The use of several wave probes would allow the separation of the incoming and reflected spectra using the WS Reflection Analysis tool.
- However these tools use linear wave assumptions and these waves are not linear.

	Toe - Centre				
	Existing	Proposed	Proposed with increased crest level	Redesigned Proposed at 2018 water level	Redesigned Proposed at 2080 water level
50th Scale					
Hmo	0.13644	0.10307	0.10304	0.10149	0.10505
Hmax	0.2928	0.22117	0.22112	0.2178	0.22543
Tp	2	1.33	1.33	1.33	1.33
Full Scale					
Hmo	6.82	5.15	5.15	5.07	5.25
Hmax	14.64	11.06	11.06	10.89	11.27
Tp	14.14	9.40	9.40	9.40	9.40

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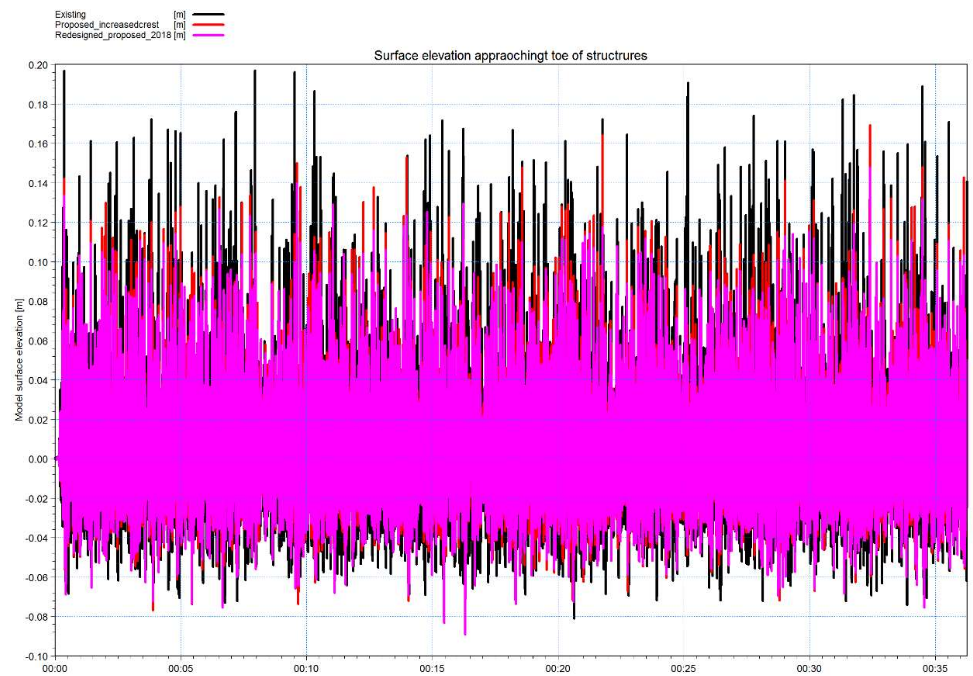
Physical / Computational modelling - issues

- While in theory it is possible to relate the overtopping to the incoming wave climate the overtopping of individual waves is affected by wave reflections
- The point here is what wave height should be used in numerical calculations (EurOtop) and what wave height was used in the derivation of the data bases such as the ANN tool? You may not get the necessary data from the SW model.
- A case for the new MIKE3 wave model?



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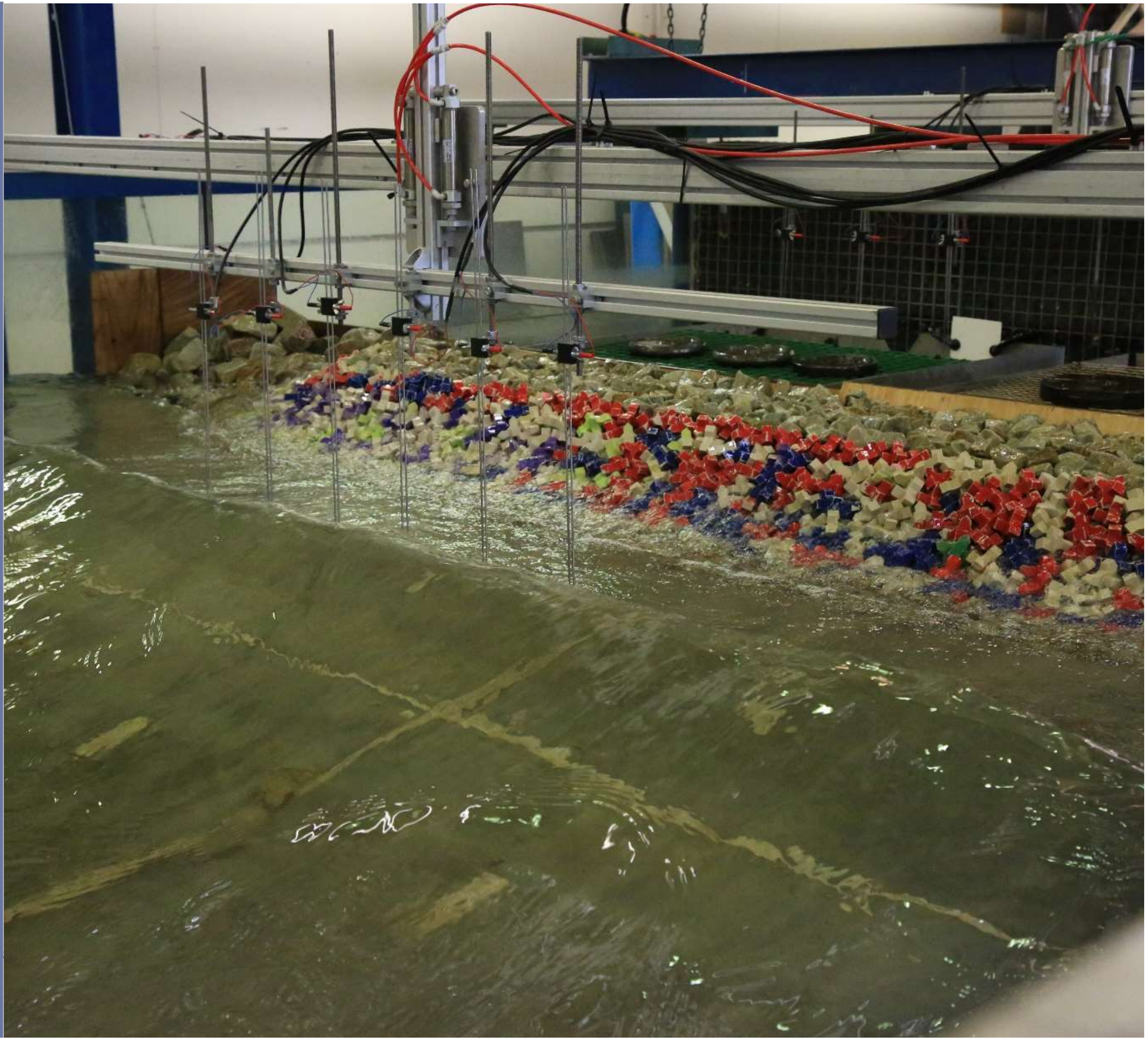
Questions



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