Stonehaven Bay Coastal Flood Protection Study

SFAG Consultation

27 August 2019

Background

- SEPA's 2015 SFRA identified the requirement for a coastal flood study in Stonehaven Bay
- Aberdeenshire Council have to deliver recommendations by December 2019
- SEPA and Scottish Government review for prioritisation in 2021 – 2026 cycle
- **100+** flood studies are being considered nationally
- This is the **starting point** in the process

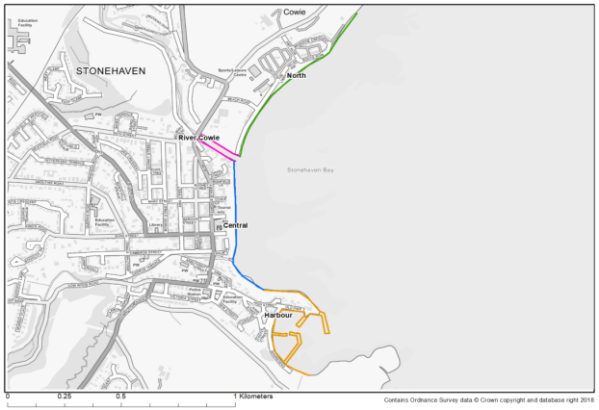
Requirements

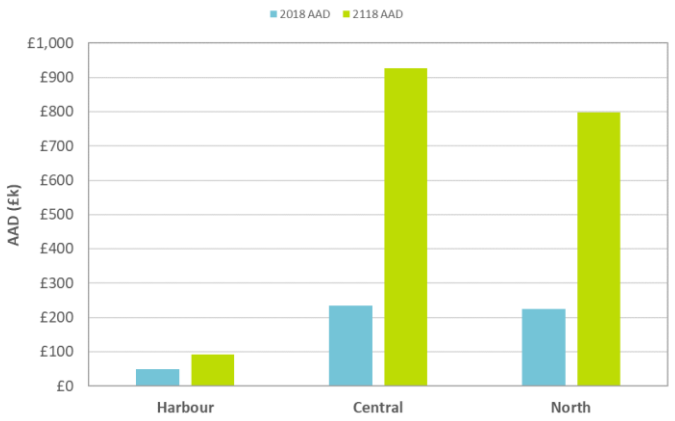
- **Scottish Government / SEPA**
  - Risk-based approach to maximise overall reduction in risk
  - "*Adaptive*" over "*precautionary*"
  - 100-year appraisal period

- **Aberdeenshire Council**
  - Implement above based on *short*, *medium* and *long-term* recommendations

Implementation

- Assessment of flood and erosion risk in 2018 and 2118
- Division of study area in to 3 primary benefit zones
- Development options for **each zone** (adaptive and precautionary)
- Appraisal of options for **each zone** (adaptive and precautionary)
- Development of preferred option for **entire bay**
- Recommendations for short, medium and long-term

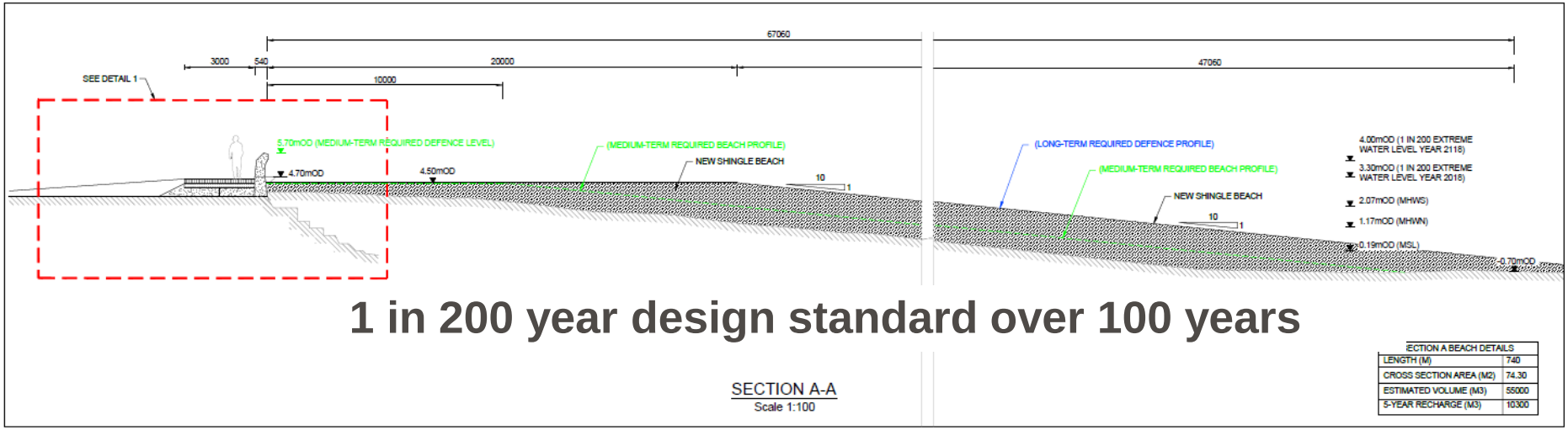




Reason for meeting

- Outcomes of initial appraisal were presented at public meeting on 13 June 2019
- Highlighted inconsistency with the description of the ***Adaptive recharge*** option in the central benefit zone
- Details challenged by public and SFAG due to the raising of the existing sea wall at the rear of the beach
- Aberdeenshire Council instructed additional design work to investigate concerns

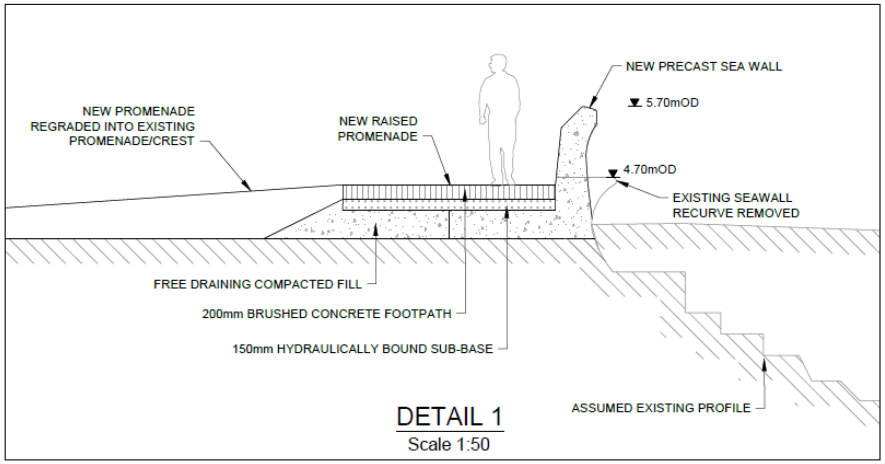
Adaptive recharge option



1 in 200 year design standard over 100 years

SECTION A-A
Scale 1:100

SECTION A BEACH DETAILS	
LENGTH (M)	740
CROSS SECTION AREA (M2)	74.30
ESTIMATED VOLUME (M3)	55000
5-YEAR RECHARGE (M3)	10300



DETAIL 1
Scale 1:50

- **2021**
  - Beach crest @ 4.5 mODN and 10m wide
  - 1:10 slope
  - Wall crest to 5.7 mODN (1m)
  - Promenade raised
- **2050**
  - Beach crest @ 4.5 mODN and 20m wide

SFAG and public concerns

- Raising of the existing wall was not communicated clearly
- This will be detrimental to the aesthetics of the bay and obscure views
- How was the overtopping performance of the beach assessed?
- Why was a larger initial beach not considered?

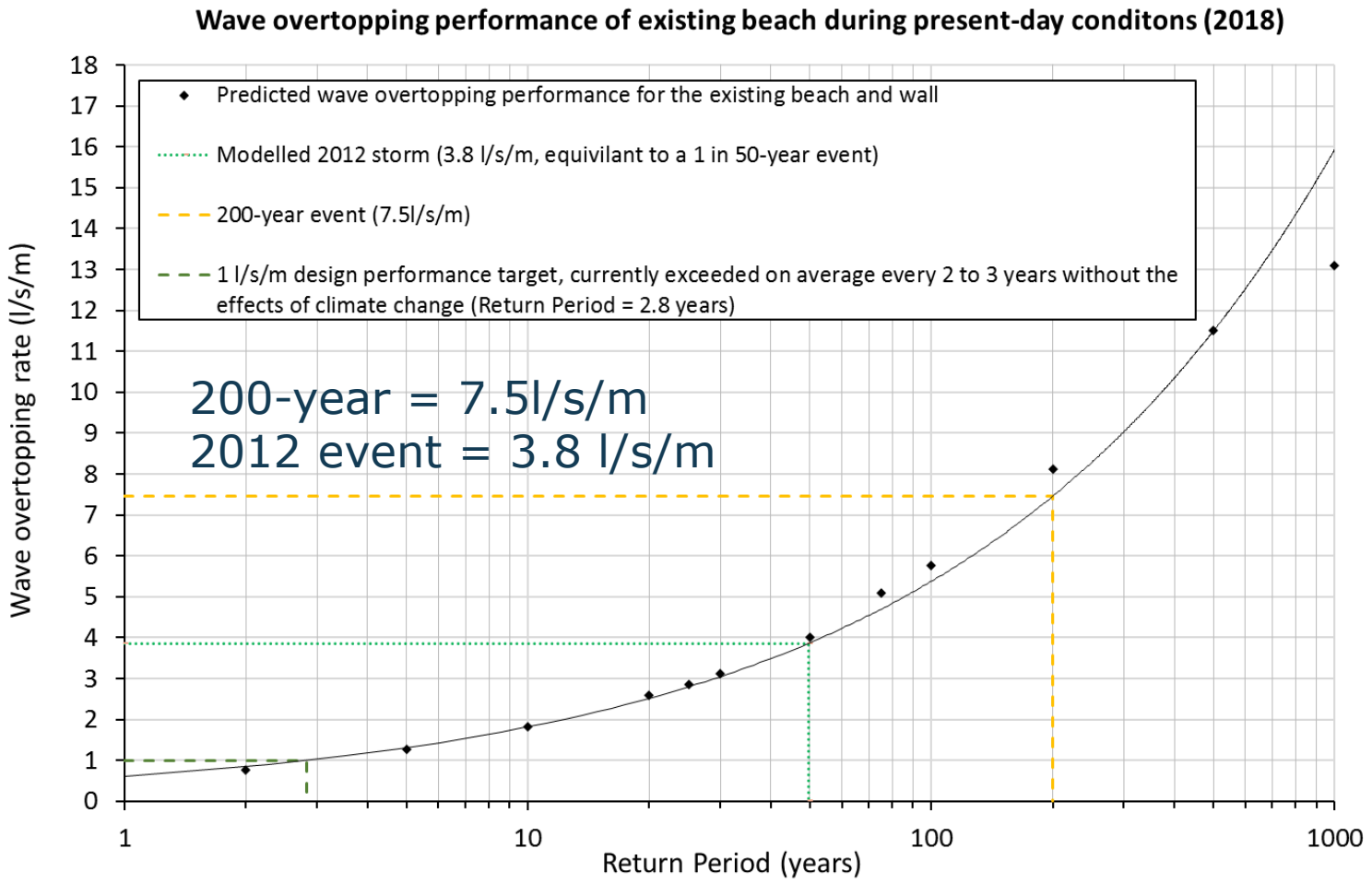
- **Aberdeenshire Council instructed further design work with the aim of better understanding the performance of the beach**

Further design work

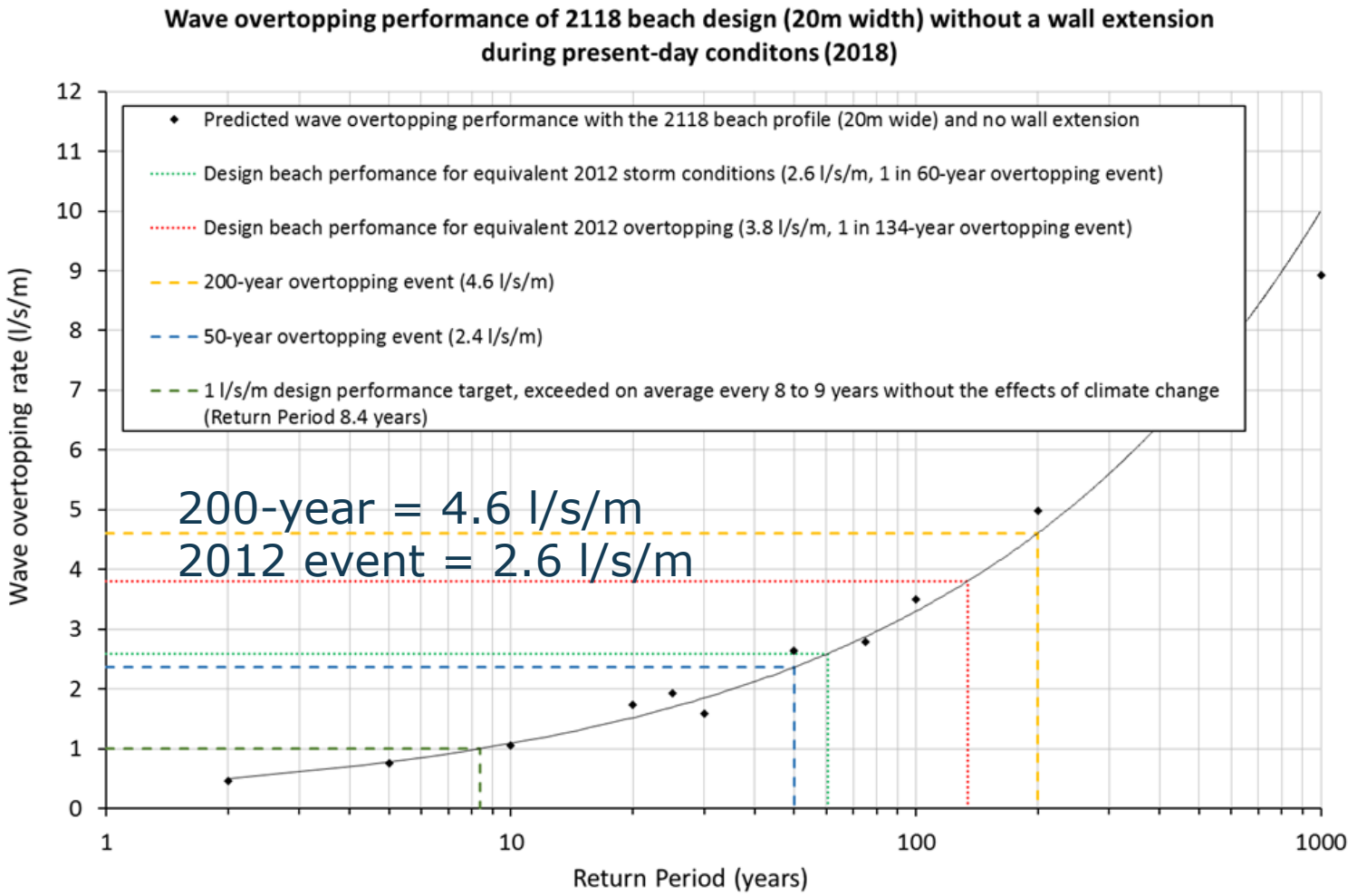
- Wave overtopping performance using EurOtop NN
- Wave overtopping performance using empirical methods
- Spatial distribution of wave overtopping volume
- Estimates of extreme wave runup height
- Numerical modelling in XBeach - G

- **Following conditions considered**
  - **2018 200-year** – H_s = 1.83m, $Tm_{-1,0}$ = 8.73s, SWL = 3.02 mODN
  - **2012 event** – H_s = 1.67m, $Tm_{-1,0}$ = 9.64s, SWL = 2.74 mODN
  - **Design standard = 1 l/s/m**

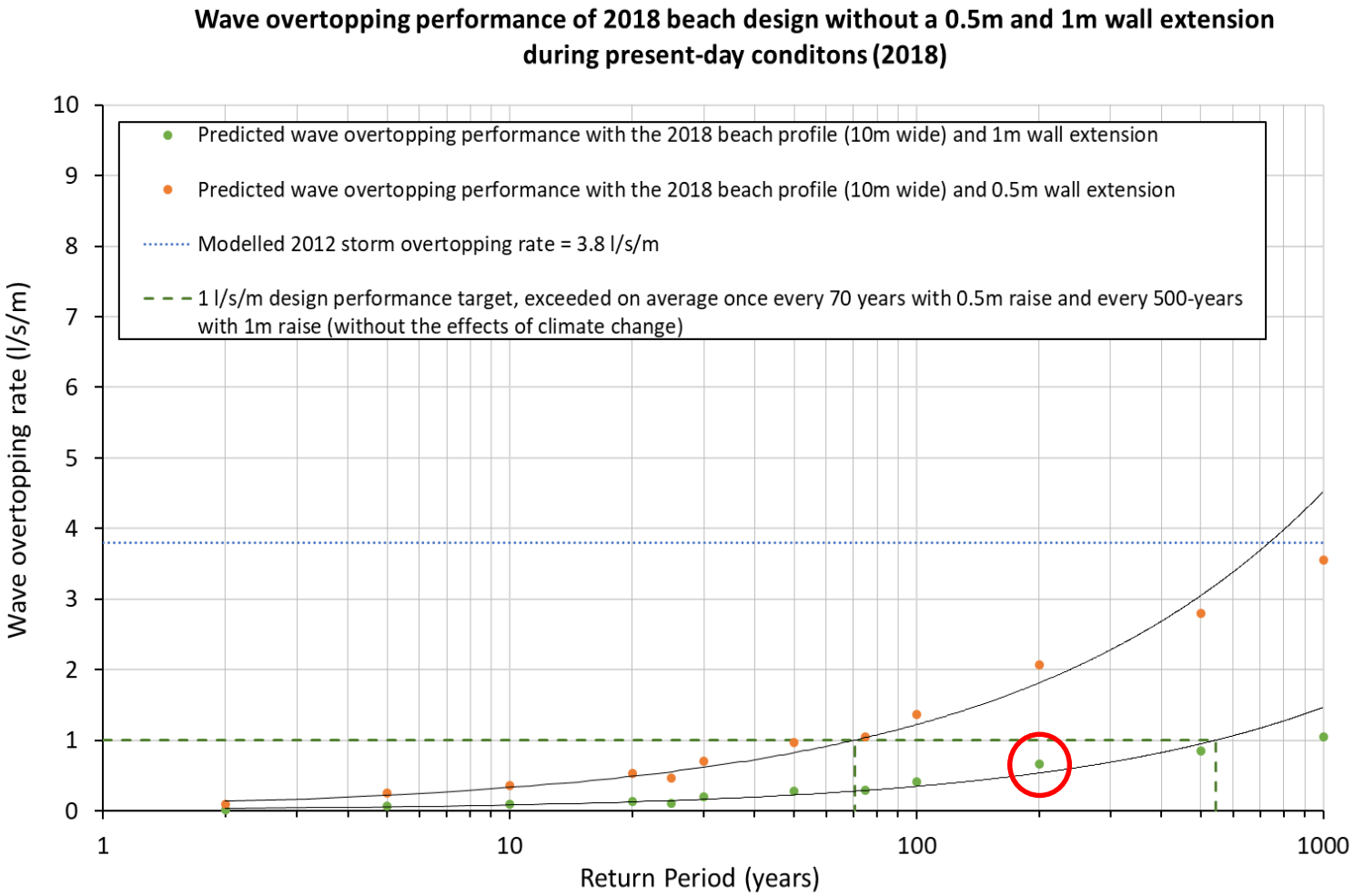
EurOtop ANN - Existing Beach



EurOtop ANN - Long-term beach profile without a wall raise

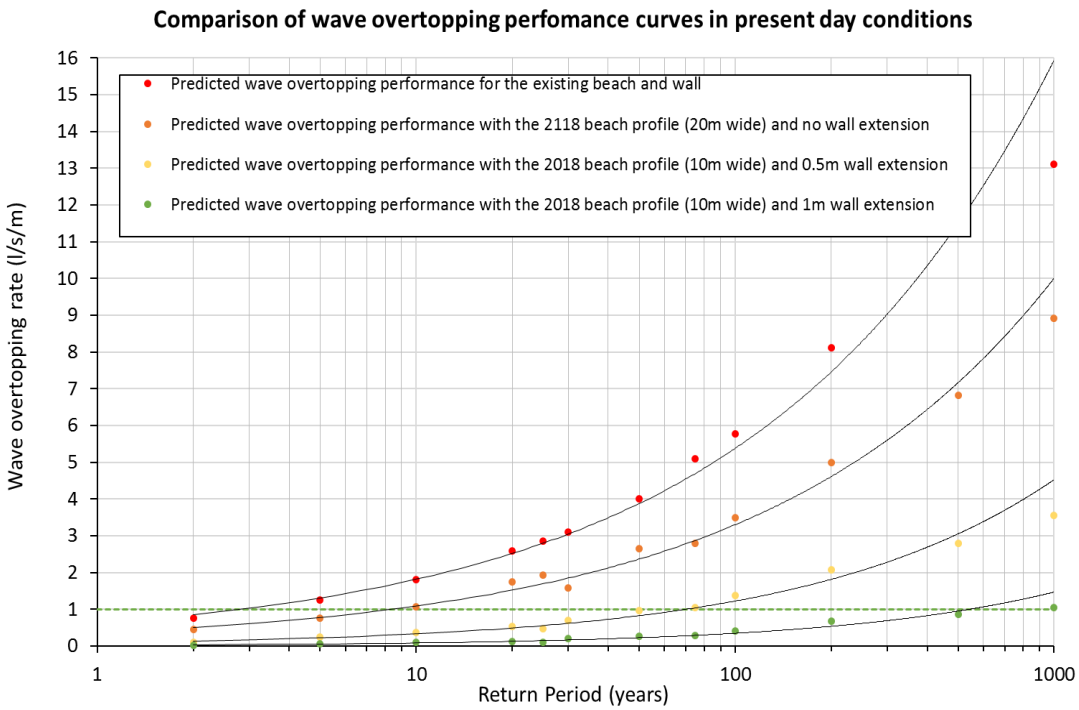


EurOtop ANN - Medium-term beach profile with a 0.5m and 1m wall raise



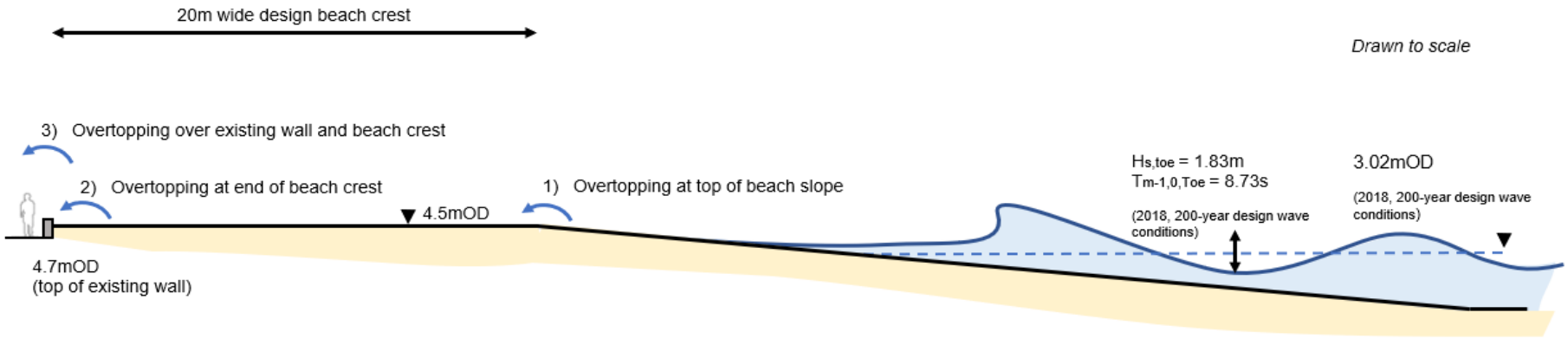
Summary Overtopping Rates

Scenario	Standard of Protection for wave overtopping design performance target (1 l/s/m)
Existing beach and wall	2-3 year
2118 beach (20m wide) and no wall	8-9 year
2018 beach (10m wide) and 0.5m wall raise	70 year
2018 beach (10m wide) and 1m wall raise	**> 200 year**



Empirical Methods vs ANN

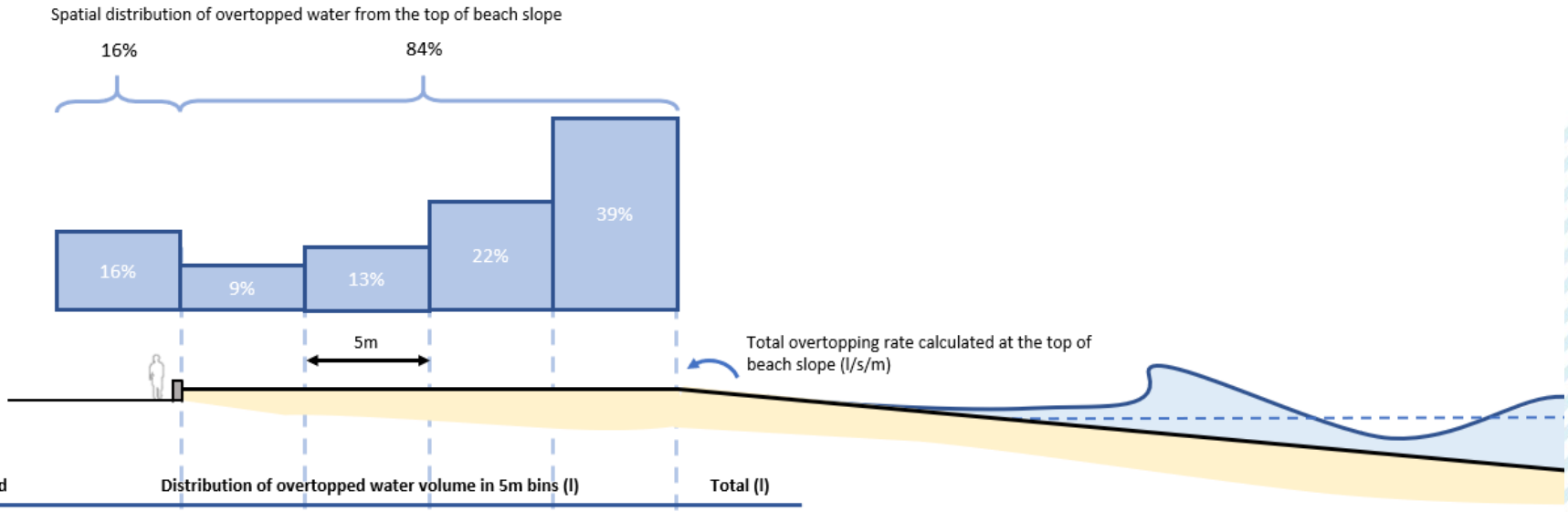
Long-term design beach profile with existing sea wall, as the base for the empirical wave overtopping calculations, with the three overtopping locations specified



Location of Overtopping	OT Rate (l/s/m)	
	EurOtop II – relatively gentle slopes	Artificial Neural Network
1. Top of beach slope	**33.0**	25.0
2. End of beach crest	**24.0**	5.5
3. Top of existing sea wall	**11.5**	4.6

Spatial Distribution of Overtopping

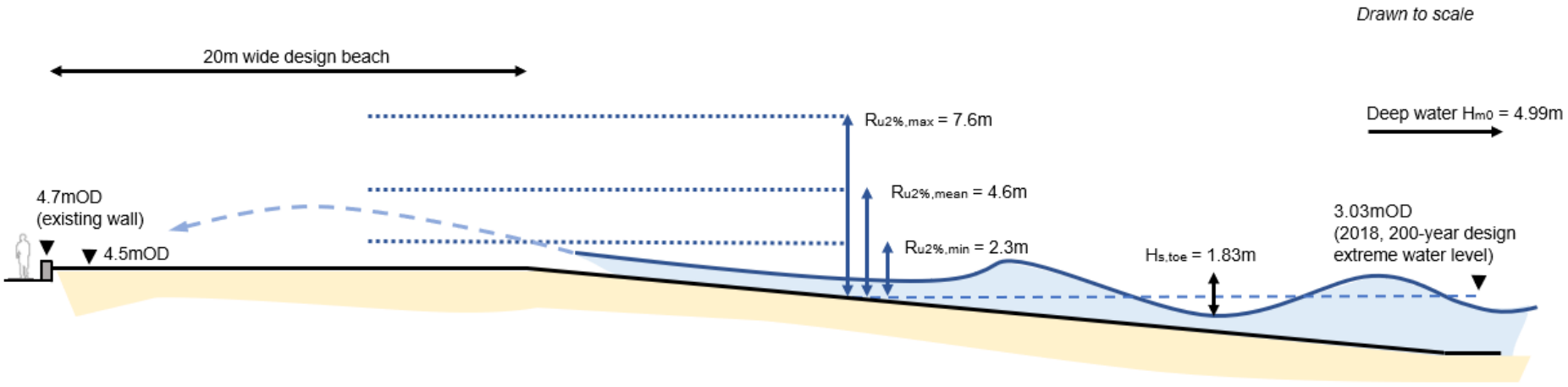
Long-term design beach profile with existing sea wall and the resulting spatial distribution of wave overtopping volumes



Method	Distribution of overtopped water volume in 5m bins (l)					Total (l)
Neural Network	4.0	2.3	3.3	5.5	9.8	25
EurOtop 2 - 'Relatively gentle slopes'	5.3	3.1	4.3	7.4	12.8	33

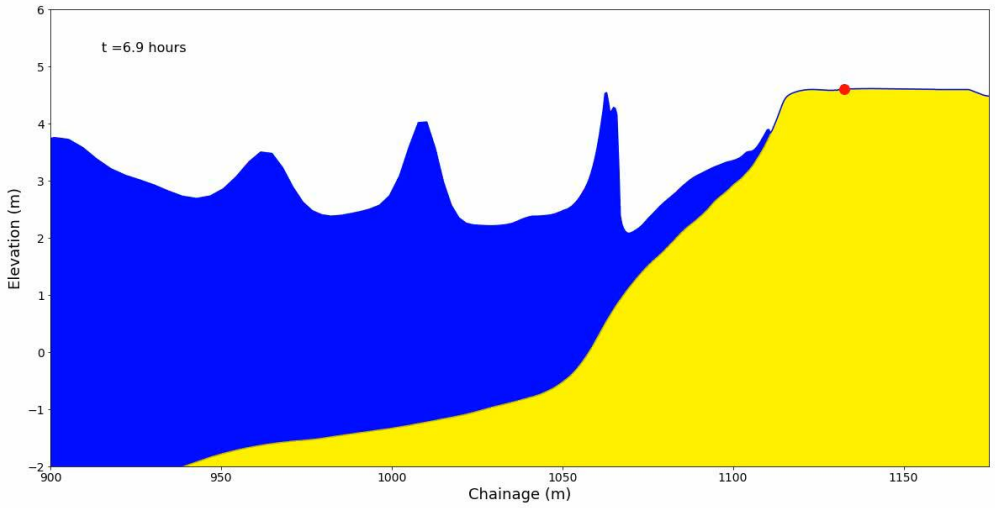
Run-up

- Six methodologies were tested to calculate run-up
- 200-year runup heights range from 2.3 to 7.6m
- Mean is 4.6m, resulting in a level of **7.63 mODN**
- Current wall crest is **4.7 mODN**



XBeach-G Modelling

- EurOtop methods are empirical
- Treat the design beach as “fixed defence”
- Beach will respond naturally to wave conditions
- Overtopping rates will vary

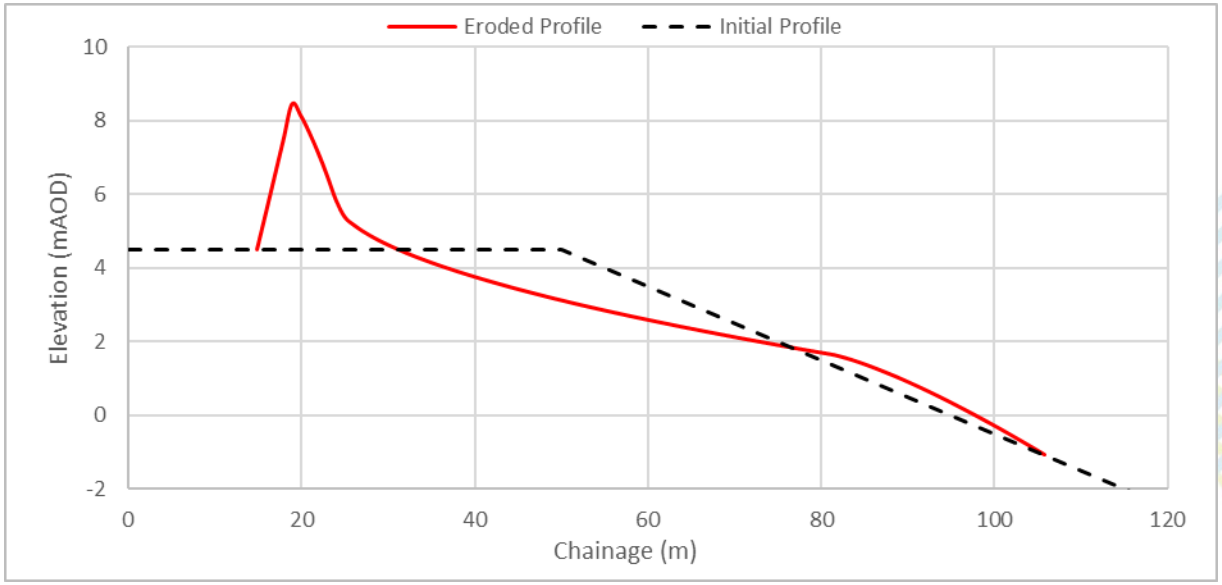


XBeach-G

- Morphodynamic modelling of the beach response to extreme events
- Fixed profile and dynamic profile modelled for the 200-year design conditions
- Estimation of overtopping rates whilst accounting for the response of the profile
- Fixed profile and dynamic profile also modelled for the 2012 storm event to compare overtopping rates

XBeach-G – Response mechanism

- Creation of large berm landward of crest
- Erosion of upper beach
- Deposition below SWL
- Tested in Shingle - B



XBeach-G – Model Setup

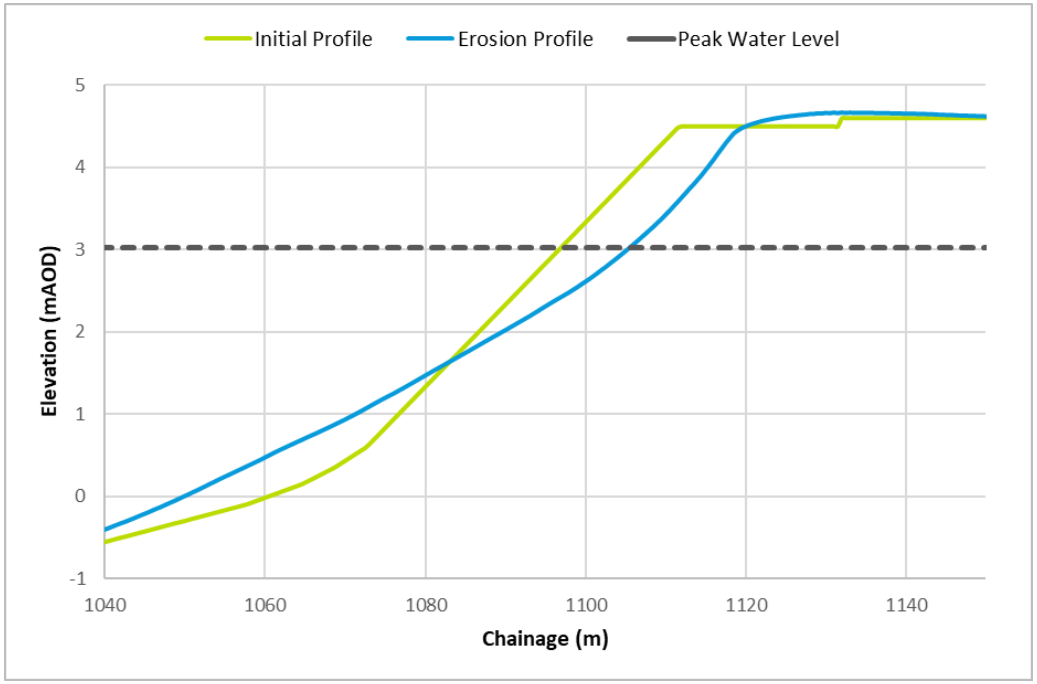
- Offshore wave climate from SWAN wave transformation model of the whole bay at location of the wave buoy
- 1D “flume” likely overestimates wave conditions reaching the beach
- Variance in water surface elevation was extracted and used to calculate nearshore H_s

$$H_{m0} = 4\sqrt{var_{zs}}$$

- The offshore wave heights were reduced by **45%**

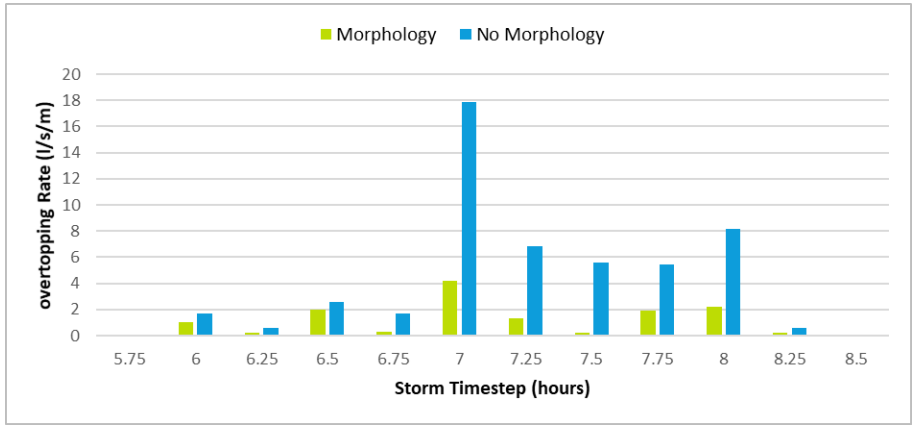
XBeach-G – 200 year Results

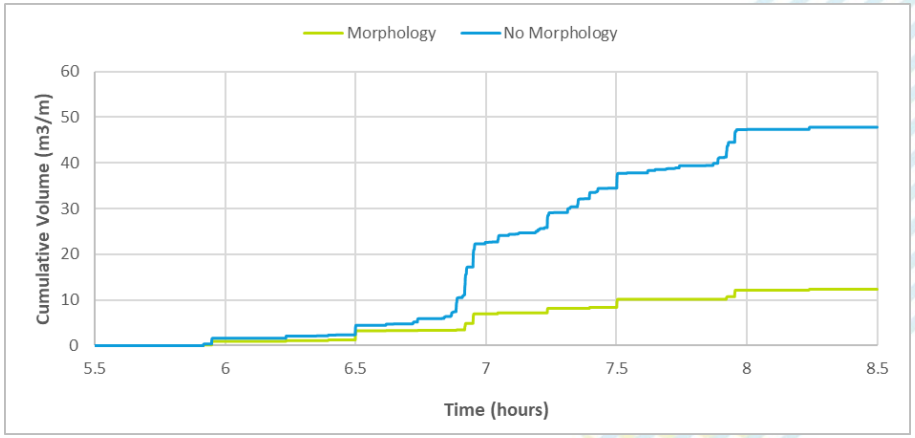
- 7m retreat of crest (30%)
- 0.2m sediment in front of wall
- 0.33 m³/m transported onto the path and lost from the beach



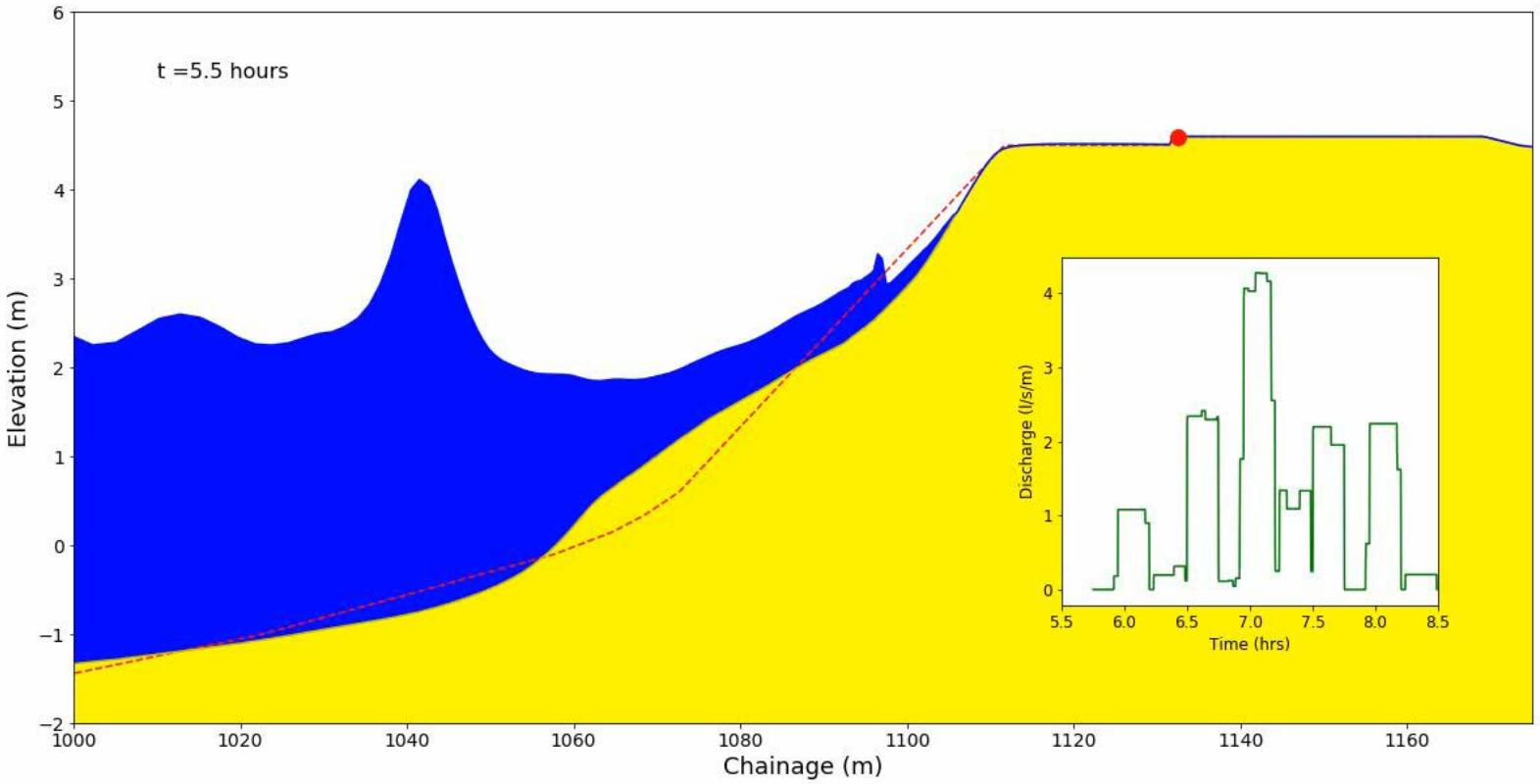
XBeach-G – 200 year Results

- Highest overtopping rate for fixed profile = **17.9 l/s/m**
- Highest overtopping rate for dynamic profile = **4.2 l/s/m**
- Exceed design standard overtopping rate of **1 l/s/m**

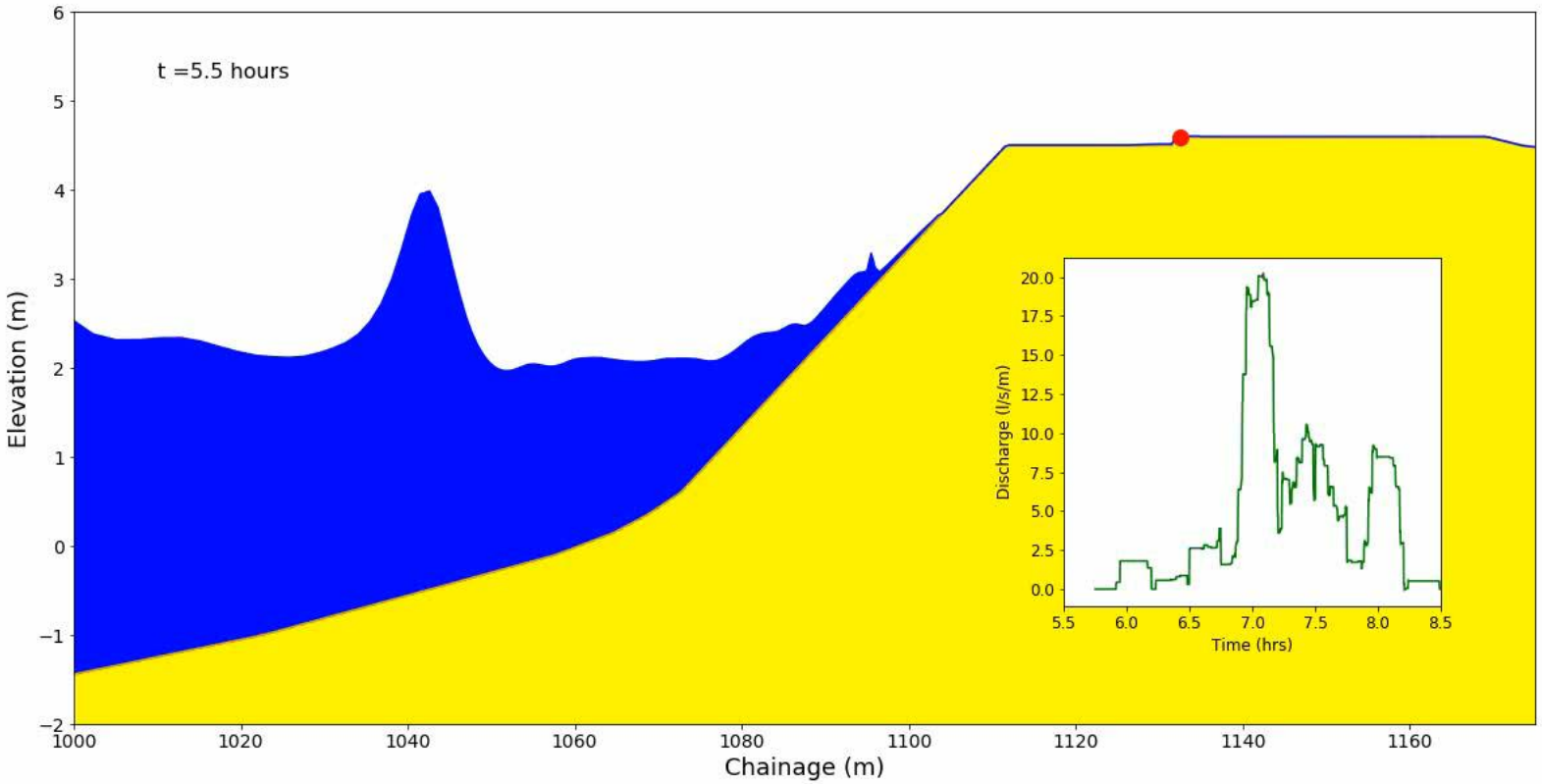




XBeach-G – Dynamic Profile

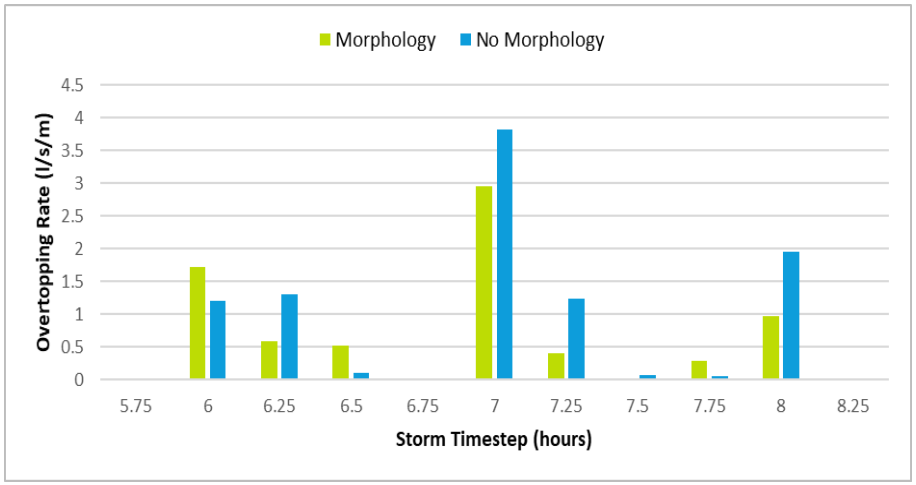


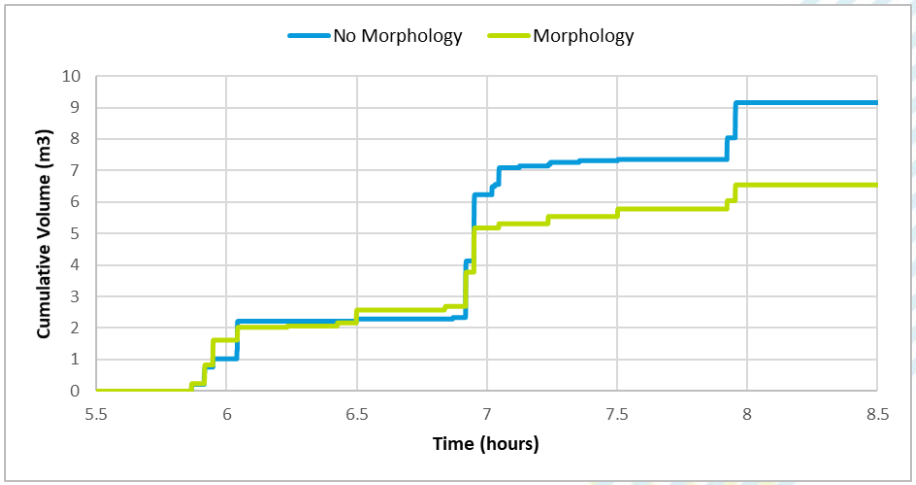
XBeach-G – Fixed Profile



XBeach-G – 2012 Results

- Highest overtopping rate for fixed profile = **3.8 l/s/m**
- Highest overtopping rate for dynamic profile = **3.0 l/s/m**
- Better than 200-yr but fails to meet design standard of **1.0 l/s/m**

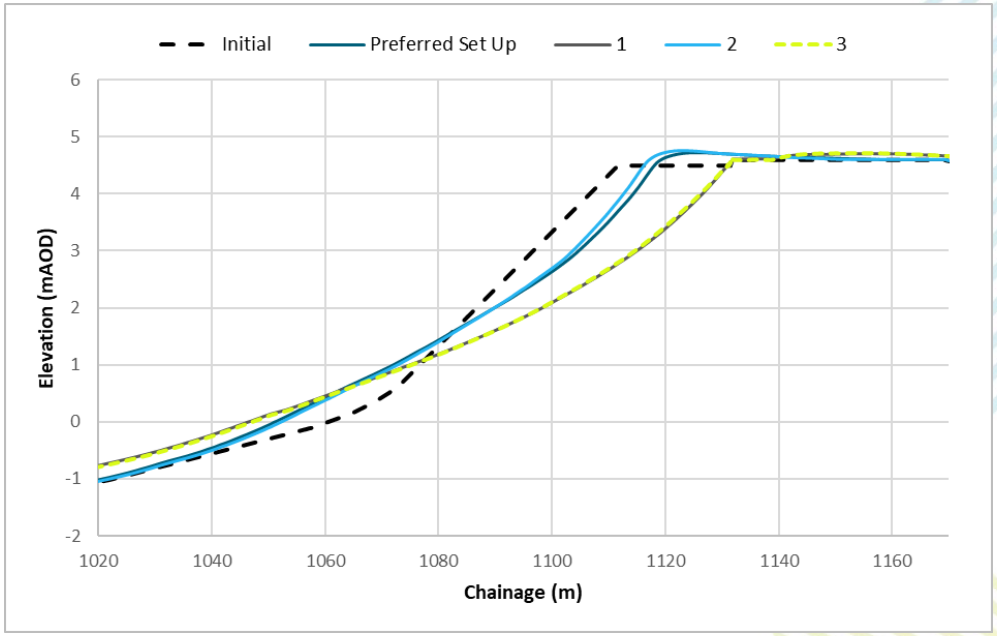




XBeach-G - Sensitivity Tests

1. Making no modification to the wave conditions at the boundary
2. Increasing the hydraulic conductivity of the beach
3. Combination of 1 and 2

- **OT rates range from 2 – 177 l/s/m**
- **Crest retreat ranges from 5 – 20m**



XBeach-G - Summary

- Flow rates comparable to EurOtop II and ANN wave overtopping rates for the fixed profile model
- The dynamic profile overtopping rates are significantly lower but still exceed the desirable limit of 1 l/s/m
- Around 7m of crest width (30%) is potentially lost during a 200-year storm event
- Very sensitive to model assumptions
- Requires calibration / validation for further design work

Conclusions and Recommendations

- If the 20m beach crest is built in present day conditions, based on ANN, the 1 l/s/m wave overtopping standard would be exceeded every 8-9 years.
- Raising the wall provides a larger efficiency in reducing overtopping than is achieved by widening the beach .
- Alternative methods of calculating overtopping rates provide even higher estimates and support level of risk.
- Simulating morphological response is shown to reduce rates but not below design standard.
- Design standard could be reduced but would caution against due to proximity of population and vulnerability. 2012 impact can be used for context.
- **Recommend the medium-term design of beach recharge scheme including raising the existing wall.**

What next?

- Study and it's recommendations will be prioritised by SEPA / Scottish Government.
- Scheme my be *funded*, *more design work* undertaken or *go no further.*
- In further phases the design will be optimised with the aim of maximising the efficiency of the beach as the primary defence along the entire section.
- The design presented here will be starting point for any future work.
- **This is a good start** – We have demonstrated a strong case for investment and that several solutions can be implemented