MOTT MACDONALD

Old Colwyn Promenade Defence & Active Travel Improvements

Wave Overtopping Assessment

15 June 2020

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1 Introduction

1.1 Project Background

Conwy County Borough Council (hereinafter referred to as the Client) require a detailed design to be carried out for a new coastal defence and active travel improvements on an approximately 1,250m long section of frontage at Old Colwyn.

Coastal defence works include:

- a large rock revetment
- protection works to existing outfalls that will be covered by the revetment
- a new pedestrian beach accesses to replace the existing ones,
- the raising and widening of the promenade.

Mott MacDonald have previously worked on nearby projects including Colwyn Bay Promenade Phase 1a & b, Colwyn Bay Promenade Phase 2 and regularly undertakes inspections along this frontage.

The existing promenade is inundated during storms, causing flooding. This will be exacerbated with future climate change. The promenade requires raising to safeguard the area from overtopping including allowances for future climate change.

Additionally, the provision of new coastal defences should enable additional regeneration and amenity benefits. This will include widening the promenade along the narrow sections to improve access for cyclists, pedestrians and vehicles.

1.2 Site Location

The site is in Colwyn Bay, North Wales. The project area is located between Porth Eirias carpark (by Colwyn Bay Watersports Centre) and Splash Point Old Colwyn.

Figure 1.1: Site Location

Source: Google Maps

This part of the frontage is fairly narrow and is mainly used by the public for cycling, walking, and fishing. There is currently no amenity on the beach or shops and restaurants on the landward side of the promenade. A railway runs along the back of the promenade on top a large embankment.

1.3 Purpose of this Report

This report aims to:

- Define existing waves, water levels and wave overtopping rates along the promenade
- Assess options and scenarios to reduce the amount of overtopping
- Make a recommendation of crest levels for revetment and promenade levels for the outline stage of the scheme based on international guidelines

2 Site Information

2.1 Design Life

The following design lives are based on the Employer's Requirements and Basis of Design (Mott MacDonald, 2020).

The design life of the coastal structures (revetment, fishing platform and steel sub-structures) is 50 years.

The design life for the other structural elements (walls, piles, new highway and promenade) is 120 years.

The design life for other ancillary design items such as guardrails, handrails and outfall grills are likely to have limited design lives in accordance with manufacturers designs.

2.2 Promenade and Beach Levels

Existing levels are derived from topographical drawings supplied by the Client (undertaken by Survey Operations dated April 2008.

Beach survey information is based on Penrhyn Bay – Colwyn Bay post storm survey undertaken in 2019 by Environmental & Engineering Services.

All levels used are in metres above ordnance datum (AOD). Horizontal control points are relative to the National Grid (OSGB36).

2.3 Tide Levels

Table 2.1 presents the tide levels which represent typical water level conditions along the frontage.

Table 2.1: Tide Levels at Colwyn Bay

Tide		Chart Datum (mCD)	Ordnance Datum (mOD)
Highest Astronomical Tide	HAT	+8.78	+4.68
Mean High Water Spring	MHWS	+7.80	+3.70
Mean High Water Neap	MHWN	+6.10	+2.00
Mean Sea Level	MSL	+4.21	+0.11
Ordnance Datum		+4.10	0.00
Mean Low Water Neap	MLWN	+2.29	-1.81
Mean Low Water Spring	MLWS	+0.66	-3.44
Lowest Astronomical Tide	LAT	-0.24	-4.34

Source: (Royal Haskoning, 2010)

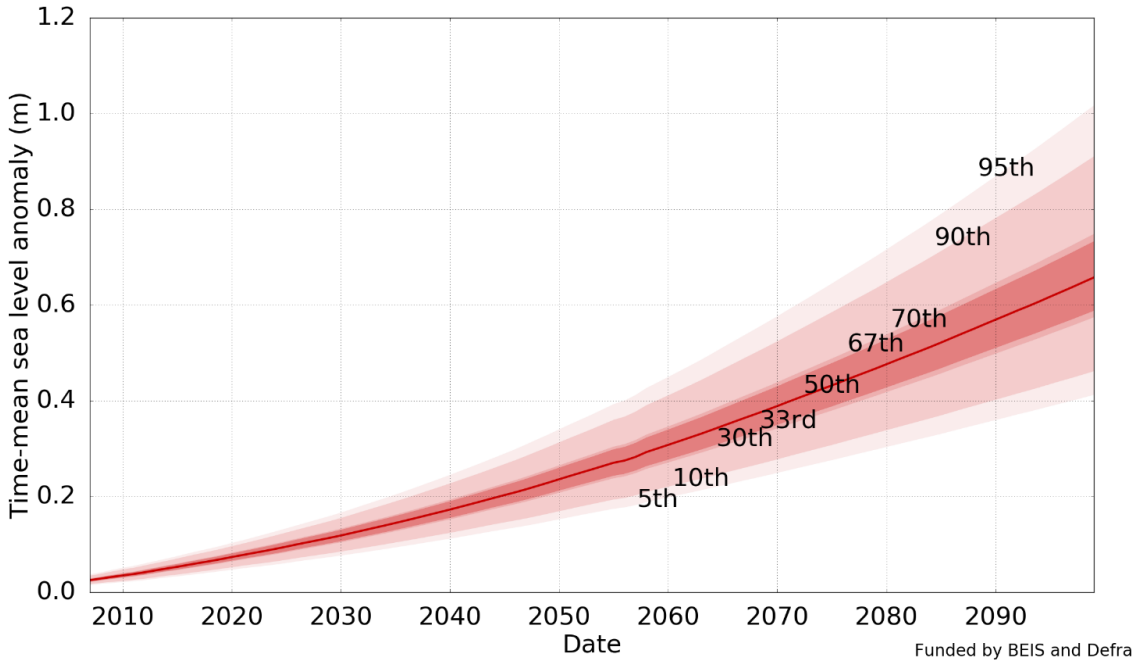
Note: MLWN and MLWS for Colwyn Bay calculation by interpolation between Llandudno and Hilbre Island.

2.4 Sea Level Rise

Tide data provided in Section 2.3 was published in the 2010 report but the actual baseline date for the levels was not provided. To allow adjustment of these levels to current mean sea levels, it has been conservatively been assumed that the data originates from 2007.

The assessment of the sea level rise covering the design life of the coastal structures is based on UK Climate Projections (UKCP 18) from (Met Office Hadley Centre, 2018). The value used in the overtopping calculation has been extracted from the data comprising the curve shown in Figure 2.1. The 95th percentile of the RCP8.5 scenario has been considered as a conservative approach at this stage. For the 50-year design life used to determine the proposed seawall design, a sea level rise allowance of 0.59m has been added to the sea levels.

Figure 2.1: UKCP18 Projections at Colwyn Bay – RCP8.5



Source: (Met Office Hadley Centre, 2018).

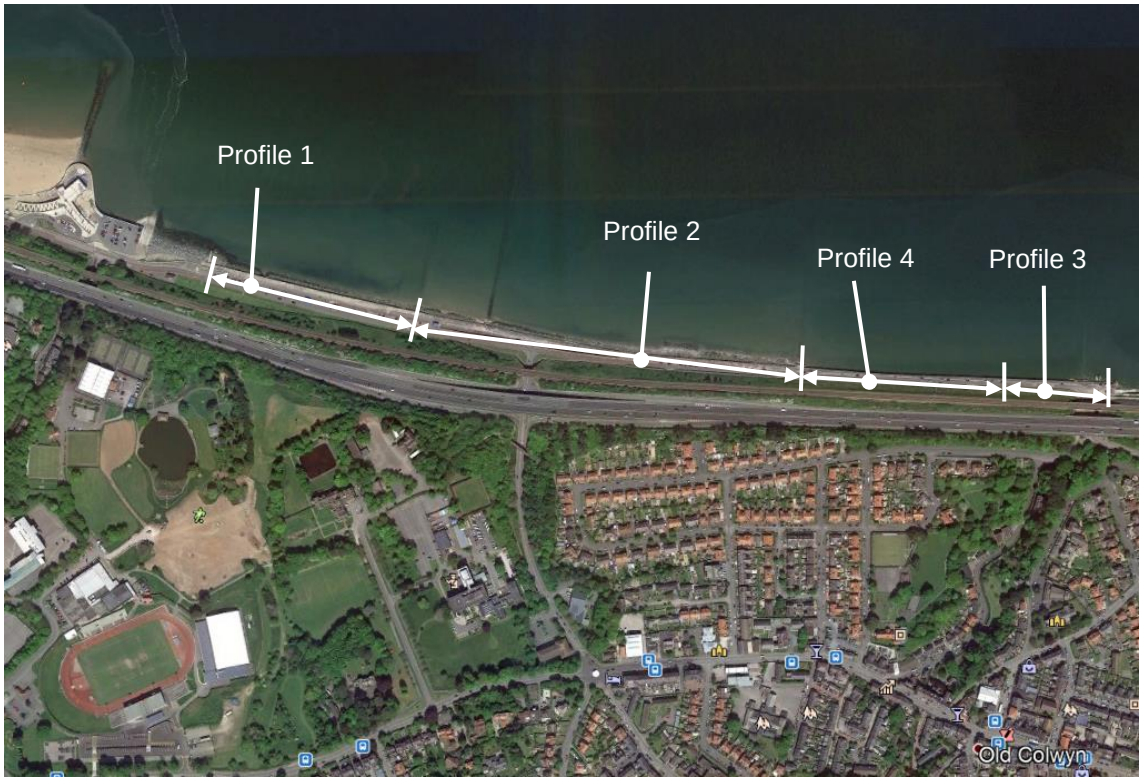
2.5 Beach Profile

The Old Colwyn Promenade frontage consists of a gently sloping sandy beach, with the geometry of the rock revetments varying along the project area. The eastern area does not include a rock revetment in front of the seawall.

The beach includes a number of stepped accesses from the promenade and a series of outfalls (owned by Welsh Water) and groynes.

The beach slope has been estimated from the beach survey at the location of four profiles. The location of these profiles can be seen in Figure 2.2.

Figure 2.2: Location of Beach Profiles



Source: Google Earth Pro (modified)

The geometry of the existing seawalls at the location of the four profiles is described in Table 2.2 as follows:

Table 2.2: Existing Seawall Levels

	Top of Seawall (m OD)	Toe of Seawall (m OD)	Wall Height (m)	Beach Slope
Profile 1	6.13	3.00	3.13	1 in 100
Profile 2	5.50	3.30	2.20	1 in 40
Profile 3	5.47	0.00	5.47	1 in 50
Profile 4	5.75	0.84	4.91	1 in 45

Photos of the structures and the beach at those profiles are shown in Photo 2.1 to Photo 2.4 below.

Photo 2.1: Profile 1

Source: MML Site Visit on 17th January 2020

Photo 2.2: Profile 2

Source: MML Site Visit on 17th January 2020

Photo 2.3: Profile 3

Source: MML Site Visit on 17th January 2020

Photo 2.4: Profile 4

Source: MML Site Visit on 17th January 2020

2.6 Beach Drawdown

Historic beach surveys dating back to 2005 along the Old Colwyn Promenade provided by the Client were reviewed to assess changes in beach levels over the years. The levels were checked at eight locations by the future beach step accesses.

The comparison between beach levels indicate that the beach is generally stable and that levels do not vary significantly with the control structures in place. The maximum variation in beach level is 0.7m while the variation at the other 7 locations varies between 0.1m and 0.5m. In light of those results a beach drawdown value of 0.5m from the current survey data has been adopted for the design of the beach steps with possibility for the steps to be extended in the future should localised erosion occur in the future (Mott MacDonald, 2020).

Local beach recharge or recycling may also be implemented if required over time.

2.7 Existing Storm Events

There is no formal record of road closures of the promenade highway from Rotary Way to Beach Road. However, it has been noticed that the number of closures has increased in recent years. The promenade is now routinely closed whenever spring tides coincide with forecast north or northwest winds.

In the past, overtopping has caused the surfacing of the promenade to get broken up, the handrails failed, sections of the seawalls have suffered from risk of undermining / voids to rear of the promenade, and the rear wall along the toe of the railway embankment has been damaged. These are repaired by the Client on a reactionary basis.

Photo 2.5: Damages to the promenade and the seawall

Source: https://www.bbc.co.uk/news/uk-wales-50069665

3 Wave Overtopping Assessment

To undertake an overtopping assessment, information on the existing extreme wave and water levels are required.

3.1 Joint Probability Analysis between Waves and Water Levels

The following joint probability of extreme waves and water levels have been extracted from (Royal Haskoning, 2010) a location offshore from Colwyn Bay.

Table 3.1: Joint probability of design waves and water levels

Return periods	WL (mOD)	Sop	Tm (s)	Hs (m)
1	2.84	0.03	6.35	2.18
	3.29	0.03	6.01	1.96
	3.75	0.03	5.58	1.71
	4.21	0.03	4.95	1.37
	4.67	0.03	2.89	0.54
10	2.84	0.03	7.70	3.15
	3.29	0.03	7.70	3.15
	3.75	0.03	7.61	3.08
	4.21	0.03	7.38	2.91
	4.67	0.03	7.02	2.65
	5.13	0.03	5.63	1.81
50	3.29	0.03	8.21	3.56
	3.75	0.03	8.17	3.54
	4.21	0.03	8.03	3.42
	4.67	0.03	7.82	3.25
	5.13	0.03	7.35	2.88
	5.58	0.03	5.58	1.71
100	3.29	0.03	8.42	3.74
	3.75	0.03	8.34	3.68
	4.21	0.03	8.25	3.60
	4.67	0.03	8.03	3.42
	5.13	0.03	7.70	3.15
	5.58	0.03	7.04	2.65
200	3.29	0.03	8.68	3.97
	3.75	0.03	8.67	3.96
	4.21	0.03	8.60	3.90
	4.67	0.03	8.41	3.74
	5.13	0.03	8.04	3.42
	5.58	0.03	7.57	3.05

Source: (Royal Haskoning, 2010) (part of table)

The offshore mean wave periods available in (Royal Haskoning, 2010) presented in Table 3.1 were propagated from the offshore location to the project area (toe of the proposed rock revetment) by applying the Goda shoaling formula. The effect of beach level fluctuations on the waves has also been included, including a 0.5m beach drawdown (section 2.6). An increase to the extreme water levels of Table 3.1 by 0.59m (section 2.4) was applied to assess the extreme water levels in 50 years' time accounting for sea level rise.

The results of the joint probability analysis of the design waves and water levels are shown in Table 3.2 and Table 3.3.

Table 3.2: Joint probability of design waves and water levels (present day)

Return period (joint probability) [yrs]	WL [mOD] (present day)	Extreme Wave Return Period R [yrs]	Tm [s]	Hs (toe) [m] Profile 1	Hs (toe) [m] Profile 2	Hs (toe) [m] Profile 3	Hs (toe) [m] Profile 4
1	2.84	0.45	8.90	1.76	1.68	2.43	2.22
	3.29	0.38	8.50	1.98	1.91	2.22	2.24
	3.75	0.33	8.05	2.00	2.07	2.01	2.05
	4.21	0.28	7.43	1.54	1.56	1.48	1.50
	4.67	0.21	5.92	0.56	0.57	0.55	0.55
10	2.84	2.68	10.66	1.88	1.80	2.55	2.34
	3.29	2.68	10.66	2.12	2.06	2.80	2.59
	3.75	1.93	10.54	2.36	2.31	3.05	2.85
	4.21	1.16	10.23	2.59	2.56	3.09	3.09
	4.67	0.73	9.75	2.82	2.80	2.93	2.95
	5.13	0.35	8.23	2.00	2.03	1.94	1.96
50	3.29	33.30	11.34	2.17	2.12	2.86	2.65
	3.75	28.54	11.31	2.42	2.38	3.11	2.91
	4.21	15.37	11.12	2.66	2.63	3.36	3.15
	4.67	6.11	10.85	2.88	2.87	3.45	3.39
	5.13	1.09	10.17	2.99	3.08	3.03	3.07
	5.58	0.33	8.05	1.86	1.88	1.81	1.83
100	3.29	108.34	11.62	2.20	2.14	2.88	2.67
	3.75	72.22	11.52	2.44	2.40	3.13	2.93
	4.21	50.00	11.40	2.68	2.65	3.38	3.18
	4.67	15.37	11.12	2.91	2.89	3.62	3.42
	5.13	2.68	10.66	3.12	3.12	3.34	3.36
	5.58	0.73	9.75	2.88	2.98	2.90	2.94

Source: MML

Table 3.3: Joint probability of design waves and water levels (in 50 years)

Return period (joint probability) [years]	WL [mOD] (in 50 years)	Extreme Wave Return Period R [yrs]	Tm [s]	Hs (toe) [m] Profile 1	Hs (toe) [m] Profile 2	Hs (toe) [m] Profile 3	Hs (toe) [m] Profile 4
1	3.43	0.45	8.90	2.09	2.02	2.44	2.46
	3.88	0.38	8.50	2.18	2.25	2.20	2.24
	4.34	0.33	8.05	1.92	1.96	1.86	1.89
	4.8	0.28	7.43	1.50	1.52	1.46	1.47
	5.26	0.21	5.92	0.55	0.56	0.55	0.55
10	3.43	2.68	10.66	2.20	2.14	2.88	2.67
	3.88	2.68	10.66	2.44	2.40	3.14	2.93
	4.34	1.93	10.54	2.68	2.66	3.27	3.18
	4.8	1.16	10.23	2.91	2.90	3.09	3.11
	5.26	0.73	9.75	2.88	2.98	2.92	2.95
	5.72	0.35	8.23	1.97	1.99	1.91	1.93
50	3.88	33.30	11.34	2.49	2.46	3.19	2.98
	4.34	28.54	11.31	2.74	2.72	3.45	3.24
	4.8	15.37	11.12	2.98	2.97	3.63	3.49
	5.26	6.11	10.85	3.21	3.21	3.45	3.47
	5.72	1.09	10.17	2.99	3.09	2.98	3.02
	6.17	0.33	8.05	1.83	1.85	1.79	1.80
100	3.88	108.34	11.62	2.52	2.48	3.21	3.01
	4.34	72.22	11.52	2.76	2.74	3.46	3.26
	4.8	50.00	11.40	3.00	2.99	3.71	3.52
	5.26	15.37	11.12	3.23	3.23	3.63	3.65
	5.72	2.68	10.66	3.27	3.38	3.31	3.36
	6.17	0.73	9.75	2.89	2.98	2.87	2.90

Source: MML

3.2 Scenarios

The following scenarios have been considered as part of the wave overtopping assessment (both for present day and in 50 years, including beach drawdown):

- Case 1: Existing structure and foreshore geometry (Baseline) including beach drawdown
- Case 2: Revetment up to existing crest level of seawall
- Case 3: Revetment up to +7.00m OD, promenade at +7.00m OD
- Case 4: Revetment up to +7.50m OD, promenade at +7.00m OD
- Case 5: Revetment up to +7.50m OD with crest and crest wall up to +8.15m OD and promenade at +7.00m OD)

The crest width of the revetment was set at 5m and its slope at 1V to 3H.

3.3 Wave Overtopping Formulae

Overtopping hazards are assessed by determining the volume of water that passes over the crest of the defence. Hazards driven by overtopping can be linked to a number of flow parameters. The outputs of overtopping analysis undertaken utilising the EurOtop Manual 2018 (Van der Meer, et al., 2018) are:

- Mean overtopping discharge (q), defined as the average overtopping volume from all waves, it is estimated in litres per second per metre length of seawall.
- Individual maximum overtopping volume (V_{max}), is defined as the maximum discharge from a single wave in litres per metre length of seawall.

These parameters (q and V_{max}) are checked against defined criteria to establish the performance of differing geometric structure configurations. In the latest EurOtop V_{max} is the preferred parameter to define overtopping hazard as this represents the maximum wave overtopping based on the structure geometry, wave conditions and typical wave distributions. Definition of the criteria for V_{max} are less established and therefore the overtopping assessment will make use of both parameters, refer to Section 3.4.

When defining the required overtopping performance of a structure it is important to consider:

- The frequency of the overtopping event; and,
- The receptors (assets, people…) at risk behind the overtopping point.

The frequency of the overtopping events, assessed by the return periods set in the joint probability analysis should relate to the expectations of the users of the structures, highway and promenade and the requirements of the asset owners/ managers.

The EurOtop Manual gives empirical formulations, or neural net/gaussian interpolation methods, that predict either the best fit to the test data or upper bound. The upper bound values of the predictions were used.

The EurOtop Manual II – 2018 Equations 5.12 & 5.13, as shown below, are used to determine the overtopping discharge on the smooth revetment sections of the scheme (armour slope smoother than 1V to 2H).

Figure 3.1: Equations for overtopping discharge of smooth revetment

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = \frac{0.026}{\sqrt{\tan\alpha}} \gamma_b \cdot \xi_{m-1,0} \cdot \exp\left[-\left(2.5 \frac{R_c}{\xi_{m-1,0} \cdot H_{m0} \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma_v}\right)^{1.3}\right] \quad 5.12$$

with a maximum of: $$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma^*}\right)^{1.3}\right] \quad 5.13$$

Source: (Van der Meer, et al., 2018).

The following EurOtop Manual II – 2018 Equation 6.6, as shown below, is used to determine the overtopping discharge on the steep revetment sections of the scheme (armour slope equal or steeper than 1V to 2H).

Figure 3.2: Equation for overtopping discharge of steep revetment

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta}\right)^{1.3}\right] \text{ for steep slopes 1:2 to 1:4/3} \quad 6.6$$

Source: (Van der Meer, et al., 2018).

The overtopping discharge at the vertical wall sections of the scheme have been determined by the EurOtop Manual II – 2018 Equation 7.2, as shown below:

Figure 3.3: Equation for overtopping discharge of vertical wall

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.054 \cdot \exp\left[-\left(2.12 \frac{R_C}{H_{m0}}\right)^{1.3}\right] \quad 7.2$$

Source: (Van der Meer, et al., 2018).

Inputs to the calculations comprise the water levels, wave heights and wave periods for each profile that resulted from the joint probability analysis, both at present day and in 50 years, the structure geometry and the beach profile for each of the profiles investigated (including beach drawdown).

The main assumptions for the calculation are as follows:

- Storm duration = 6 hours.
- Roughness of revetment γ_f = 0.55 for two-layer rock armour with impermeable core (EurOtop II)
- Concrete surface of vertical walls
- Waves acting perpendicular to the structure
- No berm
- Bullnose (Return Wall) width Br = 0.5m and height hr = 1m at Access Build-out.

3.4 Wave Overtopping Criteria

The following criteria set out in EurOtop II Manual (Van der Meer, et al., 2018) and in the EurOtop Manual (Pullen, et al., 2007), have been reviewed to assess the level of risk associated with wave overtopping for the different scenarios. The discharge limits act as guidelines to assess the frequency of extreme waves exceeding the level of the proposed sea defences.

Table 3.4: Overtopping limits for structural design of breakwaters, seawalls, dikes

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
Rubble mound breakwaters; H_{m0} > 5 m; no damage	1	2,000-3,000
Rubble mound breakwaters; H_{m0} > 5 m; rear side designed for wave overtopping	5-10	10,000-20,000

Source: (Van der Meer, et al., 2018).

Table 3.5: Overtopping limits for people and vehicles (EurOtop II)

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
People at structures with possible violent overtopping, mostly vertical structures	No access for any predicted overtopping	No access for any predicted overtopping
People at seawall / dike crest. Clear view of the sea. H_{m0} = 3 m H_{m0} = 2 m H_{m0} = 1 m H_{m0} < 0.5 m	 0.3 1 10-20 No limit	 600 600 600 No limit
Cars on seawall / dike crest, or railway close behind crest H_{m0} = 3 m H_{m0} = 2 m H_{m0} = 1 m	 <5 10-20 <75	 2000 2000 2000
Highways and roads, fast traffic	Close before debris in spray becomes dangerous	Close before debris in spray becomes dangerous

Source: (Van der Meer, et al., 2018).

Table 3.6: Tolerable discharge comparison between EurOtop Manual I & II

Return Period	Tolerable Discharge	Comment	Reference
1 in 1 year	q< 1 l/s per m V_{max}< 600 l/m.	For people and vehicles - People at seawall / dike crest. Clear view of the sea. H_{m0} = 2m.	EurOtop (2018): Table 3.3
1 in 1 year	q< 1-10 l/s per V_{max}< 500 l/m at low level.	Trained staff, well shod and protected, expecting to get wet, overtopping flows at lower levels only, no falling jets, low danger of fall from walkway.	EurOtop (2007): Table 3.2
1 in 200 year	-	No limits given for vertical structures or promenades	EurOtop (2018)
1 in 200 year	q< 200 l/s per m	No damage to paved or armoured promenade behind seawall.	EurOtop (2007): Table 3.5

Source: (Van der Meer, et al., 2018).

Table 3.7: Overtopping limits for damage to the defence crest (EurOtop Manual I – 2007)

Hazard type and reason	Mean discharge q (l/s/m)
Embankment seawalls/sea dikes	
No damage if crest and rear slope are well protected	50–200
No damage to crest and rear face of grass covered embankment of clay	1–10
No damage to crest and rear face of embankment if not protected	0.1
Promenade or revetment seawalls	
Damage to paved or armoured promenade behind seawall	200
Damage to grassed or lightly protected promenade or reclamation cover	50

Source: (Pullen, et al., 2007).

Table 3.8: Overtopping limits for people and vehicles (EurOtop Manual I – 2007)

Hazard type and reason	Mean discharge	Max volume(1)
	q (l/s/m)	V_{max} (l/m)
Trained staff, well shod and protected, expecting to get wet, overtopping flows at lower levels only, no falling jet, low danger of fall from walkway	1–10	500 at low level
Aware pedestrian, clear view of the sea, not easily upset or frightened, able to tolerate getting wet, wider walkway(2).	0.1	20–50 at high level or velocity

Source: (Pullen, et al., 2007).

In principle the overtopping limits are taken from the latest industry standard guidance, EurOtop Manual 2018 (Van der Meer, et al., 2018) as shown above. However, for areas of promenade and carriageway landward of the crest no limits are given in the current version of the guidance and the limits from the previous version of the guidance have been adopted, as shown in Table 3.9. Those values are defined to ensure that the paved promenade is not damaged during extreme events behind the crest of the revetment/ seawall.

Table 3.9: Recommended discharge limits for assets

Surface	q [l/m/s]	Return period (years)
Paved	200	100
Grass	50	100

For pedestrian and vehicle access near the crest of the structure because the area does not provide essential access, but only amenity access, the overtopping limits will be assessed for the 1 in 1-year and 1 in 10-year wave and water level conditions. The risk for pedestrians and vehicles will be assessed as part of a risk assessment and mitigation measures such as promenade or road closure will be assessed.

Table 3.10: Recommended discharge limits for users

User	Vmax [l/m]	Return period (years)
Pedestrian	600	1 - 10
Vehicle	2,000	1 - 10

Overtopping measurements vary widely even within a single series of tests in physical modelling. It would not be unreasonable to expect the results of a physical model to be between a half and twice the predicted value for the structure. Strict adherence to the specified overtopping limits, particularly as they are upper bound predictions, is not appropriate as in many instances this may result in impractical structures. For instance, if a wave wall was designed as a standard height parapet and the predictions exceeded the limit by 20% that would be deemed acceptable. However, when criteria are relaxed the risk consequences should be fully understood and supported through risk assessment.

3.5 Wave Overtopping Results

The estimated overtopping results are presented in Table 3.11 to Table 3.15 below per return period and profile location. The results cover the different scenarios described in section 3.2 and consider both present day and 50-year situations at each profile, including beach drawdown. The calculations are provided in Appendix A.

Table 3.11: Overtopping results – Case 1

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass (P)/ Exceed (E) criteria
Profile 1	**1**	53	11,852	82	16,596	E
	10	421	43,706	656	52,180	E
	50	683	52,981	918*	55,452*	E
	100	789	54,551	955*	55,789*	E
Profile 2	**1**	125	17,384	194	22,341	E
	10	236	21,581	295*	25,126*	E
	50	275*	22,665*	336**	26,138**	E
	100	287*	22,983*	354**	26,552**	E
Profile 3	**1**	96	20,623	188	33,267	E
	10	689	57,450	948*	62,159*	E
	50	1,071*	61,692*	1,343**	62,130**	E
	100	1,206**	62,725**	**	**	E
Profile 4	**1**	81	17,883	131	23,505	E
	10	590	54,901	869*	49,452*	E
	50	899*	60,195*	1,301**	51,090**	E
	100	935*	60,605*	1,458**	51,435**	E

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

Table 3.12: Overtopping results – Case 2

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass/ Exceed criteria
Profile 1	**1**	16	141	46	673	P/E
	10	391	1,225	802	18,124	E
	50	772	2,351	1,313*	27,422*	E
	100	860	3,001	1,545*	38,332*	E
Profile 2	**1**	73	179	135	2,683	P/E
	10	784	1,890	1,473*	26,085*	E
	50	1,430*	4,128*	1,669**	39,311**	E
	100	1,461*	4,550*	1,688**	41,343**	E
Profile 3	**1**	67	157	128	2,216	P/E
	10	899	2,392	1,453*	25,621*	E
	50	1,285*	5,350*	1,909**	43,843**	E
	100	1,680*	6,077*	2,067**	48,876**	E
Profile 4	**1**	42	157	85	1,756	P/E
	10	689	2,016	1,206	23,150	E
	50	982	4,192	1,631*	40,335*	E
	100	1,401	5,298	1,979**	44,522**	E

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

Table 3.13: Overtopping results – Case 3

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass/ Exceed criteria
Profile 1	**1**	0	125	1	423	P
	10	27	709	67	10,329	E
	50	73	1,289	143	17,292	P
	100	95	1,665	229	26,030	P/E
Profile 2	**1**	0	154	1	815	P/E
	10	25	686	76	11,722	E
	50	88	1,508	158	18,659	P
	100	122	1,670	251	28,442	P/E
Profile 3	**1**	0	277	1	443	P
	10	36	867	70	10,729	E
	50	105	2,105	164	22,593	P
	100	140	2,696	237	26,749	P/E
Profile 4	**1**	0	201	1	485	P
	10	37	896	74	11,125	E
	50	95	1,942	167	22,951	P
	100	147	2,405	246	27,455	P/E

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

Table 3.14: Overtopping results – Case 4

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass/ Exceed criteria
Profile 1	1	0	89	0	252	P
	10	13	575	35	7,143	P/E
	50	39	958	81	12,520	P
	100	54	1,010	138	19,809	P
Profile 2	1	0	120	0	563	P
	10	12	557	41	8,434	P/E
	50	48	1,122	91	13,574	P
	100	68	1,200	154	22,345	P
Profile 3	1	0	215	0	265	P
	10	18	692	37	7,477	E
	50	60	1,622	98	17,052	P
	100	83	2,077	144	20,478	P
Profile 4	1	0	153	0	294	P
	10	19	714	39	7,810	E
	50	54	1,496	100	17,376	P
	100	86	1,795	150	21,136	P

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

Table 3.15: Overtopping results – Case 5

		Present Day		In 50 years		
	Return period (joint probability) [yrs]	q [l/m/s]	Vmax [l/m]	q [l/m/s]	Vmax [l/m]	Pass/ Exceed criteria
Profile 1	**1**	0	16	0	51	P
	10	3	1,264	8	2,465	E
	50	9	2,945	20	5,437	P
	100	14	4,068	42	8,655	P
Profile 2	**1**	0	25	0	75	P
	10	2	1,194	11	3,160	E
	50	12	3,691	27	5,973	P
	100	17	4,167	53	10,567	P
Profile 3	**1**	0	53	0	109	P
	10	4	1,744	9	2,726	E
	50	17	5,818	36	8,758	P
	100	26	8,012	52	11,919	P
Profile 4	**1**	0	34	0	118	P
	10	4	1,837	10	3,000	E
	50	15	5,200	38	9,117	P
	100	25	6,774	54	12,380	P

* risk of flooding of the promenade (water level close to crest level of the seawall)
** frequently flooded (water level exceeds crest level of promenade)

4 Interpretation of Results and Recommendations

4.1 Interpretation of Results

The initial overtopping results for the existing structures and geometries were presented in Table 3.11 (**Case 1**). For the 1 in 10-year return period, at present day, the maximum mean overtopping discharge q estimated is 689 l/m/s with a maximum overtopping volume V_{max} of 57,450 l/m and flooding occurring in 50 years when considering the sea level rise (Profile 3). These values are significantly higher than the limits proposed by guidelines and impose risk to public health and safety. Existing structures are at high risk of flooding and damage during extreme events as overtopping values significantly exceed the overtopping criteria presented in section 3.4.

Case 1 – Existing structure and foreshore geometry (Baseline) including beach drawdown

- Extremely high wave discharge volumes (both mean and peak)
- Promenade flooded at profiles 2, 3 and 4 from 1 in 10 year events and from 1 in 50 year events at profile 1 (higher crest level).
- Exceeds defined overtopping limits
- Unsafe for the public for all extreme events
- Severe damage to the promenade, the highway and the highway equipment

For Case 2, the mean overtopping discharges are comparable to Case 1 in terms of mean discharge value with a more noticeable reduction in terms of the maximum volume. Those values still pose risks to public health and safety and leave the protected structures at high risk of flooding and damage during extreme events.

Case 2 – Revetment up to existing crest level of seawall

- Extremely high wave discharge volumes (both mean and peak)
- Promenade flooded at profiles 2, 3 from 1 in 10 year events and from 1 in 50 year events at profiles 1 and 4.
- Mean overtopping discharges comparable to Case 1. Maximum overtopping volumes are divided by 13 in average compared to Case 1 at present day.
- Exceeds defined overtopping limits
- Unsafe for the public for all extreme events
- Severe damage to the promenade, the highway and the highway equipment

For **Case 3**, the mean discharges are significantly reduced compared to the existing defence. However, the maximum overtopping volumes remain over the criteria set in section 3.4 with high risks associated to public safety and potential damage to protected structures.

The mean overtopping discharge q remains under the limit for structures of 200 l/m/s (exceeded only for 1 in 100 year events in 50 years' time) and the maximum overtopping volume is reduced under the limit of 600 l/m (pedestrians) for 1 in 1 year events at present day.

Case 3 – Revetment up to +7.00m OD, promenade at +7.00m OD

- Overtopping results are significantly reduced and meet most of the criteria set at present day
- Mean overtopping discharges are reduced by 90% in average compared to Case 1 (Baseline) at present day. Maximum overtopping volumes are reduced by 97% in average compared to Case 1 at present day.
- Exceeds defined mean overtopping discharge limit for assets in 50 years' time for 1 in 100 year events.
- Exceeds maximum overtopping limit for vehicles at present day and just meets limit for pedestrians for 1 in 1 year events in 50 years' time.

For **Case 4**, the mean overtopping discharges are significantly reduced compared to Case 1, with the mean overtopping discharge q remaining under the limit for structures of 200 l/m/s for all cases and the maximum overtopping volume reduced under the limit of 600 l/m (pedestrians) for 1 in 1 year events.

Case 4 – Revetment up to +7.50m OD, promenade at +7.00m OD

- Overtopping results are significantly reduced and meet all the criteria set at present day and in 50 years 'time
- Mean overtopping discharges are reduced by 94% in average compared to Case 1 (Baseline) at present day. Maximum overtopping volumes are reduced by 98% in average compared to Case 1 at present day.
- Meets defined mean overtopping discharge limit for assets in all return periods
- Meets maximum overtopping limit for vehicles at present day and meets limit for pedestrians for 1 in 1 year events in 50 years' time. Exceeds that limit for 1 in 10 year events and beyond.

For **Case 5**, the mean overtopping discharges are significantly reduced compared to Case 1, with the mean overtopping discharge q being under the limit for structures of 200 l/m/s for all cases and reducing the maximum overtopping volume under the limit of 600 l/m (pedestrians) for 1-1 year events, in close range of the 1 in 10 year events.

Case 5 – Revetment up to +7.50m OD with crest and crest wall up to +8.15m OD (with associated promenade at +7.00m OD)

- Overtopping results are significantly reduced and meet the criteria set at present day and in 50 years 'time
- Mean overtopping discharges are reduced by 99% in average compared to Case 1 (Baseline) at present day.
- Meets defined mean overtopping discharge limit for assets in all return periods
- Meets limit for pedestrians for 1 in 1 year events in 50 years' time. Exceeds that limit for 1 in 10 year events and beyond.

4.2 Potential Mitigations and Adaptations

Road Closure

Mitigation measures such as promenade/ road closure during severe storms are required to keep the crest level at a reasonable level. In case of extreme storm events beyond 1 in 10-year return period, road closure might be required. Barriers would be reinstalled to prevent vehicular access to the promenade and an agreed mitigation for baring non-motorised users (pedestrians, cyclists etc) from entering the promenade such as VMS signage or physical barriers.

Climate Resilience

It is recommended that the new promenade proposed be adaptable for the future (beyond 50 years). Considering the effects of sea level rise, it is likely that a raising of the sea defences be required after a certain time. This is judged as a more cost-efficient approach rather than raising the promenade to 120-year design criteria at present day.

This would materialise as a setback distance left in the promenade to build a new crest wall or building a crest wall which can be raised in the future. The crest of the rock revetment has been designed so that it can also be raised in the future as required.

Raising the road and the promenade after 50 years is more challenging, that is why it is recommended to carry out those works at present day as highway infrastructure is less adaptable than the coastal defence.

4.3 Summary

The results for **Case 1 and Case 2** (keeping the existing crest level of the seawall) are well above the defined overtopping limits (section 3.4) and would not be safe for users as well as for the integrity of the promenade, road and embankment. Severe damages would be caused during extreme events, as it is already happening, and the frequency and severity of those damages is likely to increase with sea level rise. The railway embankment is likely to suffer damages when the promenade/road is flooded during the 1 in 50 and 1 in 100-year events.

Case 3 (revetment crest at +7.00m OD) represents a significant improvement compared to **Case 1 and Case 2** as it prevents the promenade from flooding and reduces the overtopping volumes to more reasonable values, particularly for the 1 in 1 year events. However even with the widening of the crest, this scenario is not estimated to be sufficient to meet the defined overtopping criteria in 50 years' time.

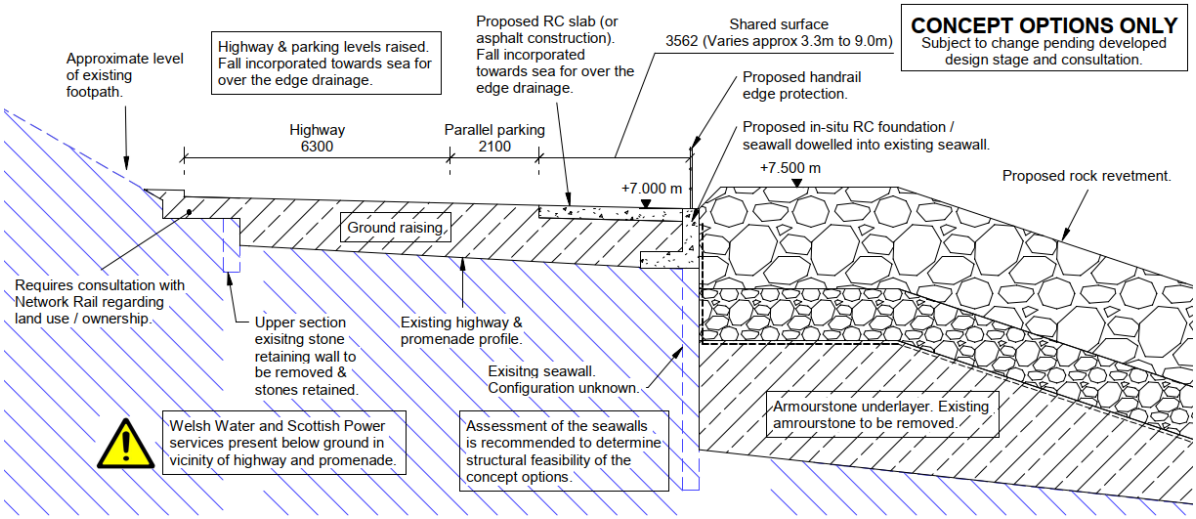
The results for **Case 4 and Case 5** (revetment crest at +7.50m OD, and crest wall at +8.15m OD for **Case 5**) are either within or in close range of the defined overtopping limits at present day and in 50 years' time.

Including certain mitigations (road closure for 1 in 10-year events) and potential for future adaptations, **Case 4** is considered to be the most suitable option to take forward. **Case 4** meets the criteria set for paved assets and generates very significant reduction in wave discharges compared to the existing defences, while still being feasible, cost efficient and adaptable. Crest levels below +7.50m OD are unlikely to meet the defined overtopping criteria which ensure durability of the assets/ structures and the safety of the public.

4.4 Outline Recommended Crest Level and Promenade Level

Based on the results presented and considering the levels of the existing structures at both extremities of the promenade (Porth Eirias and Splash Point), **Case 4** is the recommended design solution to protect the promenade from wave overtopping.

Figure 4.1: Illustration of proposed promenade raising and rock revetment crest



Mitigation measures such as promenade/ road closure are required to keep the crest level at the reasonable level proposed.

Physical modelling studies are recommended to validate the empirical formulae extracted from the EurOtop Manual used in this present study.

5 References

Met Office Hadley Centre. (2018). *UK Climate Projections (UKCP 18)*. Retrieved from Met Office: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index

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Appendices

A. Overtopping Calculations 29

A. Overtopping Calculations

Project				
Colwyn Bay Old Promenade Coastal Defence				
Wave Overtopping Formulae	Dvn/dept	MNC/PCO	Job no/file no	415437
	Calculated by	NS	Date	10/02/2020
	Checked by	FL	Date	15/02/2020

Sheet no 1 of 2

Wave Overtopping Formulae

Overtopping Discharge for Smooth Revetment:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = \frac{0.026}{\sqrt{\tan\alpha}} \gamma_b \cdot \xi_{m-1,0} \cdot \exp\left[-\left(2.5 \frac{R_c}{\xi_{m-1,0} \cdot H_{m0} \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma_v}\right)^{1.3}\right] \qquad 5.12$$

with a maximum of: $$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta \cdot \gamma^*}\right)^{1.3}\right] \qquad 5.13$$

Overtopping Discharge for Steep Revetment:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.1035 \cdot \exp\left[-\left(1.35 \frac{R_c}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta}\right)^{1.3}\right] \quad \text{for steep slopes 1:2 to 1:4/3} \qquad 6.6$$

Overtopping Discharge for Vertical Wall:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.054 \cdot \exp\left[-\left(2.12 \frac{R_C}{H_{m0}}\right)^{1.3}\right] \qquad 7.2$$

Parameters:

q	=	wave overtopping discharge (l/m/s)	γ_b	=	influence factor for a berm
g	=	gravitational acceleration constant (m/s^2)	γ_f	=	influence factor for roughness elements on a slope
H_{m0}	=	Offshore Wave Height (m)	γ_β	=	influence factor for oblique wave attack
α	=	angle between overall structure slope and horizontal (°)	γ_v	=	influence factor for a wall at the end of a slope
$\xi_{m-1,0}$	=	Breaker Parameter	γ^*	=	influence factor for non breaking waves for a storm wall on a slope or promenade
R_c	=	crest freeboard of structure (m)			

Project				
Colwyn Bay Old Promenade Coastal Defence				
Wave Overtopping Formulae	Dvn/dept	MNC/PCO	Job no/file no	415437
	Calculated by	NS	Date	10/02/2020
	Checked by	FL	Date	15/02/2020

Sheet no 2 of 2

Maximum Overtopping Volume (Revetment):

$$V_{\max} = a \cdot [\ln(N_{ow})]^{1/b} \qquad 5.57$$

α, b = parameters of the Weibull distrubution calculated from equations 5.53 & 5.54

Now = given by P_{ov} x N_w calculated from EurOtop II (2018) equations 5.52 & 5.56

Maximum Overtopping Volume (Vertical Wall):

$$V_{max} = a(lnN_{ow})^{1/b} \qquad 7.27$$

Calculated in accordance to EurOtop II (2018) equations 7.24 - 7.33

Reduction factor due to wide crest:

$C_r = 3.06 \exp(-1.5G_c/H_{m0})$ with maximum $C_r = 1$ 6.8

Return wall (Bullnose) reduction factor K_{bn}:

$$k_{bn} = \frac{q_{\text{with\_bullnose}}}{q_{\text{without\_bullnose}}} \qquad 7.23$$

Calculated in accordance to EurOtop II (2018) figures 7.21& 7.23 and equations 7.21 & 7.22

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment	Calculated by	NS	Date	10/02/2020
Profile 1 (Beach Drawdown)	Checked by	NC	Date	31/03/2020

Sheet no 1 of 5

OVERTOPPING CALCULATIONS: PROFILE 1

Existing structure and foreshore geometry - Case 1

Crest Level:	+6.13 mOD	Revetment Crest:	+3 mOD
Toe Level:	+0.89 mOD	Revetment Slope:	1: 5.15 m

	Present Day			In 50 years (including SLR)		
Return period (joint probability) [yrs]	**Freeboard R_c [m]**	**q [l/m/s]**	**V_{max} [l/m]**	**Freeboard R_c [m]**	**q [l/m/s]**	**V_{max} [l/m]**
1	3.29	0	2	2.70	52	9,453
	2.84	36	7,102	2.25	89	16,556
	2.38	53	11,852	1.79	82	16,596
	1.92	27	10,206	1.33	55	9,597
	1.46	1	1,021	0.87	2	1,637
10	3.29	0	4	2.70	78	11,168
	2.84	59	8,744	2.25	168	21,503
	2.38	133	17,959	1.79	316	34,906
	1.92	251	30,364	1.33	522	47,815
	1.46	421	43,706	0.87	656	52,180
	1.00	211	23,388	0.41	27	2,401
50	2.84	70	9,442	2.25	193	22,570
	2.38	156	19,087	1.79	361	36,272
	1.92	295	31,893	1.33	600	49,292
	1.46	497	45,383	0.87	918	55,452
	1.00	683	52,981	0.41	73	3,171
	0.55	20	1,837	-0.04	*	*
100	2.84	75	9,749	2.25	204	23,030
	2.38	164	19,423	1.79	375	36,670
	1.92	311	32,397	1.33	627	49,766
	1.46	520	45,862	0.87	955	55,789
	1.00	789	54,551	0.41	89	3,208
	0.55	59	3,499	-0.04	*	*

* With $R_c < 0$ flooding occurs, water level above crest. No overtopping can be defined.

Revetment to existing wall crest level, 1:3 Slope, 5m crest width - Case 2

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	3.29	1	3.54	37	2.70	11	4.05	445
	2.84	5	3.82	132	2.25	37	4.12	1,061
	2.38	16	3.77	141	1.79	46	3.64	673
	1.92	9	2.95	44	1.33	39	2.90	165
	1.46	0	1.20	0	0.87	0	1.19	0
10	3.29	1	4.00	57	2.70	16	4.54	679
	2.84	9	4.41	181	2.25	69	4.93	2,565
	2.38	46	4.78	310	1.79	213	5.30	7,177
	1.92	153	5.09	599	1.33	504	5.59	15,003
	1.46	391	5.35	1,225	0.87	802	5.44	18,124
	1.00	250	3.80	250	0.41	588	3.74	3,933
50	2.84	11	4.61	205	2.25	77	5.14	3,038
	2.38	53	5.02	362	1.79	232	5.54	8,487
	1.92	171	5.37	728	1.33	539	5.88	17,852
	1.46	422	5.68	1,508	0.87	1,031	6.18	30,159
	1.00	772	5.70	2,351	0.41	1,313	5.70	27,422
	0.55	425	3.55	247	-0.04	*	*	*
100	2.84	12	4.70	216	2.25	81	5.23	3,266
	2.38	55	5.09	379	1.79	238	5.61	8,908
	1.92	177	5.46	776	1.33	551	5.97	18,872
	1.46	432	5.77	1,599	0.87	1,047	6.27	31,716
	1.00	860	6.01	3,001	0.41	1,545	6.24	38,332
	0.55	1,094	5.45	2,652	-0.04	*	*	*

* With $R_c < 0$ there is flooding, water level above crest. No overtopping defined.

Revetment to +7.0m OD, 1:3 Slope, 5m crest width - Case 3

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.16	0	3.54	10	3.57	0	4.05	165
	3.71	0	3.82	79	3.12	1	4.12	423
	3.25	0	3.77	125	2.66	0	3.64	233
	2.79	0	2.95	20	2.20	0	2.90	41
	2.33	0	1.20	0	1.74	0	1.19	0
10	4.16	0	4.00	17	3.57	0	4.54	239
	3.71	0	4.41	114	3.12	2	4.93	1,031
	3.25	1	4.78	268	2.66	11	5.30	3,310
	2.79	7	5.09	406	2.20	40	5.59	8,058
	2.33	27	5.35	709	1.74	67	5.44	10,329
	1.87	4	3.80	150	1.28	10	3.74	1,502
50	3.71	0	4.61	134	3.12	3	5.14	1,217
	3.25	2	5.02	299	2.66	13	5.54	3,912
	2.79	8	5.37	472	2.20	47	5.88	9,575
	2.33	32	5.68	853	1.74	128	6.18	18,788
	1.87	73	5.70	1,289	1.28	143	5.70	17,292
	1.42	5	3.55	123	0.83	13	3.50	1,593
100	3.71	0	4.70	143	3.12	3	5.23	1,309
	3.25	2	5.09	309	2.66	14	5.61	4,110
	2.79	9	5.46	497	2.20	49	5.97	10,131
	2.33	33	5.77	900	1.74	133	6.27	19,755
	1.87	95	6.01	1,665	1.28	229	6.24	26,030
	1.42	100	5.45	1,413	0.83	193	5.46	18,907

Revetment to +7.5m OD, 1:3 Slope, 5m crest width - Case 4

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	**Freeboard R_c [m]**	**q [l/m/s]**	**$R_{u2\%}$ [m]**	**V_{max} [l/m]**	**Freeboard R_c [m]**	**q [l/m/s]**	**$R_{u2\%}$ [m]**	**V_{max} [l/m]**
1	4.66	0	3.54	3	4.07	0	4.05	92
	4.21	0	3.82	45	3.62	0	4.12	252
	3.75	0	3.77	89	3.16	0	3.64	129
	3.29	0	2.95	10	2.70	0	2.90	19
	2.83	0	1.20	0	2.24	0	1.19	0
10	4.66	0	4.00	7	4.07	0	4.54	131
	4.21	0	4.41	69	3.62	1	4.93	611
	3.75	0	4.78	240	3.16	5	5.30	2,092
	3.29	3	5.09	379	2.70	20	5.59	5,456
	2.83	13	5.35	575	2.24	35	5.44	7,143
	2.37	1	3.80	142	1.78	4	3.74	819
50	4.21	0	4.61	83	3.62	1	5.14	718
	3.75	1	5.02	268	3.16	6	5.54	2,462
	3.29	4	5.37	425	2.70	24	5.88	6,458
	2.83	16	5.68	672	2.24	73	6.18	13,673
	2.37	39	5.70	958	1.78	81	5.70	12,520
	1.92	2	3.55	107	1.33	5	3.50	834
100	4.21	0	4.70	90	3.62	1	5.23	771
	3.75	1	5.09	277	3.16	7	5.61	2,585
	3.29	4	5.46	442	2.70	26	5.97	6,831
	2.83	17	5.77	705	2.24	76	6.27	14,369
	2.37	52	6.01	1,231	1.78	138	6.24	19,809
	1.92	54	5.45	1,010	1.33	113	5.46	13,986

Project					
Colwyn Bay Old Promenade Coastal Defence					
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437	
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Profile 1 (Beach Drawdown)	Checked by	NC	Date	31/03/2020	5 of 5

Revetment to +7.5m OD, 1:3 Slope, 5m crest width with crest wall to +8.15m OD - Case 5

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	5.31	0	3.54	0	4.72	0	4.05	15
	4.86	0	3.82	5	4.27	0	4.12	51
	4.40	0	3.77	16	3.81	0	3.64	21
	3.94	0	2.95	0	3.35	0	2.90	2
	3.48	0	1.20	0	2.89	0	1.19	0
10	5.31	0	4.00	0	4.72	0	4.54	23
	4.86	0	4.41	12	4.27	0	4.93	142
	4.40	0	4.78	86	3.81	1	5.30	591
	3.94	0	5.09	379	3.35	4	5.59	1,821
	3.48	3	5.35	1,264	2.89	8	5.44	2,465
	3.02	0	3.80	88	2.43	0	3.74	151
50	4.86	0	4.61	15	4.27	0	5.14	170
	4.40	0	5.02	106	3.81	1	5.54	703
	3.94	1	5.37	461	3.35	5	5.88	2,175
	3.48	3	5.68	1,505	2.89	20	6.18	5,437
	3.02	9	5.70	2,945	2.43	21	5.70	4,790
	2.57	0	3.55	71	1.98	0	3.50	135
100	4.86	0	4.70	17	4.27	0	5.23	184
	4.40	0	5.09	113	3.81	1	5.61	741
	3.94	1	5.46	495	3.35	6	5.97	2,311
	3.48	4	5.77	1,596	2.89	21	6.27	5,732
	3.02	14	6.01	4,068	2.43	42	6.24	8,655
	2.57	13	5.45	3,297	1.98	30	5.46	5,492

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment	Calculated by	NS	Date	10/02/2020
Profile 2 (Beach Drawdown)	Checked by	NC	Date	31/03/2020

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OVERTOPPING CALCULATIONS: PROFILE 2

Existing structure and foreshore geometry - Case 1

Crest Level:	+5.5 mOD	Revetment Crest:	+3.3 mOD
Toe Level:	+1.89 mOD	Revetment Slope:	1: 3.85 m

	Present Day			In 50 years (including SLR)		
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	V_{max} [l/m]
1	2.66	0	17	2.07	95	12,199
	2.21	0	120	1.62	194	22,341
	1.75	125	17,384	1.16	14	1,646
	1.29	5	849	0.70	11	1,094
	0.83	2	1,261	0.24	2	161
10	2.66	0	34	2.07	140	14,069
	2.21	1	246	1.62	295	25,162
	1.75	236	21,581	1.16	40	2,677
	1.29	31	2,408	0.70	65	3,075
	0.83	53	3,021	0.24	90	1,978
	0.37	34	2,362	-0.22	*	*
50	2.21	1	317	1.62	336	26,138
	1.75	275	22,665	1.16	45	2,751
	1.29	37	2,497	0.70	75	3,133
	0.83	62	3,098	0.24	114	1,991
	0.37	92	2,535	-0.22	*	*
	-0.08	*	*	-0.67	*	*
100	2.21	1	354	1.62	354	26,552
	1.75	287	22,983	1.16	47	2,772
	1.29	39	2,525	0.70	78	3,151
	0.83	65	3,119	0.24	118	1,996
	0.37	98	2,551	-0.22	*	*
	-0.08	*	*	-0.67	*	*

* With R_c < 0 flooding occurs, water level above crest. No overtopping can be defined.

Revetment to existing wall crest level, 1:3 Slope, 5m crest width - Case 2

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	**Freeboard R_c [m]**	**q [l/m/s]**	**$R_{u2\%}$ [m]**	**V_{max} [l/m]**	**Freeboard R_c [m]**	**q [l/m/s]**	**$R_{u2\%}$ [m]**	**V_{max} [l/m]**
1	2.66	2	3.40	47	2.07	34	3.40	1,089
	2.21	18	3.71	120	1.62	135	3.71	2,683
	1.75	73	3.87	179	1.16	176	3.87	1,523
	1.29	52	2.99	54	0.70	189	2.99	475
	0.83	1	1.21	0	0.24	46	1.21	0
10	2.66	4	3.87	76	2.07	47	3.87	1,603
	2.21	28	4.31	182	1.62	175	4.31	5,071
	1.75	122	4.71	382	1.16	469	4.71	12,110
	1.29	354	5.03	881	0.70	962	5.03	21,950
	0.83	784	5.32	1,890	0.24	1,473	5.32	26,085
	0.37	659	3.84	480	-0.22	*	*	*
50	2.21	33	4.51	212	1.62	192	4.51	5,955
	1.75	137	4.95	465	1.16	502	4.95	14,252
	1.29	386	5.32	1,093	0.70	1,013	5.32	26,106
	0.83	830	5.65	2,350	0.24	1,669	5.65	39,311
	0.37	1,430	5.84	4,128	-0.22	*	*	*
	-0.08	*	*	*	-0.67	*	*	*
100	2.21	36	4.60	226	1.62	199	4.60	6,375
	1.75	142	5.02	492	1.16	512	5.02	14,932
	1.29	397	5.41	1,171	0.70	1,031	5.41	27,574
	0.83	846	5.75	2,497	0.24	1,688	5.75	41,343
	0.37	1,461	6.01	4,550	-0.22	*	*	*
	-0.08	*	*	*	-0.67	*	*	*

* With R_c < 0 there is flooding, water level above crest. No overtopping defined.

Revetment to +7.0m OD, 1:3 Slope, 5m crest width - Case 3

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.16	0	3.40	5	3.57	0	3.40	279
	3.71	0	3.71	55	3.12	1	3.71	815
	3.25	0	3.87	154	2.66	0	3.87	229
	2.79	0	2.99	23	2.20	0	2.99	41
	2.33	0	1.21	0	1.74	0	1.21	0
10	4.16	0	3.87	10	3.57	0	3.87	354
	3.71	0	4.31	88	3.12	2	4.31	1,319
	3.25	1	4.71	246	2.66	10	4.71	3,853
	2.79	6	5.03	385	2.20	39	5.03	8,863
	2.33	25	5.32	686	1.74	76	5.32	11,722
	1.87	4	3.84	158	1.28	10	3.84	1,532
50	3.71	0	4.51	106	3.12	2	4.51	1,516
	3.25	1	4.95	277	2.66	13	4.95	4,479
	2.79	8	5.32	449	2.20	46	5.32	10,432
	2.33	30	5.65	830	1.74	129	5.65	19,839
	1.87	88	5.84	1,508	1.28	158	5.84	18,659
	1.42	5	3.58	129	0.83	13	3.58	1,621
100	3.71	0	4.60	115	3.12	3	4.60	1,614
	3.25	1	5.02	287	2.66	13	5.02	4,687
	2.79	8	5.41	474	2.20	49	5.41	11,009
	2.33	32	5.75	878	1.74	134	5.75	20,837
	1.87	95	6.01	1,662	1.28	251	6.01	28,442
	1.42	122	5.60	1,670	0.83	207	5.60	20,018

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment Profile 2 (Beach Drawdown)	Calculated by	NS	Date	10/02/2020
	Checked by	NC	Date	31/03/2020

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Revetment to +7.5m OD, 1:3 Slope, 5m crest width - Case 4

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.66	0	3.40	1	4.07	0	3.40	154
	4.21	0	3.71	29	3.62	0	3.71	563
	3.75	0	3.87	120	3.16	0	3.87	124
	3.29	0	2.99	12	2.70	0	2.99	19
	2.83	0	1.21	0	2.24	0	1.21	0
10	4.66	0	3.87	4	4.07	0	3.87	209
	4.21	0	4.31	50	3.62	1	4.31	854
	3.75	0	4.71	213	3.16	5	4.71	2,606
	3.29	2	5.03	361	2.70	20	5.03	6,311
	2.83	12	5.32	557	2.24	41	5.32	8,434
	2.37	1	3.84	149	1.78	4	3.84	833
50	4.21	0	4.51	62	3.62	1	4.51	969
	3.75	0	4.95	242	3.16	6	4.95	2,995
	3.29	3	5.32	407	2.70	24	5.32	7,357
	2.83	15	5.65	656	2.24	73	5.65	14,920
	2.37	48	5.84	1,122	1.78	91	5.84	13,754
	1.92	2	3.58	112	1.33	5	3.58	848
100	4.21	0	4.60	69	3.62	1	4.60	1,027
	3.75	1	5.02	251	3.16	6	5.02	3,126
	3.29	4	5.41	424	2.70	25	5.41	7,749
	2.83	16	5.75	689	2.24	77	5.75	15,647
	2.37	52	6.01	1,230	1.78	154	6.01	22,345
	1.92	68	5.60	1,200	1.33	124	5.60	15,020

Project					
Colwyn Bay Old Promenade Coastal Defence					
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437	
Overtopping Assessment	Calculated by	NS	Date	10/02/2020	Sheet no
Profile 2 (Beach Drawdown)	Checked by	NC	Date	31/03/2020	5 of 5

Revetment to +7.5m OD, 1:3 Slope, 5m crest width with crest wall to +8.15m OD - Case 5

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	5.31	0	3.40	0	4.72	0	3.95	9
	4.86	0	3.71	2	4.27	0	4.23	75
	4.40	0	3.87	25	3.81	0	3.71	27
	3.94	0	2.99	1	3.35	0	2.93	2
	3.48	0	1.21	0	2.89	0	1.20	0
10	5.31	0	3.87	0	4.72	0	4.44	16
	4.86	0	4.31	7	4.27	0	4.87	117
	4.40	0	4.71	68	3.81	1	5.25	537
	3.94	0	5.03	334	3.35	4	5.57	1,755
	3.48	2	5.32	1,194	2.89	11	5.59	3,160
	3.02	0	3.84	100	2.43	0	3.78	167
50	4.86	0	4.51	10	4.27	0	5.08	143
	4.40	0	4.95	86	3.81	1	5.50	647
	3.94	1	5.32	414	3.35	5	5.86	2,119
	3.48	3	5.65	1,440	2.89	20	6.19	5,486
	3.02	12	5.84	3,691	2.43	27	5.85	5,973
	2.57	0	3.58	80	1.98	0	3.53	148
100	4.86	0	4.60	12	4.27	0	5.17	156
	4.40	0	5.02	92	3.81	1	5.58	685
	3.94	1	5.41	447	3.35	6	5.96	2,260
	3.48	3	5.75	1,533	2.89	21	6.28	5,798
	3.02	13	6.01	4,061	2.43	53	6.41	10,567
	2.57	17	5.60	4,167	1.98	38	5.60	6,629

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment	Calculated by	NS	Date	10/02/2020
Profile 3 (Beach Drawdown)	Checked by	NC	Date	31/03/2020

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OVERTOPPING CALCULATIONS: PROFILE 3

Existing structure and foreshore geometry - Case 1

Crest Level:	+5.47 mOD	Verticall Wall	
Toe Level:	+0.0 mOD	Beach Slope:	1:51.3

	Present Day			In 50 years (including SLR)		
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	V_{max} [l/m]
1	2.63	98	16,850	2.04	188	33,267
	2.18	96	20,623	1.59	196	29,461
	1.72	98	17,379	1.13	185	22,762
	1.26	55	9,073	0.67	166	26,220
	0.80	2	1,391	0.21	29	3,534
10	2.63	140	19,207	2.04	246	28,357
	2.18	267	32,226	1.59	571	54,472
	1.72	456	46,975	1.13	825	64,790
	1.26	605	56,421	0.67	948	62,159
	0.80	689	57,450	0.21	**	**
	0.34	373	32,990	-0.25	*	*
50	2.18	302	33,492	1.59	424	37,273
	1.72	517	48,466	1.13	955	64,476
	1.26	802	60,392	0.67	1,343	62,130
	0.80	1,071	61,692	0.21	**	**
	0.34	1,034	43,157	-0.25	*	*
	-0.11	*	*	-0.70	*	*
100	2.18	317	34,033	1.59	524	44,563
	1.72	535	48,897	1.13	**	**
	1.26	836	60,873	0.67	**	**
	0.80	1,206	62,725	0.21	**	**
	0.34	**	**	-0.25	*	*
	-0.11	*	*	-0.70	*	*

* With $R_c < 0$ flooding occurs, water level above crest. No overtopping can be defined.

* * Out of equation boundaries. Relatively too large waves

Revetment to existing wall crest level, 1:3 Slope, 5m crest width - Case 2

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	2.63	35	4.58	304	2.04	97	4.60	1,788
	2.18	47	4.18	222	1.59	128	4.15	2,216
	1.72	67	3.78	157	1.13	153	3.55	1,376
	1.26	43	2.86	43	0.67	177	2.83	448
	0.80	1	1.18	0	0.21	51	1.18	0
10	2.63	46	5.11	404	2.04	204	5.63	4,141
	2.18	150	5.51	792	1.59	476	6.03	10,273
	1.72	376	5.87	1,627	1.13	853	6.21	18,799
	1.26	645	5.86	2,288	0.67	1,130	5.86	24,585
	0.80	899	5.52	2,392	0.21	1,453	5.50	25,621
	0.34	628	3.71	392	-0.25	*	*	*
50	2.18	163	5.73	913	1.59	503	6.26	11,928
	1.72	403	6.14	1,904	1.13	976	6.66	23,554
	1.26	812	6.48	3,640	0.67	1,565	6.89	36,754
	0.80	1,285	6.56	5,350	0.21	1,909	6.56	43,843
	0.34	1,419	5.76	3,928	-0.25	*	*	*
	-0.11	*	*	*	-0.70	*	*	*
100	2.18	169	5.83	969	1.59	515	6.36	12,697
	1.72	411	6.21	1,992	1.13	989	6.74	24,597
	1.26	827	6.58	3,844	0.67	1,640	7.09	39,848
	0.80	1,419	6.88	6,636	0.21	2,067	6.89	48,876
	0.34	1,680	6.35	6,077	-0.25	*	*	*
	-0.11	*	*	*	-0.70	*	*	*

* With R_c < 0 there is flooding, water level above crest. No overtopping defined.

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment Profile 3 (Beach Drawdown)	Calculated by	NS	Date	10/02/2020
	Checked by	NC	Date	31/03/2020

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Revetment to +7.0m OD, 1:3 Slope, 5m crest width - Case 3

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.16	0	4.58	277	3.57	1	4.60	420
	3.71	0	4.18	193	3.12	1	4.15	443
	3.25	0	3.78	129	2.66	0	3.55	195
	2.79	0	2.86	13	2.20	0	2.83	34
	2.33	0	1.18	0	1.74	0	1.18	0
10	4.16	0	5.11	319	3.57	2	5.63	1,122
	3.71	3	5.51	498	3.12	10	6.03	3,334
	3.25	14	5.87	749	2.66	31	6.21	7,103
	2.79	28	5.86	921	2.20	52	5.86	9,748
	2.33	36	5.52	867	1.74	70	5.50	10,729
	1.87	3	3.71	130	1.28	9	3.66	1,377
50	3.71	4	5.73	537	3.12	12	6.26	3,861
	3.25	16	6.14	842	2.66	42	6.66	9,347
	2.79	52	6.48	1,464	2.20	103	6.89	17,480
	2.33	105	6.56	2,105	1.74	164	6.56	22,593
	1.87	79	5.76	1,387	1.28	142	5.68	17,180
	1.42	4	3.47	108	0.83	12	3.44	1,498
100	3.71	4	5.83	557	3.12	13	6.36	4,113
	3.25	17	6.21	872	2.66	43	6.74	9,768
	2.79	55	6.58	1,538	2.20	114	7.09	19,347
	2.33	140	6.88	2,696	1.74	194	6.89	26,305
	1.87	142	6.35	2,331	1.28	237	6.31	26,749
	1.42	104	5.47	1,452	0.83	189	5.42	18,601

Revetment to +7.5m OD, 1:3 Slope, 5m crest width - Case 4

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.66	0	4.58	215	4.07	0	4.60	265
	4.21	0	4.18	145	3.62	0	4.15	266
	3.75	0	3.78	93	3.16	0	3.55	106
	3.29	0	2.86	6	2.70	0	2.83	15
	2.83	0	1.18	0	2.24	0	1.18	0
10	4.66	0	5.11	253	4.07	1	5.63	734
	4.21	1	5.51	490	3.62	5	6.03	2,276
	3.75	7	5.87	680	3.16	16	6.21	4,999
	3.29	14	5.86	771	2.70	27	5.86	6,819
	2.83	18	5.52	692	2.24	37	5.50	7,477
	2.37	1	3.71	125	1.78	3	3.66	735
50	4.21	2	5.73	521	3.62	6	6.26	2,623
	3.75	8	6.14	745	3.16	23	6.66	6,668
	3.29	29	6.48	1,177	2.70	62	6.89	13,063
	2.83	60	6.56	1,622	2.24	98	6.56	17,052
	2.37	43	5.76	1,031	1.78	80	5.68	12,420
	1.92	1	3.47	96	1.33	4	3.44	769
100	4.21	2	5.83	535	3.62	7	6.36	2,791
	3.75	9	6.21	766	3.16	24	6.74	6,964
	3.29	30	6.58	1,230	2.70	70	7.09	14,566
	2.83	83	6.88	2,077	2.24	120	6.89	20,233
	2.37	82	6.35	1,738	1.78	144	6.31	20,478
	1.92	56	5.47	1,039	1.33	110	5.42	13,701

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment Profile 3 (Beach Drawdown)	Calculated by	NS	Date	10/02/2020
	Checked by	NC	Date	31/03/2020

Sheet no 5 of 5

Revetment to +7.5m OD, 1:3 Slope, 5m crest width with crest wall to +8.15m OD - Case 5

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	5.31	0	4.58	53	4.72	0	4.60	109
	4.86	0	4.18	31	4.27	0	4.15	57
	4.40	0	3.78	17	3.81	0	3.55	14
	3.94	0	2.86	0	3.35	0	2.83	1
	3.48	0	1.18	0	2.89	0	1.18	0
10	5.31	0	5.11	74	4.72	0	5.63	501
	4.86	0	5.51	336	4.27	2	6.03	1,559
	4.40	1	5.87	1,123	3.81	7	6.21	3,092
	3.94	3	5.86	1,798	3.35	8	5.86	2,865
	3.48	4	5.52	1,744	2.89	9	5.50	2,726
	3.02	0	3.71	63	2.43	0	3.66	115
50	4.86	0	5.73	385	4.27	3	6.26	1,762
	4.40	2	6.14	1,292	3.81	11	6.66	4,582
	3.94	8	6.48	3,433	3.35	31	6.89	8,854
	3.48	17	6.56	5,818	2.89	36	6.56	8,758
	3.02	10	5.76	3,274	2.43	21	5.68	4,699
	2.57	0	3.47	53	1.98	0	3.44	107
100	4.86	0	5.83	410	4.27	3	6.36	1,861
	4.40	2	6.21	1,349	3.81	12	6.74	4,765
	3.94	8	6.58	3,612	3.35	37	7.09	10,384
	3.48	26	6.88	8,012	2.89	52	6.89	11,919
	3.02	24	6.35	6,492	2.43	46	6.31	9,357
	2.57	14	5.47	3,427	1.98	28	5.42	5,200

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment	Calculated by	NS	Date	10/02/2020
Profile4 (Beach Drawdown)	Checked by	NC	Date	31/03/2020

Sheet no: 1 of 5

OVERTOPPING CALCULATIONS: PROFILE 4

Existing structure and foreshore geometry - Case 1

Crest Level: +5.75 mOD — Verticall Wall

Toe Level: +1.13 mOD — Beach Slope: 1: 45 m

Return period (joint probability) [yrs]	Present Day: Freeboard R_c [m]	Present Day: q [l/m/s]	Present Day: V_{max} [l/m]	In 50 years (including SLR): Freeboard R_c [m]	In 50 years (including SLR): q [l/m/s]	In 50 years (including SLR): V_{max} [l/m]
1	2.91	54	9,756	2.32	132	21,583
	2.46	79	15,511	1.87	131	23,505
	2.00	81	17,883	1.41	111	16,501
	1.54	40	9,145	0.95	85	10,205
	1.08	0	1,505	0.49	8	1,774
10	2.91	82	11,534	2.32	211	25,882
	2.46	172	21,930	1.87	381	39,981
	2.00	317	35,557	1.41	622	53,510
	1.54	517	49,417	0.95	753	57,692
	1.08	590	54,901	0.49	869	49,452
	0.62	289	27,427	0.03	**	**
50	2.46	197	23,034	1.87	427	41,266
	2.00	363	36,997	1.41	700	54,873
	1.54	595	51,042	0.95	1,050	61,352
	1.08	899	60,195	0.49	1,301	51,090
	0.62	899	54,257	0.03	**	**
	0.17	*	*	-0.42	*	*
100	2.46	209	23,510	1.87	448	41,810
	2.00	377	37,418	1.41	724	55,262
	1.54	622	51,566	0.95	1,092	61,726
	1.08	935	60,605	0.49	1,458	51,435
	0.62	1,122	55,633	0.03	**	**
	0.17	*	*	-0.42	*	*

* With $R_c < 0$ flooding occurs, water level above crest. No overtopping can be defined.

* * Out of equation boundaries. Relatively too large waves

Revetment to existing wall crest level, 1:3 Slope, 5m crest width - Case 2

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	2.91	11	4.25	212	2.32	63	4.62	1,402
	2.46	28	4.20	217	1.87	85	4.21	1,756
	2.00	42	3.83	157	1.41	93	3.59	1,011
	1.54	22	2.90	43	0.95	94	2.85	289
	1.08	0	1.19	0	0.49	8	1.18	0
10	2.91	16	4.76	268	2.32	98	5.31	2,463
	2.46	67	5.18	466	1.87	271	5.71	6,907
	2.00	204	5.55	949	1.41	604	6.08	15,065
	1.54	478	5.86	1,887	0.95	891	5.89	21,574
	1.08	689	5.55	2,016	0.49	1,206	5.55	23,150
	0.62	435	3.74	318	0.03	859	3.69	5,195
50	2.46	75	5.40	535	1.87	291	5.94	8,068
	2.00	223	5.81	1,118	1.41	639	6.34	17,626
	1.54	513	6.16	2,260	0.95	1,170	6.69	30,593
	1.08	982	6.47	4,192	0.49	1,631	6.59	40,335
	0.62	1,170	5.83	3,475	0.03	1,684	5.74	31,860
	0.17	691	3.50	326	-0.42	*	*	*
100	2.46	79	5.49	567	1.87	299	6.03	8,613
	2.00	229	5.88	1,172	1.41	649	6.42	18,433
	1.54	525	6.26	2,395	0.95	1,188	6.79	32,257
	1.08	998	6.57	4,418	0.49	1,784	6.93	45,225
	0.62	1,401	6.38	5,298	0.03	1,979	6.37	44,522
	0.17	1,506	5.53	3,645	-0.42	*	*	*

* With R_c < 0 there is flooding, water level above crest. No overtopping defined.

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment Profile4 (Beach Drawdown)	Calculated by	NS	Date	10/02/2020
	Checked by	NC	Date	31/03/2020

Sheet no 3 of 5

Revetment to +7.0m OD, 1:3 Slope, 5m crest width - Case 3

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.16	0	4.25	140	3.57	1	4.62	435
	3.71	0	4.20	201	3.12	1	4.21	485
	3.25	0	3.83	143	2.66	0	3.59	211
	2.79	0	2.90	15	2.20	0	2.85	36
	2.33	0	1.19	0	1.74	0	1.18	0
10	4.16	0	4.76	178	3.57	1	5.31	760
	3.71	1	5.18	374	3.12	7	5.71	2,488
	3.25	7	5.55	554	2.66	27	6.08	6,465
	2.79	28	5.86	919	2.20	53	5.89	9,950
	2.33	37	5.55	896	1.74	74	5.55	11,125
	1.87	3	3.74	137	1.28	9	3.69	1,422
50	3.71	2	5.40	404	3.12	8	5.94	2,898
	3.25	9	5.81	621	2.66	31	6.34	7,556
	2.79	33	6.16	1,073	2.20	89	6.69	15,704
	2.33	95	6.47	1,942	1.74	167	6.59	22,951
	1.87	87	5.83	1,487	1.28	147	5.74	17,658
	1.42	4	3.50	113	0.83	12	3.46	1,532
100	3.71	2	5.49	419	3.12	9	6.03	3,096
	3.25	10	5.88	643	2.66	33	6.42	7,909
	2.79	35	6.26	1,129	2.20	93	6.79	16,562
	2.33	99	6.57	2,042	1.74	198	6.93	26,709
	1.87	147	6.38	2,405	1.28	246	6.37	27,455
	1.42	111	5.53	1,542	0.83	194	5.47	18,979

Revetment to +7.5m OD, 1:3 Slope, 5m crest width - Case 4

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	4.66	0	4.25	87	4.07	0	4.62	276
	4.21	0	4.20	153	3.62	0	4.21	294
	3.75	0	3.83	108	3.16	0	3.59	115
	3.29	0	2.90	7	2.70	0	2.85	16
	2.83	0	1.19	0	2.24	0	1.18	0
10	4.66	0	4.76	117	4.07	1	5.31	477
	4.21	1	5.18	345	3.62	3	5.71	1,641
	3.75	3	5.55	525	3.16	14	6.08	4,491
	3.29	14	5.86	770	2.70	28	5.89	6,984
	2.83	19	5.55	714	2.24	39	5.55	7,810
	2.37	1	3.74	131	1.78	3	3.69	765
50	4.21	1	5.40	373	3.62	4	5.94	1,903
	3.75	4	5.81	572	3.16	17	6.34	5,230
	3.29	17	6.16	877	2.70	52	6.69	11,530
	2.83	54	6.47	1,496	2.24	100	6.59	17,376
	2.37	47	5.83	1,106	1.78	84	5.74	12,847
	1.92	1	3.50	100	1.33	5	3.46	792
100	4.21	1	5.49	387	3.62	4	6.03	2,030
	3.75	5	5.88	588	3.16	18	6.42	5,471
	3.29	18	6.26	917	2.70	55	6.79	12,155
	2.83	56	6.57	1,568	2.24	123	6.93	20,603
	2.37	86	6.38	1,795	1.78	150	6.37	21,136
	1.92	61	5.53	1,106	1.33	114	5.47	14,053

Project				
Colwyn Bay Old Promenade Coastal Defence				
Calculations for	Dvn/dept	MNC/PCO	Job no/file no	415437
Overtopping Assessment Profile4 (Beach Drawdown)	Calculated by	NS	Date	10/02/2020
	Checked by	NC	Date	31/03/2020

Sheet no 5 of 5

Revetment to +7.5m OD, 1:3 Slope, 5m crest width with crest wall to +8.15m OD - Case 5

	Present Day				In 50 years (including SLR)			
Return period (joint probability) [yrs]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]	Freeboard R_c [m]	q [l/m/s]	$R_{u2\%}$ [m]	V_{max} [l/m]
1	5.31	0	4.25	13	4.72	0	4.62	118
	4.86	0	4.20	34	4.27	0	4.21	69
	4.40	0	3.83	21	3.81	0	3.59	16
	3.94	0	2.90	0	3.35	0	2.85	1
	3.48	0	1.19	0	2.89	0	1.18	0
10	5.31	0	4.76	24	4.72	0	5.31	235
	4.86	0	5.18	147	4.27	1	5.71	865
	4.40	1	5.55	596	3.81	5	6.08	2,527
	3.94	3	5.86	1,794	3.35	8	5.89	3,008
	3.48	4	5.55	1,837	2.89	10	5.55	3,000
	3.02	0	3.74	71	2.43	0	3.69	127
50	4.86	0	5.40	173	4.27	1	5.94	992
	4.40	1	5.81	697	3.81	6	6.34	2,914
	3.94	4	6.16	2,108	3.35	23	6.69	6,932
	3.48	15	6.47	5,200	2.89	38	6.59	9,117
	3.02	12	5.83	3,618	2.43	23	5.74	5,095
	2.57	0	3.50	59	1.98	0	3.46	117
100	4.86	0	5.49	187	4.27	1	6.03	1,054
	4.40	1	5.88	732	3.81	7	6.42	3,043
	3.94	4	6.26	2,230	3.35	24	6.79	7,294
	3.48	16	6.57	5,463	2.89	54	6.93	12,380
	3.02	25	6.38	6,774	2.43	50	6.37	10,076
	2.57	15	5.53	3,731	1.98	31	5.47	5,562