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Jersey SMP

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Memo

Subject: Extreme Sea Levels for Jersey (Appendix A)

1. Extreme Sea Levels at St Helier

The accurate assessment of extreme sea levels is of critical importance for subsequent stages of the Jersey SMP study. HR Wallingford (2009) and Prime (2018) have provided estimates for extreme sea levels for Jersey although a relatively consistent discrepancy of 0.33m was previously noted (Table 1-1). AECOM has undertaken a detailed investigation of available data to provide an independent check of the two studies, including any applied datum conversions.

Table 1-1: Extreme sea level in HR Wallingford (2009) and Prime (2018)

RP (years)	AEP (%)	HR Wallingford (2009) (m OD)	Prime (2018) (m OD)	Difference (m)	AECOM (m OD)
1	**100**	6.557	6.24	0.32	6.12
10	**10**	6.788	6.46	0.33	6.39
25	**4**	6.880	6.55	0.33	6.50
50	**2**	6.949	6.62	0.33	6.58
100	**1.00**	7.019	6.69	0.33	6.67
200	**0.50**	-	6.76	-	6.76
1000	**0.10**	-	6.93	-	6.97

Extreme sea levels in HR Wallingford (2009) were based on the information produced by HR Wallingford (1991) taking account of sea level rise over the intervening period. Extreme sea levels for various return periods were derived from mean high water spring tidal level and a surge component for each site. Prime (2018) used water level data from the tide gauge in St Helier Harbour to derive extreme value estimates for a range of return periods. The study replicates the methodology known as skew joint probability (SSJPM) for the coast of Jersey. The results in Prime (2018) consist of extreme sea levels of annual exceedance, ranging from 100% Annual Exceedance Probability (AEP) to 0.1% AEP. Table 1-2 shows the return period values and the 95% confidence interval above CD and OD. The Admiralty Chart Datum at St. Helier is 5.88m below Ordnance Datum Local (ODL or OD).

Table 1-2: Extreme sea levels at St Helier (Prime, 2018)

RP (years)	AEP (%)	Extreme Water Level (m CD)	95th percentile confidence interval (m CD)		Extreme Water Level (m OD)	95th percentile confidence interval (m OD)	
1	**100**	12.12	12.11	12.12	6.24	6.23	6.24
10	**10**	12.34	12.33	12.36	6.46	6.45	6.48
20	**5**	12.41	12.40	12.44	6.53	6.52	6.56
25	**4**	12.43	12.42	12.47	6.55	6.54	6.59
50	**2**	12.50	12.48	12.56	6.62	6.60	6.68
75	**1.33**	12.54	12.52	12.62	6.66	6.64	6.74
100	**1**	12.57	12.55	12.66	6.69	6.67	6.78
200	**0.50**	12.64	12.61	12.76	6.76	6.73	6.88
1000	**0.10**	12.81	12.76	13.08	6.93	6.88	7.20

To evaluate the previous studies, AECOM obtained water level measurements, including tide and surge data, from the operational gauge at St Helier. The dataset was made available by the British Oceanographic Data Centre (BODC) and covers a period of 25 years from 1993 to 2018 with data provided at 15 minute intervals. Using this dataset standard fitting techniques were applied assuming a Weibull probability distribution to derive estimates of extreme water level for this location. The results of the analysis are given in Table 1-1 and presented graphically in Figure 1. It can be seen that the AECOM derived values are very similar to Prime (2018), particularly for the higher return periods. For lower return periods (i.e. <50yrs) the AECOM values are slightly lower than those derived by Prime. It is therefore recommended that the Prime extreme sea levels should be used as the reference values for the estimation of extreme levels at other locations around the island which provide marginally conservative estimates at lower return periods.

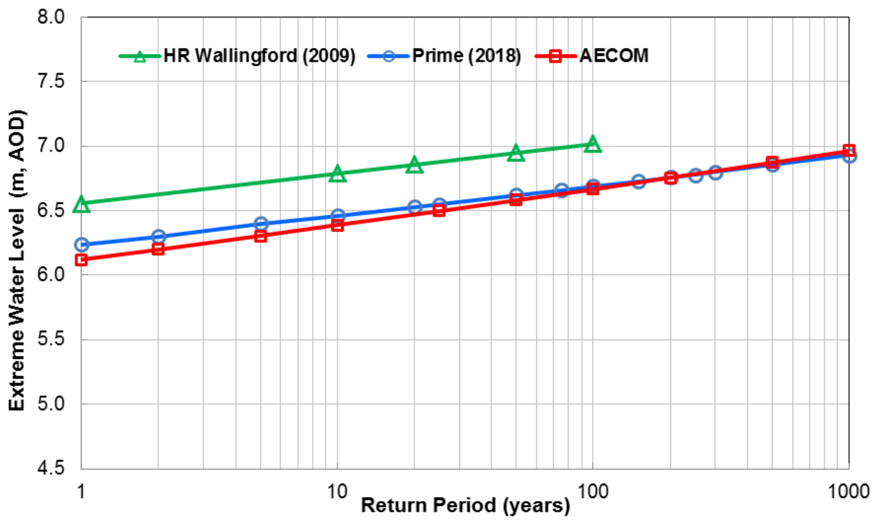

Figure 1-1: Comparison of extreme sea level estimates

2. Water level variation around the Jersey Coastline

The variability in extreme sea levels around the Jersey coastline was presented in reports by HR Wallingford (1991 and 2009). The locations where extreme sea levels were estimated are identified in Figure 2. Table 2-1 and Table 2-2 provide these estimated still water levels which include the mean high water springs (MHWS) tidal level and a surge component for the different return periods. HR Wallingford (2009) updated water levels to account for changes in mean sea level over the last two decades or so, assuming a rise of 2mm per year.

Relative changes in extreme water level around the island have been derived from Table 1-1 and Table 1-2, in which HR8 is used as the reference site. Table 2-3 presents differences in extreme sea level relative to Site HR8.

Table 2-1: Extreme sea levels (m OD) from HR Wallingford (1991) with MHWS levels for reference

RP (years)	HR3	HR4	HR7	HR8	HR20	HR19	HR14
MHWS	4.5	4.9	5.1	5.1	5.1	5.2	5.2
0.2	5.3	5.7	5.9	5.9	5.9	6.0	6.0
1	5.9	6.3	6.5	6.5	6.5	6.6	6.6
5	6.1	6.5	6.7	6.7	6.7	6.8	6.8
10	6.2	6.6	6.8	6.8	6.8	6.9	6.9
20	6.2	6.6	6.8	6.8	6.9	6.9	6.9
50	6.3	6.7	6.9	6.9	7.0	7.0	7.0

Table 2-2: Extreme sea levels (m OD) from HR Wallingford (2009)

RP (years)	HR5	HR7 / HR8	HR14 / HR19
1	6.356	6.557	6.657
10	6.588	6.788	6.887
20	6.657	6.857	6.957
50	6.749	6.949	7.049
100	6.820	7.019	7.119

Table 2-3: Change of extreme sea level (m) relative to HR8

HR3	HR5	HR7	HR8	HR20	HR19	HR14
-0.6	-0.2	0	-	0	+0.1	+0.1

To account for the variation of water level around the island, AECOM has used the values in Table 2-3 as derived from HR Wallingford (1991) and HR Wallingford (2009). For this analysis the island has been divided into four zones to characterise extreme sea level variations, as defined in Figure 3 and Table 2-4.

Table 2-4: Assignment of key locations within zones

Zone 1	Zone 2	Zone 3	Zone 4
Area 4 Royal Bay of Grouville	Area 1 Area 2 Area 3 St Catherine’s Bay	Bonne Nuit Bouley Bay St Ouen’s Bay	La Greve de Lecq Stinky Bay

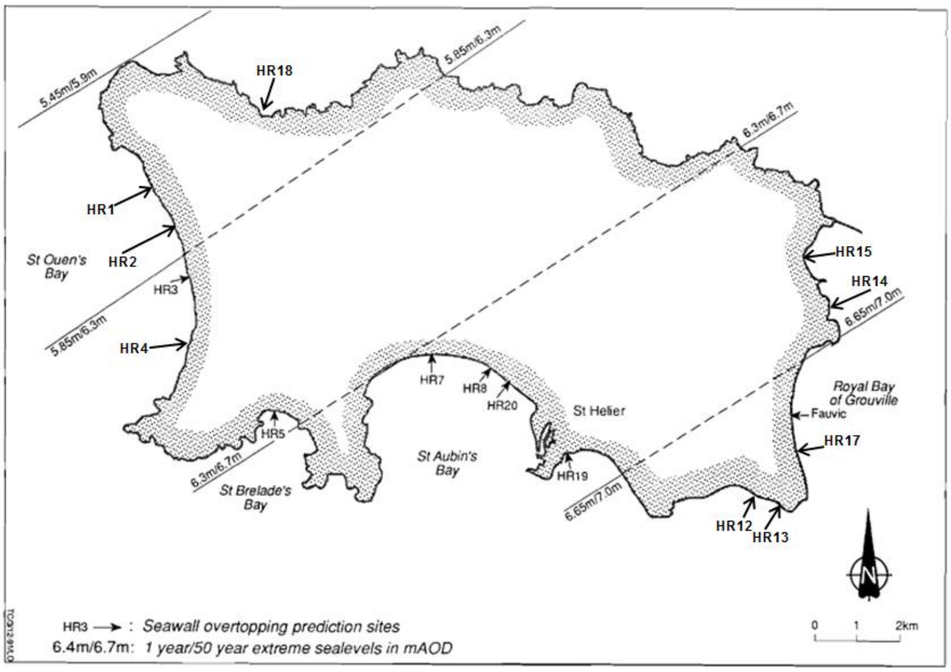

Figure 2-1: Location of extreme sea level estimates (HR Wallingford, 1991)

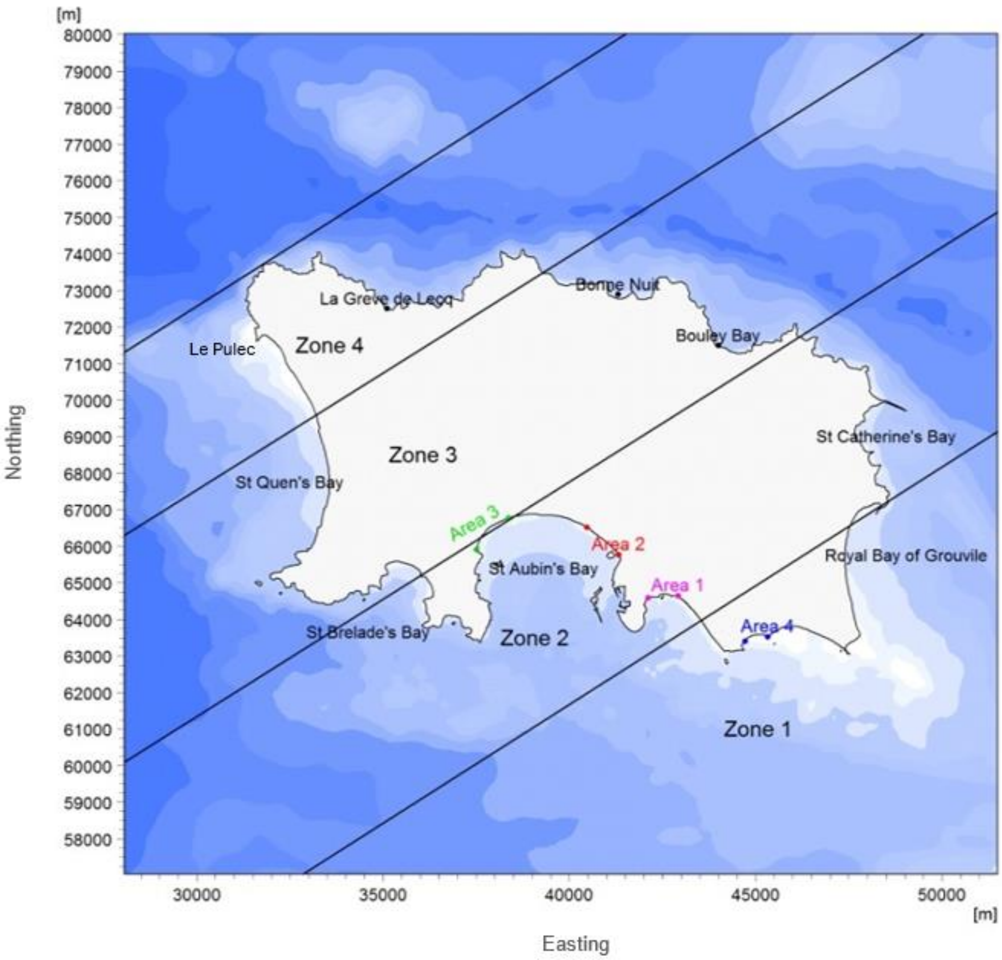

Figure 2-2: Zones defined for extreme sea level adjustments

3. Climate Change Adjustments

Flood risk will be assessed both for present day and in the future, incorporating the effects of climate change. The impact of sea level rise (SLR) has been assessed by considering present, short, medium and long-term epochs, i.e. 2020, 2040, 2070 and 2120.

Following discussions with NOC in August 2018, it has been agreed that AECOM will use the 50th percentile results for the conservative RCP8.5 climate change emission scenario ("business as usual") to inform planning policy for the island. Results from the analysis of SLR and assessment of vertical land movement (Prime, 2018) are summarised in Table 3-1. These estimates were provided up to 2100 and therefore a non-linear extrapolation of the data has been used to derive values for the year 2120.

As no information is available for extreme still water levels caused by the skew surge for Jersey, the skew surge adjustments provided in UKCP09 for the nearest UK coastal region (Southwest of England) are used as a best estimate (Table 3-2). It can be seen that the contribution of skew surge to SLR is relatively small (i.e. in the range from 2% to 10%).

Table 3-1: SLR and contribution of vertical land movement

Year	SLR (m)	Vertical land movement (m)
2020	0.07	0.005
2040	0.19	0.009
2070	0.40	0.015
2120	0.83	0.024

Table 3-2: Increase due to skew surge (m)

RP (years)	AEP (%)	2020	2040	2070	2120
1	**100**	0.002	0.005	0.011	0.019
10	**10**	0.004	0.010	0.020	0.036
20	**5**	0.004	0.012	0.022	0.041
25	**4**	0.005	0.012	0.023	0.042
50	**2**	0.005	0.013	0.026	0.047
75	**1.33**	0.005	0.014	0.028	0.050
100	**1**	0.006	0.015	0.029	0.052
200	**0.50**	0.006	0.016	0.031	0.057
1000	**0.10**	0.007	0.020	0.038	0.068

Measurements from the St Helier tide gauge have also been used to analyse historic trends in the data between 1993 and 2017. Figure 4 shows the tide gauge data combined with sea level projections. The thin black line represents the monthly average level and the thick black line the annual average values. The three lines are sea level projections at 5% (pink), 50% (green) and 95% (black) probability under the RCP8.5 scenario for Jersey. The other three solid lines are sea level projections at 5% (red), 50% (yellow) and 95% (blue) probability under the RCP4.5 scenario.

Figure 4 shows the significant variability in sea levels dependent on the averaging period. The observed variation in mean sea levels to date is compatible with the predicted SLR trend from 2020 onwards.

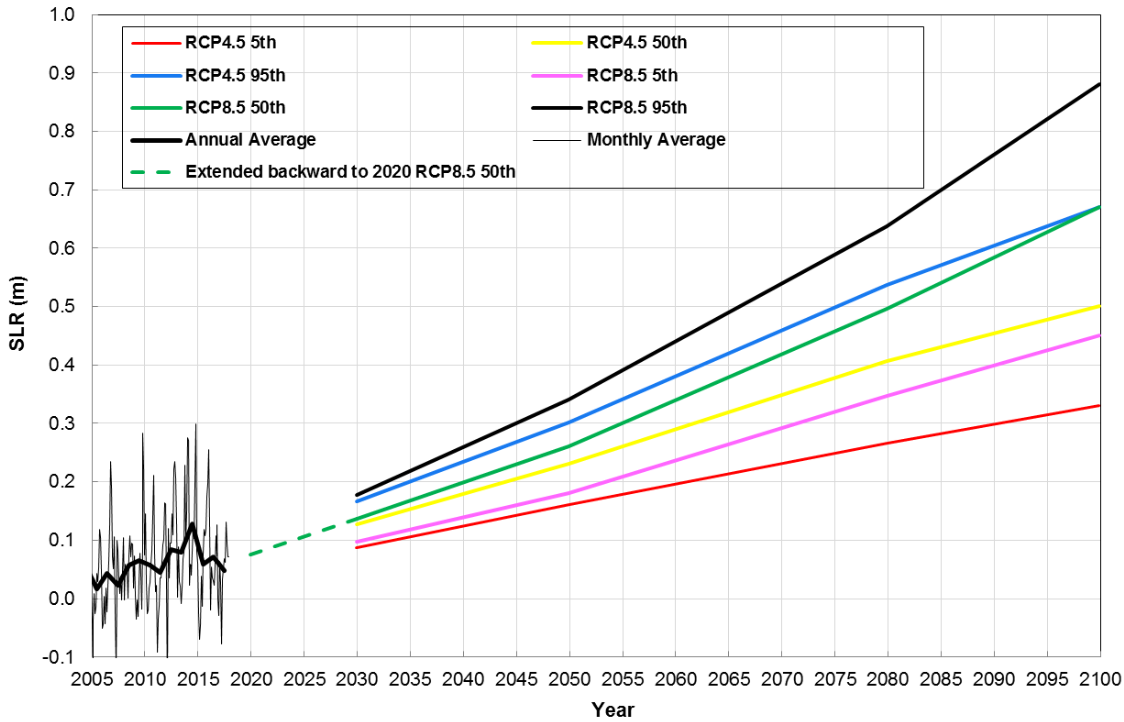

Figure 3-1: Historic mean sea level variation and SLR under RCP4.5 and RCP8.5 climate change scenarios

4. Summary of Extreme Sea Levels

Following our independent check of previous studies, the application of extreme sea level estimates provided by Prime (2018) are considered to be appropriate for subsequent use in the Jersey SMP study. By incorporating the effects of climate change and variation around the island, extreme sea levels for four zones have been derived for the present day (2020) and the future epochs in 2040, 2070 and 2120. The results are summarised in Table 4-1 to Table 4-4.

Table 4-1: Extreme sea levels (m OD) for 2020

RP	AEP (%)	Zone 1	Zone 2	Zone 3	Zone 4
1	**100**	6.42	6.32	6.12	5.72
10	**10**	6.64	6.54	6.34	5.94
20	**5**	6.71	6.61	6.41	6.01
25	**4**	6.73	6.63	6.43	6.03
50	**2**	6.81	6.71	6.51	6.11
75	**1.33**	6.85	6.75	6.55	6.15
100	**1.00**	6.88	6.78	6.58	6.18
200	**0.50**	6.95	6.85	6.65	6.25
1000	**0.10**	7.12	7.02	6.82	6.42

Table 4-2: Extreme sea levels (m OD) for 2040

RP	AEP (%)	Zone 1	Zone 2	Zone 3	Zone 4
1	100	6.55	6.45	6.25	5.85
10	10	6.77	6.67	6.47	6.07
20	5	6.84	6.74	6.54	6.14
25	4	6.86	6.76	6.56	6.16
50	2	6.93	6.83	6.63	6.23
75	1.33	6.97	6.87	6.67	6.27
100	1.00	7.00	6.90	6.70	6.30
200	0.50	7.08	6.98	6.78	6.38
1000	0.10	7.25	7.15	6.95	6.55

Table 4-3: Extreme sea levels (m OD) for 2070

RP	AEP (%)	Zone 1	Zone 2	Zone 3	Zone 4
1	100	6.77	6.67	6.47	6.07
10	10	7.00	6.90	6.70	6.30
20	5	7.07	6.97	6.77	6.37
25	4	7.09	6.99	6.79	6.39
50	2	7.17	7.07	6.87	6.47
75	1.33	7.21	7.11	6.91	6.51
100	1.00	7.24	7.14	6.94	6.54
200	0.50	7.31	7.21	7.01	6.61
1000	0.10	7.49	7.39	7.19	6.79

Table 4-4: Extreme sea levels (m OD) for 2120

RP	AEP (%)	Zone 1	Zone 2	Zone 3	Zone 4
1	100	7.21	7.11	6.91	6.51
10	10	7.45	7.35	7.15	6.75
20	5	7.52	7.42	7.22	6.82
25	4	7.54	7.44	7.24	6.84
50	2	7.62	7.52	7.32	6.92
75	1.33	7.66	7.56	7.36	6.96
100	1.00	7.69	7.59	7.39	6.99
200	0.50	7.77	7.67	7.47	7.07
1000	0.10	7.95	7.85	7.65	7.25

5. Further Review after UKCP18

Revised guidance UK Climate Projections UKCP18 is made available after the majority of modelling has been completed within the Jersey SMP study. The UKCP18 provides the most up-to-date assessment of how the climate of the Jersey may change up to 2100 and post-2100. Further review is carried out here after the UKCP18 guidance is released.

The existing still water levels at Jersey has been derived based on RCP8.5 scenario for (a) water level extremes (Prime 2018), (b) Sea Level Rise (SLR) (Prime 2018) and (c) skew surge (UKCP09) for the present day (2020) and the future epochs in 2040, 2070 and 2120. To make a comparison we downloaded the SLR and still water levels from the UKCP18 website (https://ukclimateprojections-ui.metoffice.gov.uk/). UKCP18 assumes that the changes in extreme water levels are mostly driven by SLR and the surge components won't change. Table 5-1 & Table 5-2 and Figures 5 & 6 show the SLR, still water levels and their differences between the present AECOM data and the UKCP18 result.

It can be seen that the differences in SLR and still water levels are relatively small (<10cm) for all four epochs. The present AECOM data are slightly higher (8-10cm) than UKCP18 results, which will provide a conservative estimate for wave overtopping. Considering these small differences in water level, redoing the calculation for wave overtopping is not recommended.

Table 5-1: Comparison of SLR and Surge Skewness

Year	AECOM		UKCP2018		Difference (cm)	
	SLR (cm)	Skewness (cm)	SLR (cm)	Skewness (cm)	SLR (cm)	Skewness (cm)
2020	7.5	0.6	5.4	0	-2.1	-0.6
2040	19.9	1.5	17.0	0	-2.9	-1.5
2070	41.5	2.9	41.0	0	-0.5	-2.9
2120	85.4	5.2	94.2	0	8.8	-5.2

Table 5-2: Comparison of extreme sea level for 2020 and 2040

AEP (%)	2020			2040		
	AECOM (m, OD)	UKCP2018 (m, OD)	Difference (cm)	AECOM (m, OD)	UKCP2018 (m, OD)	Difference (cm)
100	6.32	6.23	-9.0	6.45	6.35	-10.0
10	6.54	6.46	-8.0	6.67	6.58	-9.1
5	6.61	6.53	-8.0	6.74	6.65	-9.1
4	6.63	6.56	-7.0	6.76	6.67	-8.9
2	6.71	6.63	-8.0	6.83	6.74	-8.9
1.33	6.75	6.67	-8.0	6.87	6.78	-8.8
1.00	6.78	6.70	-8.0	6.9	6.81	-8.9
0.50	6.85	6.77	-8.0	6.98	6.88	-9.7
0.10	7.02	6.94	-8.0	7.15	7.06	-9.4

Table 5-3: Comparison of extreme sea level for 2070 and 2070

AEP (%)	2070			2100		
	AECOM (m, OD)	UKCP2018 (m, OD)	Difference (cm)	AECOM (m, OD)	UKCP2018 (m, OD)	Difference (cm)
100	6.67	6.59	-8.5	7.11	7.12	0.7
10	6.90	6.82	-8.1	7.35	7.35	0.2
5	6.97	6.89	-8.1	7.42	7.42	0.1
4	6.99	6.91	-7.9	7.44	7.44	0.3
2	7.07	6.98	-8.9	7.52	7.51	-0.7
1.33	7.11	7.02	-8.8	7.56	7.55	-0.6
1.00	7.14	7.05	-8.8	7.59	7.58	-0.6
0.50	7.21	7.12	-8.7	7.67	7.66	-1.5
0.10	7.39	7.30	-9.4	7.85	7.83	-2.2

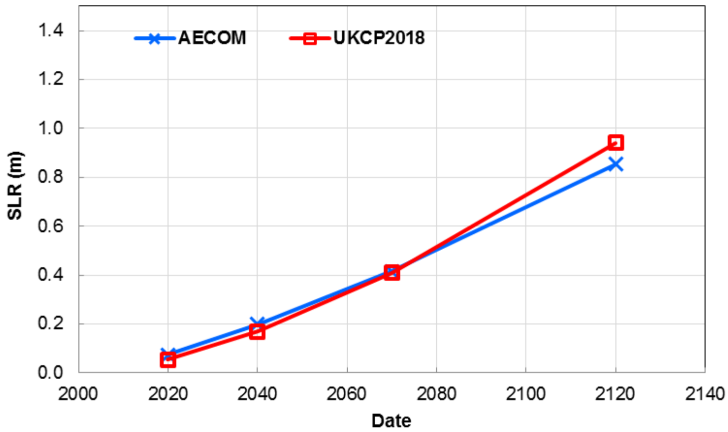

Figure 5-1: Comparison of SLR AECOM and UKCP18

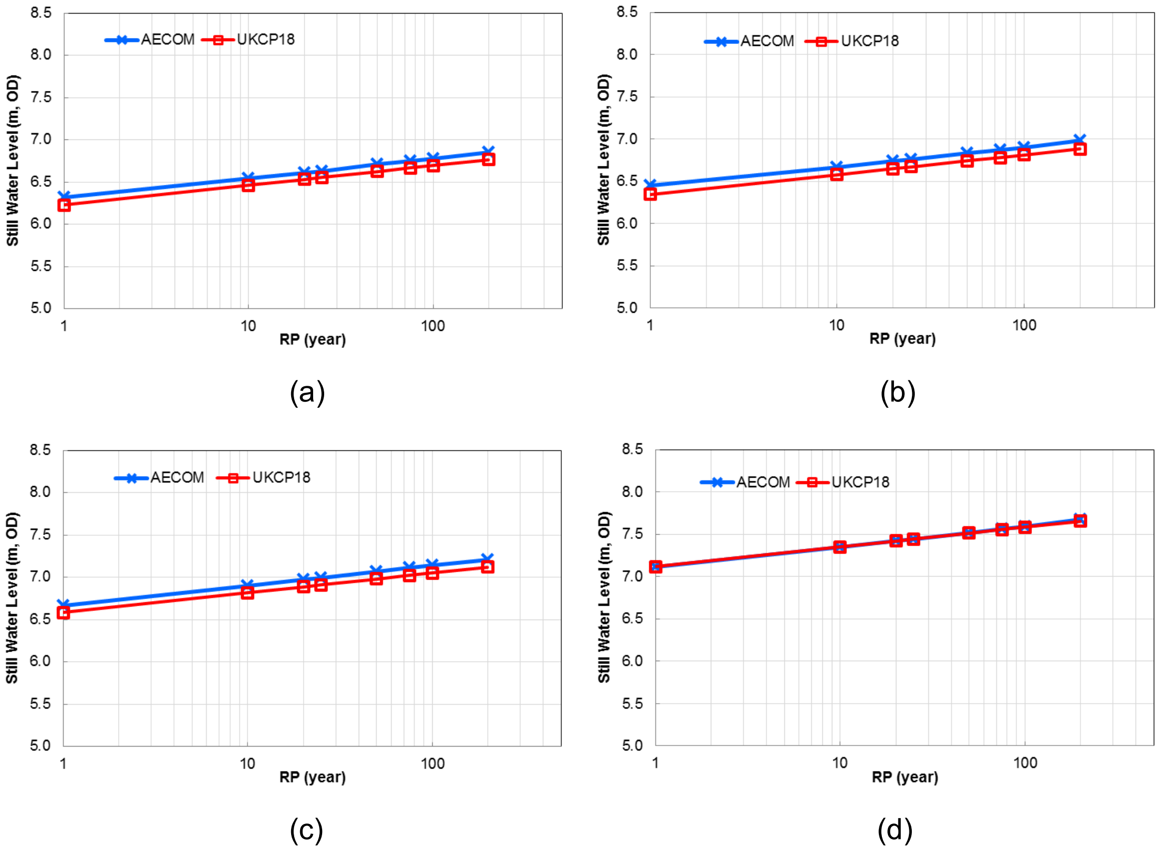

Figure 5-2: Comparison of extreme water level between AECOM and UKCP18 (a) 2020 (b) 2040 (c) 2070 and (d) 2010

6. Limitations and Uncertainty

There is a high degree of uncertainty associated with the prediction of future sea level rise. Prime (2018) made use of a European climate projection model to predict SLR for Jersey. The strong influence of physical processes such as storm tracks and jet streams are currently not well represented in the model. Moreover, Figure 4 shows the uncertainty in present SLR projections, both across climate scenarios (RCP4.5 and RCP8.5) and four time epochs. Therefore, although the research is the most up to date in terms of regional SLR projections, there remain inherent limitations and uncertainties.

The detailed design of any future scheme would need to consider the above uncertainties in more detail so the range of SLR is understood and taken account of during development of the design.

References

Prime (2018), Jersey sea level and coastal conditions climate review. National Oceanography Centre.

HR Wallingford (2009), The effects of climate change on Jersey's Coastal defence structures. Report EX5964, Release 6.0.

HR Wallingford (1991), Jersey Coastal Management Study. HR Wallingford Report EX2490, December 1991.