Christchurch Bay and Harbour Flood and Coastal Erosion Risk Management Study

Technical Annex 3: Coastal Conditions

Prepared by

New Forest District Council and Halcrow Group Limited

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Prepared by

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Contents

1 Introduction

This Technical Annex provides a summary of typical and extreme coastal conditions within Christchurch Bay, i.e. wind, offshore/ onshore waves, water levels and tidal currents, and Christchurch Harbour. The information within this Annex has been extracted from the first round Poole and Christchurch Bays Shoreline Management Plan (Halcrow, 1999).

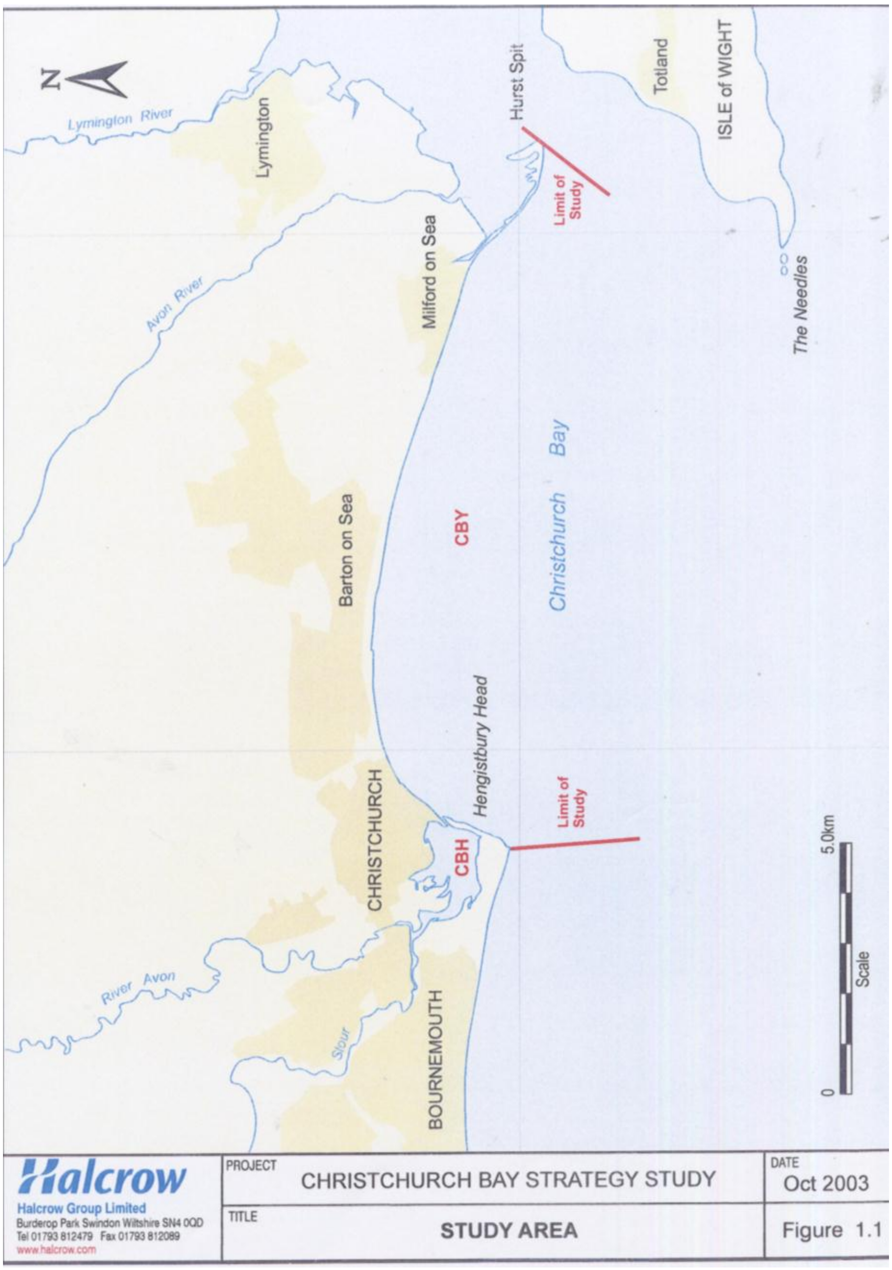

Figure 1.1. Study Area

2 Christchurch Bay

2.1 Wind

The main influence of the wind upon the shoreline is indirect through the generation of waves, water surface currents and water level set-up. These indirect influences are generally included in records of water level and waves. In addition the wind can physically mobilise light sediments and thus have a direct impact upon the movement of beach sands and the formation of dunes.

2.2 Offshore Wave Climate

During the development of the Poole and Christchurch Bays Shoreline Management Plan (SMP) five years of data from a model node offshore from Poole Bay (50.5 degrees North, 1.66 degrees West) was purchased from the UK Meteorological Office. This five year period of wave data, obtained between 1993 and 1997, was considered sufficient to provide an overview of the wave conditions for planning purposes.

The dominant offshore wave direction is from the south to south west. This corresponds to the direction of the longest fetches and strongest winds. However due to the sheltering effect of Durleston Head much of the wave energy from this direction will not reach the study frontage and it will be considerably attenuated due to refraction and diffraction.

The inclusion of swell wave data in the offshore wave conditions leads to a bi-modal wave height to wave period relationship, as shown in Table 1.2. This indicates that the longest wave periods of the record are associated with wave heights of 0.5m to 1.0m, demonstrating the importance of inclusion of swell waves in the analysis of coastal conditions.

While the normal offshore wave conditions should be well represented by data from the Met Office mode, estimation of extreme conditions from this data set is subject to uncertainty due to the relatively short period of available data, see Table 1.3. The alternative is to use longer-term estimates of the offshore waves that have been derived from wind data from Portland. The extreme storm waves which are required for the analysis and design of coastal defences are reasonably represented by the waves hindcast from Portland wind data, see Table 1.4.

Table 1.1: Normal Offshore Wave Climate, Height vs Direction

Wave height (m)	Wave Direction Sector (degrees)																	
	30 - 10	**50 – 30**	**70 - 50**	**90 – 70**	**110 - 90**	**130 - 110**	**150 - 130**	**170 - 150**	**190 - 170**	**210 - 190**	**230 - 210**	**250 - 230**	**270 - 250**	**290 - 270**	**310 - 290**	**330 - 310**	**350 - 330**	**10 - 350**	**Totals**
7.0 – 7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5 – 7.0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
6.0 – 6.5	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	3
5.5 – 6.0	0	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0	6
5.0 – 5.5	0	0	0	0	0	0	0	0	0	7	16	4	1	0	0	0	0	0	28
4.5 – 5.0	0	0	0	0	0	0	0	0	0	8	35	5	4	0	0	0	0	0	52
4.0 – 4.5	0	0	0	0	0	2	0	1	5	16	54	32	17	5	0	0	0	0	132
3.5 – 4.0	0	0	0	0	0	2	1	1	6	27	113	99	20	1	0	0	0	0	270
3.0 – 3.5	0	0	1	8	0	15	9	5	14	95	211	99	14	4	1	0	0	1	477
2.5 – 3.0	3	5	0	54	41	23	2	9	20	125	196	118	77	26	13	1	0	1	714
2.0 – 2.5	2	11	27	33	80	68	28	12	42	176	370	206	71	36	15	4	3	4	1188
1.5 – 2.0	25	59	67	130	103	53	48	42	63	243	489	251	151	86	32	19	7	11	1879
1.0 – 1.5	102	174	244	277	155	103	78	68	67	428	889	423	214	132	78	82	80	73	3667
0.5 – 1.0	116	160	165	208	154	75	69	42	37	478	1271	976	130	98	96	125	167	149	4516
0 – 0.5	44	41	46	52	54	11	4	11	10	150	479	478	47	48	38	31	34	34	1612
% in sector	2	3.1	3.8	5.2	4	2.4	1.6	1.3	1.8	12	28	19	5.1	3	1.9	1.8	2	1.9	14546

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)
Numbers show occurrences of three hourly wave events over the five year period

Table 1.2: Normal Offshore Wave Climate, Height vs Period

Wave height (m)	**Wave period (Tz, s)**											
	1.0 – 0.0	**2.0 – 1.0**	**3.0 – 2.0**	**4.0 – 3.0**	**5.0 -- 4.0**	**6.0 – 5.0**	**7.0 – 6.0**	**8.0 – 7.0**	**9.0 – 8.0**	**10.0 – 9.0**	**11.0 – 10.0**	**12.0 – 11.0**
7.0 – 7.5	0	0	0	0	0	0	0	0	0	0	0	0
6.5 – 7.0	0	0	0	0	0	0	0	0	2	0	0	0
6.0 – 6.5	0	0	0	0	0	0	0	0	3	0	0	0
5.5 – 6.0	0	0	0	0	0	0	0	0	6	0	0	0
5.0 – 5.5	0	0	0	0	0	0	0	8	20	0	0	0
4.5 – 5.0	0	0	0	0	0	0	0	35	17	0	0	0
4.0 – 4.5	0	0	0	0	0	0	0	129	3	0	0	0
3.5 – 4.0	0	0	0	0	0	0	41	229	0	0	0	0
3.0 – 3.5	0	0	0	0	0	1	397	79	0	0	0	0
2.5 – 3.0	0	0	0	0	0	91	614	9	0	0	0	0
2.0 – 2.5	0	0	0	0	8	1013	165	2	0	0	0	0
1.5 – 2.0	0	0	0	51	593	1132	80	20	3	0	0	0
1.0 – 1.5	0	0	0	659	2373	453	120	42	16	2	2	0
0.5 – 1.0	0	0	0	1886	1723	529	213	99	42	13	5	6
0 – 0.5	4	0	0	820	443	177	86	46	20	11	5	0

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)
Numbers show occurrences of three hourly wave events over the five year period

Table 1.3: Offshore Extreme Waves from Met Office Model Data

Return Period (yrs)	All Directions	
	Significant Wave Height Hs (m)	**Standard Error (m)**
1	5.5	0.2
5	6.3	0.4
10	6.7	0.6
20	7.0	0.8
50	7.4	1.2

Source: Analysis of 5 year time series (1993 to 1997) of Met Office wave data for SMP (Halcrow, 1999)

Table 1.4: Offshore Extreme Waves from Wind Hindcast

	Direction Sector											
	135		**150**		**180**		**210**		**240**		**All**	
Return period (yrs)	**Hs (m)**	**Tm (s)**	**Hs (m)**	**Tm (s)**	**Hs (m)**	**Tm (s)**	**Hs (m)**	**Tm (s)**	**Hs (m)**	**Tm (s)**	**Hs (m)**	**Tm (s)**
1	3.7	6.5	3.9	6.5	4.9	7.1	4.8	7.3	5.8	8.5	5.9	8.6
5	4.6	7.1	4.5	6.9	5.7	7.5	5.5	7.7	6.6	8.9	6.7	8.9
15	5.3	7.4	4.9	7.1	6.2	7.8	6.0	7.9	7.1	9.2	7.1	9.2
20	5.5	7.5	5.0	7.1	6.4	7.8	6.1	8.0	7.2	9.3	7.3	9.3
50	6.0	7.8	5.3	7.3	6.8	8.0	6.4	8.2	7.6	9.5	7.7	9.5
100	6.4	8.0	5.6	7.4	7.1	8.1	6.7	8.3	7.9	9.6	7.9	9.6

Source: HR (1989), based on 15 year hindcast from Portland wind data

Nearshore Wave Climate

Nearshore waves and their variability are probably the most significant factor for driving sediment transport and coastal evolution. The strong indentation of Christchurch Bay has largely been caused by historic erosion of soft cliffs. However, the inshore wave conditions depend on the diffraction and refraction caused by the evolving shape of the coast and the seabed. It is well known that the equilibrium bay shape is closely linked to the dominant offshore swell wave direction and the position of relatively non-erodible hard points. The historical alignment of Christchurch Bay is strongly related to the swell waves from the south west and thus it is important that wave analysis take the offshore wave conditions into account.

The nearshore wave climate consists of transformed swell and storm waves that have been generated offshore from the study frontage together with 'local' waves that are generated over the relatively short fetches within the confines of Christchurch Bay. In general transformed waves from offshore will be dominant at positions along the open coast. The dominant wave direction is from the south-west to south-east, with the largest waves originating from the south-west. The annual 10% exceedance significant inshore wave height is 1 to 1.5 m. Swell wave energy that propagates into the study area from the North Atlantic will have most influence on the western facing parts of Christchurch Bay.

During development of the SMP the five year series of offshore wave data was transformed inshore to a series of nearshore points for subsequent analysis. The model took into account the shallow water processes of refraction, shoaling, diffraction and depth limited wave breaking. The results were verified against nearshore wave measurements and showed very good agreement. The wave model results were used to derive timeseries of nearshore waves along the entire study frontage. The nearshore locations analysed are generally on the 2m to 4m below Chart Datum contour, depending on the model bathymetry. These time series were analysed to derive:

- wave height against direction and period scatter tables;
- extreme nearshore wave heights; and
- the distribution of alongshore wave energy, to assist in the analysis of beach processes.

Scatter diagrams for the modelled nearshore wave position at Christchurch Harbour entrance, Barton on Sea and at Hurst Beach the west end of Hurst Spit are shown in Tables 1.5 to 1.7 below. The easterly facing coast between Hengistbury Head Long Groyne and Christchurch Harbour entrance may be expected to be more sheltered that the rest of Christchurch Bay from waves from the south west. However, it is relatively more exposed to the south east, resulting in very similar extreme waves.

Table 1.5a: Wave height scatter, offshore Christchurch Harbour entrance

Wave height (m)	**Wave direction (degrees)**			
	120 - 150	**150 - 180**	**180 - 210**	**Totals**
5.0 – 5.5	0	1	0	1
4.5 – 5.0	0	4	0	4
4.0 – 4.5	1	6	0	7
3.5 – 4.0	7	10	0	17
3.0 – 3.5	6	22	0	28
2.5 – 3.0	14	29	1	44
2.0 – 2.5	27	75	1	103
1.5 – 2.0	79	149	2	230
1.0 – 1.5	159	253	40	452
0.5 – 1.0	235	560	199	994
0 – 0.5	136	2157	5507	7800
% in sector	6.9	33.6	59.4	9680

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)
Numbers show occurrences of three hourly wave events over the five year period

Table 1.5b: Wave period scatter, offshore Christchurch Harbour entrance

Wave height (m)	**Wave period (s)**					
	0 –2	**2 – 4**	**4 – 6**	**6 – 8**	**8 – 10**	**10 - 12**
5.0 – 5.5	0	0	0	1	0	0
4.5 – 5.0	0	0	0	4	0	0
4.0 – 4.5	0	0	0	7	0	0
3.5 – 4.0	0	0	0	16	1	0
3.0 – 3.5	0	0	0	27	1	0
2.5 – 3.0	0	0	22	21	1	0
2.0 – 2.5	0	0	57	40	6	0
1.5 – 2.0	0	0	163	63	4	0
1.0 – 1.5	0	17	273	152	10	0
0.5 – 1.0	0	119	526	341	8	0
0 – 0.5	0	1148	5077	1430	127	18

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)

Numbers show occurrences of three hourly wave events over the five year period

Table 1.6a: Wave height scatter table, Barton on Sea

Wave height (m)	**Wave direction (degrees)**			
	150 - 180	**180 - 210**	**210 - 240**	**Totals**
5.5 – 6.0	0	0	0	0
5.0 – 5.5	0	2	0	2
4.5 – 5.0	0	12	0	12
4.0 – 4.5	0	42	0	42
3.5 – 4.0	0	71	0	71
3.0 – 3.5	1	115	0	116
2.5 – 3.0	1	339	0	340
2.0 – 2.5	17	494	0	511
1.5 – 2.0	41	876	0	917
1.0 – 1.5	154	1356	21	1531
0.5 – 1.0	338	2160	563	3061
0 – 0.5	299	1225	1553	3077
% in sector	8.8	68.6	22.1	9680

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)

Numbers show occurrences of three hourly wave events over the five year period

Table 1.6b: Wave period scatter table, Barton on Sea

Wave height (m)	**Wave period (s)**					
	0 –2	**2 – 4**	**4 – 6**	**6 – 8**	**8 – 10**	**10 - 12**
5.0 – 5.5	0	0	0	0	2	0
4.5 – 5.0	0	0	0	3	9	0
4.0 – 4.5	0	0	0	17	25	0
3.5 – 4.0	0	0	0	62	9	0
3.0 – 3.5	0	0	0	112	4	0
2.5 – 3.0	0	0	6	332	2	0
2.0 – 2.5	0	0	113	398	0	0
1.5 – 2.0	0	5	623	287	2	0
1.0 – 1.5	0	58	1188	273	11	1
0.5 – 1.0	0	393	2290	330	37	11
0 – 0.5	0	828	1898	288	57	6

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)
Numbers show occurrences of three hourly wave events over the five year period

Table 1.7a: Wave height scatter table, Hurst Beach

Wave height (m)	**Wave direction (degrees)**			
	150 - 180	**180 - 210**	**210 - 240**	**Totals**
3.5 – 4.0	0	0	0	0
3.0 – 3.5	0	3	7	10
2.5 – 3.0	0	8	36	44
2.0 – 2.5	0	36	122	158
1.5 – 2.0	1	94	665	760
1.0 – 1.5	3	166	1551	1720
0.5 – 1.0	10	245	2950	3205
0 – 0.5	539	201	3043	3783
% in sector	5.71	7.78	86.51	9680

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)
Numbers show occurrences of three hourly wave events over the five year period

Table 1.7b: Wave period scatter table, Hurst Beach

Wave height (m)	Wave period (s)					
	0 –2	2 – 4	4 – 6	6 – 8	8 – 10	10 - 12
3.5 – 4.0	0	0	0	0	0	0
3.0 – 3.5	0	0	0	5	5	0
2.5 – 3.0	0	0	0	21	23	0
2.0 – 2.5	0	0	3	138	17	0
1.5 – 2.0	0	2	199	553	6	0
1.0 – 1.5	0	46	1124	550	0	0
0.5 – 1.0	0	362	2464	350	22	7
0 – 0.5	0	874	2328	485	85	11

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)
Numbers show occurrences of three hourly wave events over the five year period

It should be noted that although depth limitation of waves was taken into account in the transformation of the waves to the nearshore points, the extrapolation of the wave heights to extreme return periods does not. Due to the relatively short length of the offshore wave time series used for the analysis there is considerable uncertainty over the estimated wave heights for longer periods. Since it is usually recommended not to extrapolate beyond 3 to 5 times the record length, this would mean that the maximum return periods predicted should not exceed 25 years. In order to enable comparison with other estimates the 1 in 50 year value has been included in the analysis. However for many coastal structures the nearshore wave conditions will be depth limited, hence it is most important to make adequate allowances in design conditions for the tide level and surge heights. In this situation the wave period is as important a design parameter as the unbroken wave height. Example estimates of extreme nearshore wave condition at Hurst Point, Barton on Sea and Christchurch Harbour entrance are summarised in Table 1.8. It should be noted that the wave heights are smaller at Hurst Beach due to the sheltering afforded by the Shingles Bank.

Table 1.8: Estimated Extreme Wave Conditions

Return Period (years)	Significant wave height, Hs(m)		
	Christchurch Harbour Entrance	Barton on Sea	Hurst Point
1	4.1	4.8	1.6
5	4.8	5.0	1.9
10	5.0	5.0	2.1
20	5.2	5.1	2.3
50	5.3	5.1	2.6

Source: Analysis of 1993 to 1997 offshore wind data from Met Office model for SMP (Halcrow, 1999)

2.4 Water Levels

Tidal water level predictions for Christchurch Bay were obtained from data in the Admiralty Tide Tables for Hurst Point and principal tidal levels are shown in Table 1.9 below. The tidal range generally decreases towards the east from approximately 1.5 m at Swanage to 2.6 m at Hurst Narrows. The distortion of the tidal curve by shallow water effects, which results in a double high water between Swanage and Southampton, produces a corresponding long stand of high water within Christchurch Bay.

Table 1.9: Tide Levels for Hurst Point

	Tide Level (mODN)
Mean High Water Spring (MHWS)	+0.9
Mean High Water Neap (MHWN)	+0.5
Mean Sea Level (MSL)	-0.1
Mean Low Water Neap (MLWN)	-0.5
Mean Low Water Spring (MLWS)	-1.3

Source: Admiralty Tide Tables

Extreme water level analysis has been undertaken at Hurst Point and Hengistbury Head and the results are provide in Table 1.10 below. There is little difference between the two estimates, probably because they are based on almost the same data set.

Table 1.10: Extreme Water Levels for Christchurch Bay

Return period (years)	**Extreme Water Level at Hurst Point (mODN)** (*)	**Extreme Water Level at Hengistbury Head (mODN)** (**)
1	-	1.7
2	1.8	-
5	1.9	-
10	2.0	2.0
20	2.2	-
50	2.3	2.2
100	2.4	2.4

Sources:
(*) Halcrow (1994) – based on 25 years of tide and surge from POL model
(**) Dixon and Tawn (1997)
For the study area the current recommended allowance for sea level rise is 6mm/year.

2.5 Tidal Currents

The tidal currents are strongest in the region of Shingles Bank and the Western Solent entrance due to the flow constriction causing local acceleration. Typical peak flood and ebb spring currents near Shingles Bank are of the order of 1m/s. Strong currents, >1.5m/s are experienced around the entrance to Christchurch Harbour. Elsewhere within Christchurch Bay tidal currents are relatively weak, with peak spring currents less than 0.5m/s. During the flood tide the flow is in an easterly direction whilst on the falling tide the flow is westwards offshore. The modelling for the CIRIA (1998) study identified a weak clockwise gyre in the tidal residuals for Christchurch Bay.

3 Christchurch Harbour

3.1 Wave Climate

Within Christchurch Harbour the wave climate is dominated by locally generated waves. Using wind data, local hindcasts have been used to estimate extreme wave conditions for several locations. Extreme wave heights are all less than 0.8m, at high tide due to short fetch lengths. The results are shown in Figure 3.1.

3.2 Water Levels

Tidal level data for Christchurch Harbour are available for the entrance, Mudeford Quay and at the inner part of the harbour, Christchurch Quay. Principal levels are provided in Table 3.1.

Table 3.1: Tide Levels for Christchurch Harbour

	Tide Level (mODN)	
	Christchurch Quay	**Mudeford Quay**
Mean High Water Spring (MHWS)	+0.9	+0.9
Mean High Water Neap (MHWN)	+0.5	+0.5
Mean Sea Level (MSL)	+0.3	+0.2
Mean Low Water Neap (MLWN)	0.0	-0.2
Mean Low Water Spring (MLWS)	-0.1	-0.3

Source: Admiralty Tide Tables

The Admiralty Tide Tables (1998) comments that the tidal levels for Christchurch Harbour entrance are for a point inside the bar, and that outside the bar the water level falls about 0.6m lower on spring tides.

Table 3.2: Extreme Water Levels for Christchurch Harbour

Return period (years)	**Extreme Water Levels within Christchurch Harbour (mODN)** (*)	**Extreme Water Levels Offshore of Christchurch Harbour (mODN)** (**)
1	-	-
2	-	1.8
5	-	2.0
10	1.4	2.1
50	1.5	2.3
100	1.6	2.4

Source: Halcrow (1994) – based on 25 years of tide and surge from POL model
Sources:
(*) Hague (1992) – based on 14 years of data
(**)Halcrow (1994) – based on 25 years of tide and surge from POL model

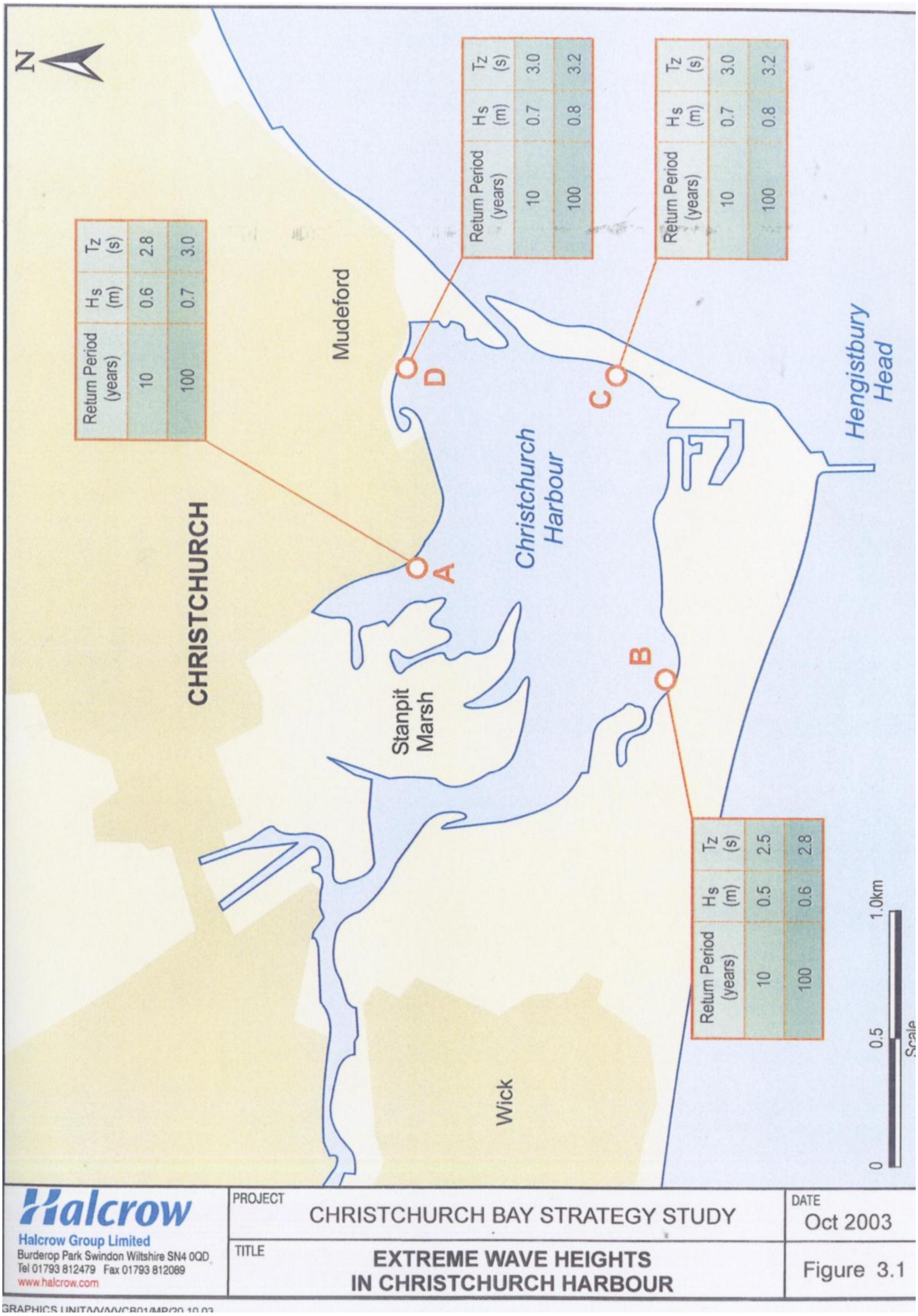

Figure 3.1. Extreme Wave Heights in Christchurch Harbour

The fluvial and tidal influence on water levels was investigated by BMT (1993). During high river flows the fluvial discharge apparently prevents the ingress of the flood tide into the harbour and the flow is constantly ebbing in The Run. Under such flood conditions water levels can back up in the harbour, leading to flooding at Christchurch. From a brief analysis of relatively recent significant flooding events BMT (1993) concluded that extreme water levels and flooding was primarily tidally controlled at Mudeford Quay, whilst at Christchurch Quay fluvial flooding was more likely.

3.3 Tidal Currents

Mathematical modelling of tidal currents in Christchurch Harbour and in the adjacent part of Christchurch Bay was undertaken by BMT (1993). The study also included collection of field data in The Run for calibration of the model. Peak tidal currents occur in The Run and are around 1.6m/s on a spring tide. Currents are much lower elsewhere within the Harbour and the adjacent part of Christchurch Bay.

3.4 Fluvial Flows

There is significant fluvial input into Christchurch Harbour. Average daily river input from the Stour is 50 cumecs and for the Avon 20 cumecs. The Avon gives fairly consistent flows, whilst flow in the Stour varies considerably in response to periods of heavy rainfall. The maximum recorded instantaneous flow in the Stour was 310 cumecs in Dec 1979 and the peak discharge in the Avon on the same day was 120 cumecs (BMT, 1993). Estimates of flow rates for various return periods are shown in Table 3.3.

Table 3.3: Extreme Freshwater Inputs to Christchurch Harbour

Return period (yrs)	**Daily Mean Flow (cumecs)**	
	Stour (Throop)	**Avon (Knapp Mill)**
2	102	51
5	137	57
10	163	61
25	199	66
50	229	70
100	262	74

Source: Indicative only, based on data from 1990 to 1993. Source BMT (1993)

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