Curtin

UNIVERSITY OF TECHNOLOGY

Centre for Marine Science and Technology

Commercial Report

FULL-SCALE BOAT WAKE AND WIND WAVE TRIALS ON THE SWAN RIVER

Final Report

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Swan River Trust

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EXECUTIVE SUMMARY

This report describes the second stage of an investigation into boat wakes on the Swan River, performed by Curtin University's Centre for Marine Science and Technology, together with the Australian Maritime College, for the Swan River Trust. The first stage of the investigation was a desktop study into boat wakes and wind waves on the Swan River. In that report, boat wakes were predicted using a database of deep-water model test results. Wind waves were predicted with empirical formulae, using 7 years of measured wind data on the Swan River.

The present study focuses on measuring boat wakes and wind waves at full scale, at locations of interest on the Swan River. Nine different hull forms have been tested in dedicated trials, with each trial including a full range of boat speeds, at two different distances away from the waverecorder. These dedicated trials were performed at Ashfield Parade, Quarry Point and South Perth. Wind wave measurements were performed at Ashfield Parade and Quarry Point.

As well as the dedicated trials, cumulative boat wake trials have been performed at Quarry Point, Chidley Point and Goodwood Parade. These experiments have measured the total wave energy produced at each location during a normal busy period, as well as the types of vessels producing the highest wave energy at each location.

Wind wave measurements were used to assess the suitability of the wind wave prediction method. It was found that while the mean values were well predicted, the maximum wave heights and periods were under-predicted at Quarry Point. These results were used to modify the wind wave prediction method, and the resulting method used for all comparisons at Quarry Point.

The results from the dedicated trials at Ashfield Parade showed that the speed of 8 knots (the present speed limit) roughly corresponds to the highest-energy boat wakes for the Bayliner 27, Haines Hunter 680, Quintrex 570 and Quintrex 470. This unfortunate situation is partly due to the short length of these vessels, causing a hump speed at close to 8 knots, and partly due to the water depth in this region (2 – 4m) giving a detrimental shallow-water effect particularly at this speed. At higher speeds, each of these vessels is able to plane and produce less wave energy than at hump speed, but still higher than the extreme wind wave energy. Only at speeds less than 6 knots did all of the vessels produce less wave energy than the extreme wind waves. At 5 knots, all vessels produced a tiny wake.

The dedicated trials at Quarry Point showed that the smaller vessels (Haines Hunter 680 and LeisureCat) produced wave energy slightly less than that of the extreme wind waves at their hump speed (8 – 10 knots), and smaller wave energy at higher and lower speeds. The larger vessels (Riviera 48 and Star Flyte Express) produced very large wave energy at all speeds above 9 knots, up to 10 times the extreme wind wave energy. The wave energy was comparable between the recreational craft and the ferry. For both of these vessels, the water depth in the area (4 – 6m) played an important role, with the shallow-water critical speed of 12 – 15 knots helping to cause large wave energy in this speed range. Star Flyte Express in particular produced a classical "critical speed" wave pattern at 12 knots, with associated high resistance and high wave energy produced.

Of the sites tested for cumulative wave energy, Chidley Point produced the largest total wave energy, despite having the smallest number of vessels passing. At Chidley Point as well as at Quarry Point, the boats producing the largest wave energy during a normal busy weekend period were the large recreational craft. Some of these boats produced especially large breaking waves on the shoreline. The Star Flyte Express, Captain Cook and James Stirling produced comparatively small wave energy at Chidley Point and Quarry Point. The primary reason for the difference between the recreational and commercial craft was speed, with the recreational craft tending to travel at higher speeds and hence produce larger wave energy. The waterski area at Goodwood Parade was also tested for cumulative wave energy, and despite having a very large number of passing boats (around 420 in a 4-hour period), the total boat wake energy was around half that of the other sites. Also, the wake energy produced by individual boats was in the order of 10% of that produced by large recreational craft at the other locations.

CONTENTS

ACKNOWLEDGEMENTS

The Boating Industry Association of WA arranged recreational vessels for the dedicated trials. The vessels trialled included recreational vessels produced by Haines Hunter, LeisureCat, Quintrex and Riviera.

Rottnest Express provided the Star Flyte Express and her crew for dedicated trials before her normal ferry run.

Captain Cook Cruises allowed access to the River Lady for trials past Ashfield Parade, and helped with GPS measurements.

Melville Water measured wind data mentioned was supplied by the WA Climate Services Centre, Bureau of Meteorology.

The WA Department of Transport provided:

- permission and Notices to Mariners for waverecorder equipment to be installed on the riverbed and on navigational pilons
- DoT boat and crew to direct vessel traffic while each trial took place
- measured tide data from Barrack St jetty
- raw soundings data for Quarry Point and Ashfield Parade

The Swan River Trust liaised with all parties and provided general organization of the project. They also provided boats and crew to install waverecorder equipment and help with directing traffic during trials.

NOMENCLATURE

c_g	Wave group velocity [ms^{-1}]
E	Energy per wavelength, per metre of wave crest [Jm^{-1}]
$\overline{E}$	Wave energy density [Jm^{-2}]
E_c	Cumulative energy per metre of wave crest length [Jm^{-1}]
g	Acceleration due to gravity [9.81ms^{-2}]
h	Water depth [m]
h_w	Waverecorder depth [m]
k	Wave number $= 2\pi/\lambda$ [m^{-1}]
H	Wave height [m]
p	Measured pressure above atmospheric [Pa]
$\overline{P}$	Wave power per metre of wave crest length [Wm^{-1}]
T	Wave period [s]
y	Lateral distance between vessel sailing line and measurement point [m]
z	Local wave elevation [m]
λ	Wave length [m]

All times given are West Australian Standard time, synchronized to GPS.
All positions given are measured using GPS, relative to WGS84 datum.

1 INSTRUMENTATION AND CALCULATION METHODS

The instrumentation used for this project is described below, together with the calculation methods used.

1.1 Waverecorder

Wave parameters were measured using a Unispan PT2X pressure sensor waverecorder (see http://www.unispan.com.au/INW/PT2X.htm), measuring at 8 samples per second. For all trials, the waverecorder was mounted 0.5m – 0.9m beneath the still water level, so that it lay close to the surface but still stayed submerged in the deepest troughs.

Two mounting methods were used for the waverecorder: pilon-mounted or seabed-mounted. Where a fixed pilon was available, this was used as a solid platform on which to mount the waverecorder. At Ashfield Parade, where no pilon was available, the waverecorder was mounted on a submerged frame sitting on the seabed. Photos of the mounting methods at all locations are shown in Figures 1 – 5.

Figure 1: Submerged seabed-mounted frame used at Ashfield Parade, with waverecorder attached to top

Figure 2: Submerged waverecorder attached to frame mounted on Quarry Point pilon

Figure 3: Submerged waverecorder attached to old Ellam St jetty

Figure 4: Submerged waverecorder attached to frame mounted on Chidley Point pilon

Figure 5: Submerged waverecorder attached directly to Goodwood Parade pilon

The waverecorder measures pressure, which is then converted into free surface displacements. Since the waverecorder is close to the surface, pressure changes are essentially proportional to wave elevations. The method used to convert measured pressure to wave elevation, heights, periods, power and energy is described in Appendix A. The error analysis is described in Appendix B.

1.2 Recordable GPS units

Recordable GPS units were used on all boats trialled. The GPS units used were a Velocitek "Speed Puck" unit (www.velocitek.com) and a Navi GT-11 unit (www.locosystech.com). The GPS units recorded time-stamped latitude and longitude at 1 second intervals, from which the boat's track, speed and heading could be obtained. A GPS fix was also taken at the position of the waverecorder, so that the transverse distance from the boat's track to the waverecorder could be determined for each run.

2 LIST OF VESSELS TESTED IN DEDICATED TRIALS

The vessels tested in dedicated trials are as shown below. The most important boat parameters for wake production are length and displacement, with exact hull shape details being of secondary importance. Therefore, a list of popular vessel types was chosen which spanned the range of vessel sizes using the upper and lower reaches of the river.

Hull details for the vessels tested are shown below. The hull length (LH) is the measured length of the hull according to ISO8666.

Vessel name	Hull length	Beam	Website / Further information
Star Flyte Express	38.9m	8.5m	www.rottnestexpress.com.au
Captain Cook River Lady	24.9m	5.6m	www.captaincookcruises.com.au
Riviera Offshore Express 48	15.2m	4.9m	www.riviera.com.au
SRT Noel Robins	8.5m	2.8m	
LeisureCat Mako 9000	9.0m	2.9m	www.leisurecat.com.au
Bayliner 275	8.4m	2.9m	www.bayliner.com
Haines Hunter Patriot 680	6.8m	2.5m	www.haineshunter.com.au
Quintrex Freedom Sport 570	5.7m	2.4m	www.quintrex.com.au
Quintrex Freedom Sport 470	4.7m	2.1m	www.quintrex.com.au

Table 1: Details of vessels tested in dedicated trials

3 DEDICATED TRIALS AT ASHFIELD PARADE

The Ashfield Parade trials were undertaken just south of Ron Courtney Island, running parallel to the western bank at headings of 13° and 193°. The waverecorder was attached to the frame shown in Figure 1, and located at 31°55.39692'S, 115°56.35374'E. Buoys were set up so that the trials could be undertaken at distances of approximately 25m and 50m from the waverecorder. The relative position of the buoys and waverecorder can be seen in the photos later in this section.

A chart extract showing the trials location and approximate position of the waverecorder is shown below.

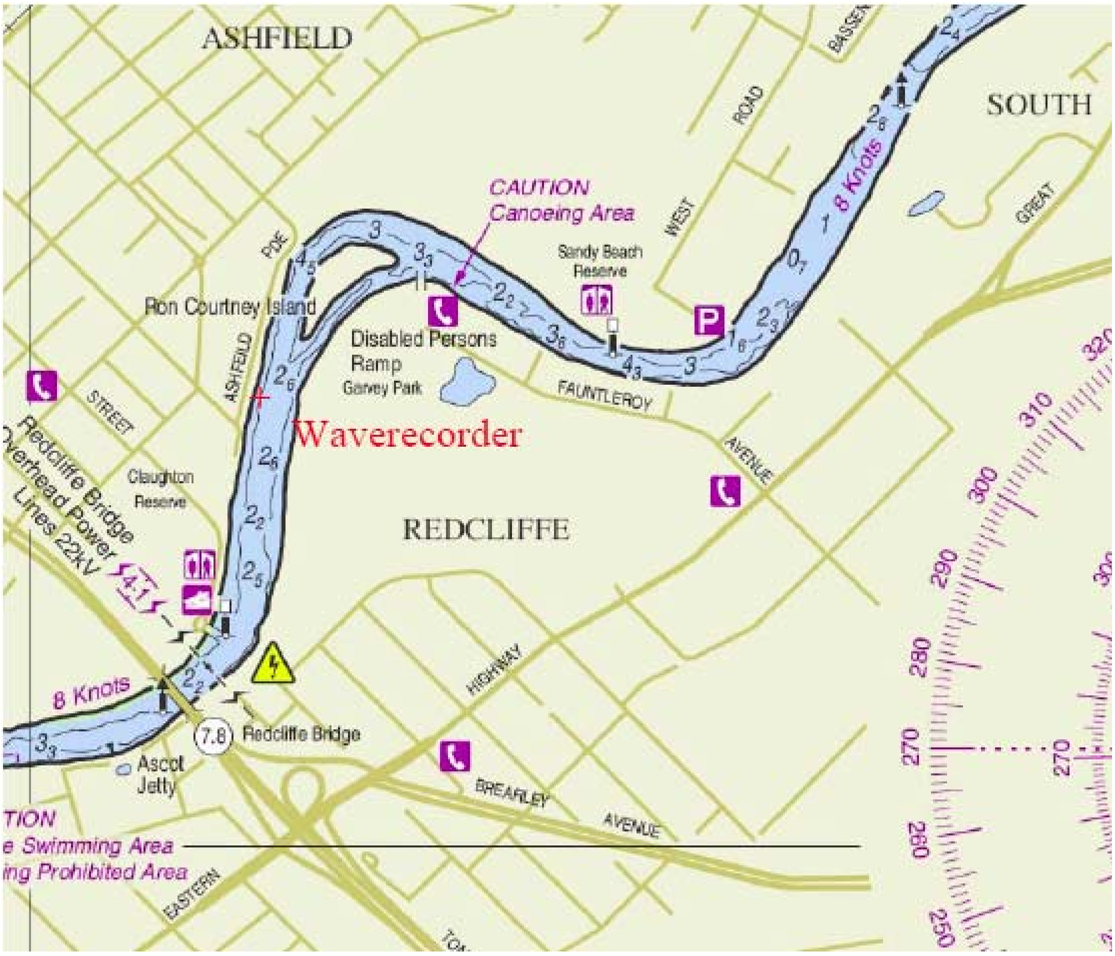

Figure 6: Extract from chart of Ashfield Parade trials location. Waverecorder position marked as red cross.

An example GPS trace from one of the dedicated trials at Ashfield Parade is shown below. Positions are shown relative to the waverecorder at (0,0). The early runs (blue colour) are close to the waverecorder, while the later runs (red colour) are further off.

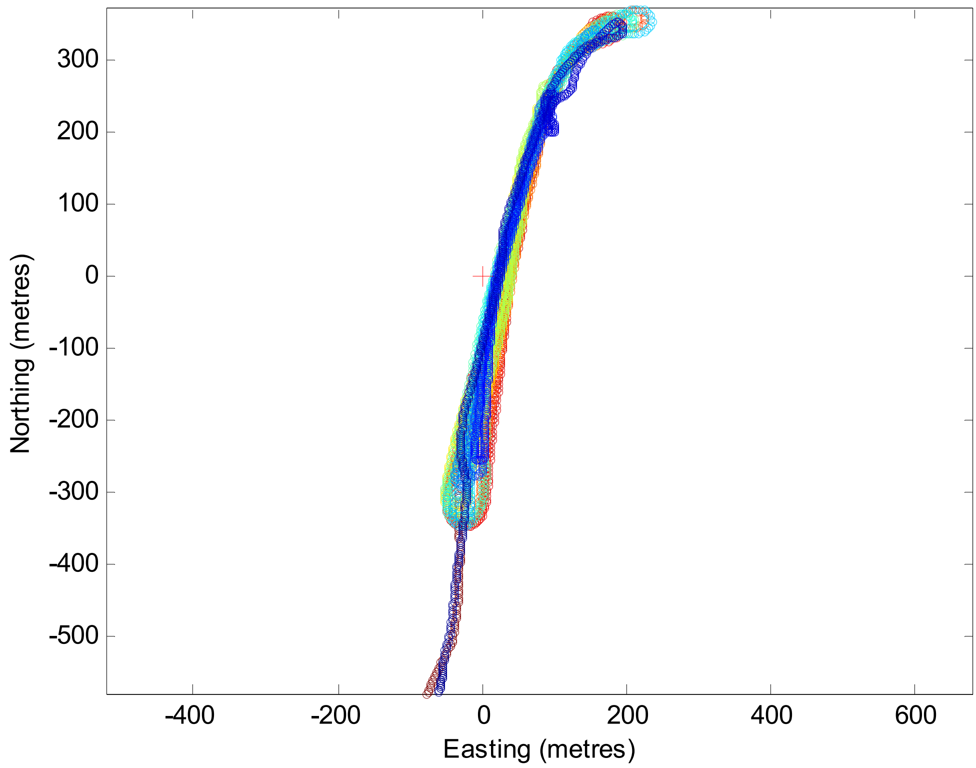

Figure 7: Example GPS trace from Ashfield Parade, for Haines Hunter 680. GPS positions shown relative to waverecorder (red cross). Colours show times, from blue (start) to red (end).

The runs were made long enough so that the wake had time to be measured by the waverecorder and then die down before the next run. It was attempted to keep the boat speed constant during each run, though this was not always possible, especially at close to hump speed.

An "up and back" run was done at each speed, before moving up to the next speed.

The GPS position and speed of the boat were recorded by the recordable GPS brought onto each boat. These results were later processed to determine the transverse distance from the waverecorder (at the closest point in each run) and the speed. The stated speeds are averaged over a run length of 100m each side of the waverecorder, and the amount of variability is also given.

Waves were measured using the pressure sensor waverecorder, logged internally, and later converted into measured wave elevations as described in Section 1 and Appendix A.

Currents were negligible for all of the trials at Ashfield Parade.

The dedicated trials results for each vessel at Ashfield Parade will now be described.

3.1 Bayliner 275

The Bayliner 275 was tested at Ashfield Parade on 2nd February 2010, from 06:45 to 07:55. Wind conditions as measured at Melville Water were S – SSW, 12 – 17 knots. The mean water depth at the waverecorder during the trials was approximately 1.9m.

The displacement of the Bayliner 275 in the tested condition was approximately 2.7 tonnes, with draft 0.6m.

The wake results for the Bayliner 275 are shown below.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 200m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
06:47:20	25.8	5.2	10.0	0.037	1.25	2	4
06:48:49	25.2	5.1	4.6	0.084	1.75	13	41
06:50:40	24.5	6.1	3.8	0.086	1.50	11	33
06:52:14	28.2	6.0	2.6	0.080	1.25	8	19
06:53:47	21.5	7.1	3.4	0.123	1.75	27	90
06:55:04	25.9	7.0	2.9	0.149	2.00	48	167
06:56:38	23.6	8.1	2.3	0.270	2.00	156	545
06:58:09	24.1	8.2	13.5	0.238	2.50	164	610
07:00:10	21.9	9.1	11.3	0.291	2.50	245	911
07:01:39	24.5	8.8	19.2	0.391	2.00	328	1150
07:03:34	23.0	9.7	20.6	0.349	2.50	354	1320
07:05:11	23.1	9.7	24.7	0.321	2.00	222	776
07:07:22	22.8	10.8	20.8	0.255	1.50	97	286
07:09:06	24.1	10.7	30.8	0.269	1.75	130	428
07:11:15	21.0	12.4	9.1	0.271	1.75	132	434
07:12:57	25.4	11.3	27.3	0.296	2.25	222	800
07:15:17	49.6	5.2	10.5	0.057	2.00	7	25
07:17:02	49.9	5.2	8.6	0.058	1.25	4	10
07:19:40	52.6	6.5	6.2	0.073	2.25	13	49
07:22:36	46.4	6.2	5.5	0.101	2.25	26	92
07:25:41	52.7	7.1	2.3	0.089	1.75	14	47
07:27:55	50.9	7.2	4.7	0.208	2.25	109	395
07:30:27	48.4	8.2	6.2	0.293	2.00	184	642
07:32:48	51.8	8.0	6.1	0.285	2.25	205	740
07:36:14	47.4	9.2	9.1	0.250	2.25	158	569
07:38:17	51.4	10.2	21.2	0.242	2.25	148	534
07:40:14	51.8	10.5	17.8	0.222	1.50	73	217
07:42:12	53.4	10.0	16.0	0.203	3.50	163	702
07:44:31	47.9	11.5	6.1	0.178	1.75	57	187
07:46:11	48.5	11.8	14.6	0.245	1.75	107	353
07:48:36	51.2	12.0	6.0	0.192	2.00	79	276
07:50:23	50.5	12.4	9.5	0.233	1.75	98	321

Table 2: Wake trials results for Bayliner 275 at Ashfield Parade

An example wave elevation trace and corresponding photo are shown below, for the largest measured wave height case.

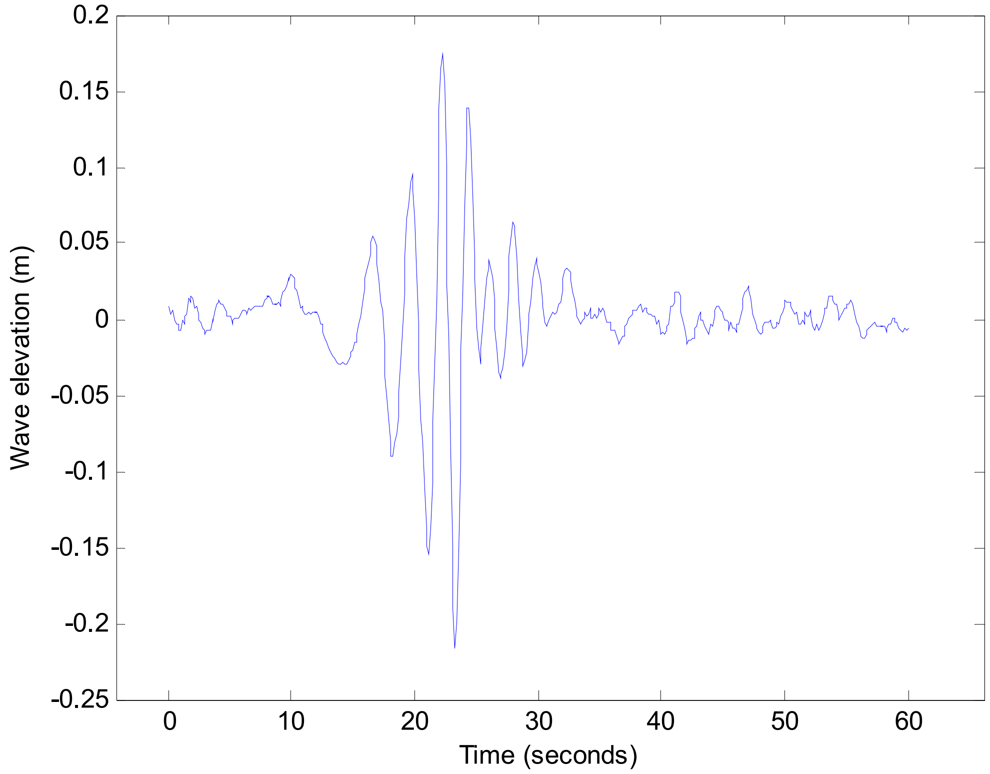

Figure 8: Measured wave elevation for Bayliner 275 example case (largest wave height): 8.8 knots at 07:01

Figure 9: Photo of Bayliner 275 example case (largest wave height): 8.8 knots at 07:01. Waverecorder is beneath white buoy in foreground.

3.2 Haines Hunter Patriot 680

The Haines Hunter Patriot 680 was tested at Ashfield Parade on 2nd February 2010, from 08:55 to 10:25. Wind conditions measured at Melville Water at the time were SSE – S, 9 – 13 knots. The mean water depth at the waverecorder during the trial was approximately 1.9m.

The displacement in the tested condition was approximately 2.1 tonnes (bare hull 1500kg, Honda 225 outboard 270kg, 350l fuel tank ⅓ full 90kg, 3pax 210kg).

Measured wake results for the Haines Hunter Patriot 680 are shown below.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 200m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
08:59:18	22.4	5.9	1.8	0.084	1.75	13	41
09:05:42	19.3	6.1	1.2	0.086	1.50	11	33
09:08:28	24.4	6.5	1.3	0.093	1.75	16	52
09:10:55	24.6	6.9	2.2	0.106	2.00	24	84
09:13:34	20.1	7.2	1.9	0.219	2.00	103	359
09:15:55	18.1	7.5	1.6	0.222	2.25	125	452
09:18:27	22.8	8.4	1.7	0.306	2.25	237	855
09:21:19	19.9	8.7	4.0	0.303	2.25	233	840
09:23:46	21.9	11.2	1.7	0.210	2.00	95	332
09:26:49	16.4	9.8	1.2	0.231	2.25	136	490
09:29:02	24.5	9.6	7.5	0.216	2.25	118	425
09:31:59	17.3	10.5	3.4	0.262	2.00	148	517
09:34:03	22.9	12.1	0.8	0.234	1.75	99	325
09:36:25	17.3	11.9	3.5	0.261	1.75	122	402
09:38:14	26.0	14.9	3.4	0.229	1.50	78	231
09:40:24	16.4	13.4	6.6	0.245	1.50	90	265
09:43:14	40.0	5.4	1.1	0.063	1.25	5	12
09:46:43	34.5	5.5	1.4	0.040	1.25	2	5
09:49:29	38.3	6.3	1.1	0.073	1.75	10	31
09:52:07	34.0	6.6	1.7	0.089	1.25	10	24
09:55:24	37.8	7.2	1.5	0.212	1.75	81	265
09:58:52	38.9	7.4	0.8	0.152	2.25	59	212
10:01:09	39.3	8.5	1.5	0.242	2.25	149	536
10:04:25	41.0	8.0	2.3	0.201	2.25	103	370
10:07:09	37.4	10.8	6.5	0.192	2.00	79	277
10:09:55	40.3	11.2	1.8	0.180	1.50	48	142
10:12:14	39.8	9.4	3.1	0.218	2.25	120	434
10:15:04	37.8	9.8	3.1	0.164	2.50	78	289
10:17:24	39.8	11.6	1.1	0.159	1.75	45	149
10:19:51	36.9	11.5	4.2	0.193	1.75	67	221
10:21:53	38.8	12.6	3.2	0.173	1.75	54	176
10:24:11	37.4	13.0	1.2	0.196	1.50	57	169

Table 3: Wake trials results for Haines Hunter Patriot 680 at Ashfield Parade

An example wave elevation time trace is shown below, for the largest wave height case.

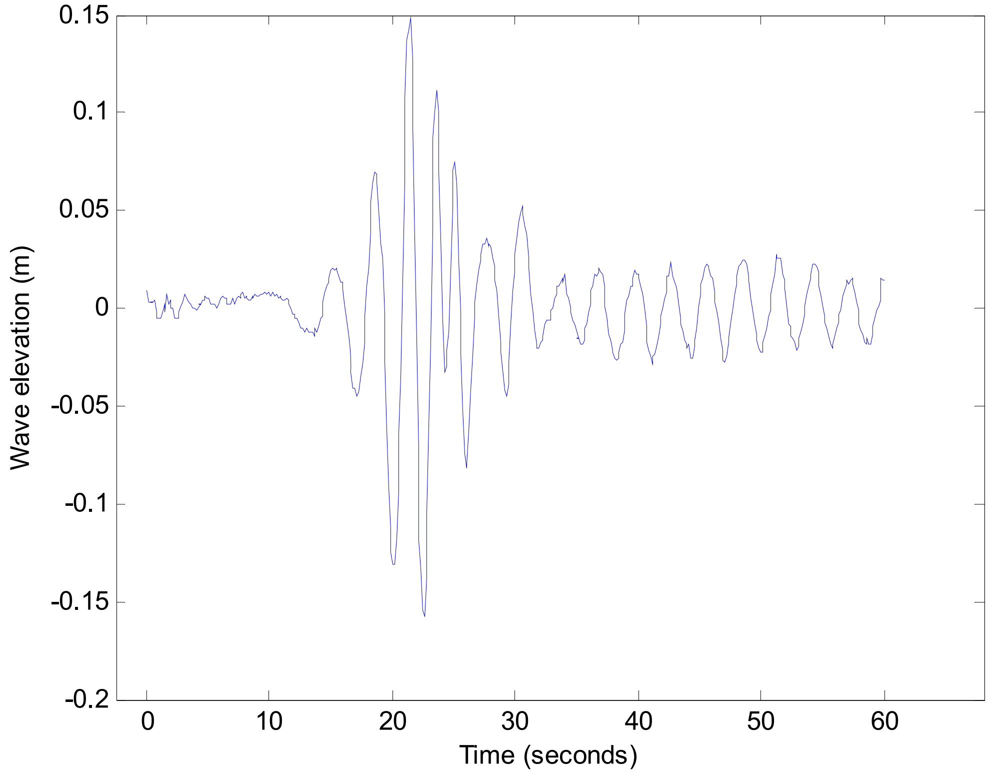

Figure 10: Measured wave elevation for Haines Hunter Patriot 680 example case (largest wave height): 8.4 knots at 09:18

3.3 Quintrex Freedom Sport 470

The Quintrex Freedom Sport 470 was tested at Ashfield Parade on 3rd February 2010, from 06:50 to 08:10. The wind conditions at the time, as measured at Melville Water, were SSE, 8 – 12 knots. The mean water depth at the waverecorder during the trial was approximately 1.9m.

The hull displacement in the tested condition was approximately 740kg (hull 400kg, 60hp outboard 160kg, 70l fuel tank ¾ full = 40kg, 2pax = 140kg).

Measured wake results for the Quintrex Freedom Sport 470 are shown below.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 200m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
06:52:03	20.0	4.8	1.0	0.021	1.50	1	2
06:54:57	20.5	4.8	1.5	0.026	1.25	1	2
06:56:17	24.3	5.4	13.1	0.026	1.00	1	1
07:02:13	22.6	5.6	1.0	0.088	1.50	12	34
07:03:14	20.6	5.8	4.1	0.073	1.50	8	23
07:06:44	22.0	6.7	2.1	0.185	1.75	61	201
07:08:44	18.9	6.7	1.8	0.180	1.50	48	142
07:10:25	19.8	8.6	1.7	0.177	1.50	47	137
07:11:51	22.2	8.1	2.2	0.183	2.00	72	251
07:13:30	24.8	9.8	15.2	0.137	1.50	28	83
07:14:57	19.6	8.6	3.8	0.158	1.50	37	109
07:17:00	20.0	8.4	11.2	0.185	1.50	51	151
07:19:03	21.8	10.4	36.0	0.127	1.50	24	71
07:21:28	25.8	10.9	10.8	0.114	1.25	16	40
07:23:10	22.6	11.0	4.3	0.121	1.25	18	45
07:24:59	24.7	13.2	10.6	0.089	1.50	12	35
07:26:42	17.9	13.3	8.6	0.115	1.75	24	78
07:29:43	25.1	5.2	2.3	0.038	1.50	2	7
07:31:16	16.9	5.7	5.8	0.091	1.50	12	36
07:33:18	21.9	5.9	1.5	0.110	1.50	18	53
07:34:55	47.7	6.0	2.4	0.064	1.50	6	18
07:37:05	38.9	5.8	1.2	0.107	1.75	21	68
07:39:58	39.6	5.4	1.8	0.047	1.50	3	10
07:42:35	40.1	5.2	1.4	0.033	1.25	1	3
07:45:12	39.3	6.7	1.1	0.139	1.50	29	84
07:47:22	37.8	6.8	3.1	0.175	2.00	66	231
07:49:43	34.9	8.0	2.7	0.191	1.75	65	214
07:51:25	37.8	8.3	3.0	0.152	2.50	67	249
07:53:12	39.9	8.6	3.1	0.130	1.50	25	75
07:54:56	42.7	9.2	17.3	0.090	2.00	17	61
07:56:55	40.8	9.6	17.2	0.095	1.75	16	53
07:59:39	44.0	9.3	23.0	0.098	1.50	14	42
08:01:37	36.3	9.9	18.5	0.114	1.25	16	40
08:03:48	40.4	10.3	34.7	0.121	1.50	22	64
08:05:42	37.4	10.2	27.4	0.104	1.25	13	33
08:07:39	39.1	12.0	10.8	0.106	1.25	14	34
08:08:55	35.3	11.5	7.0	0.122	1.50	22	66

Table 4: Wake trials results for Quintrex Freedom Sport 470 at Ashfield Parade

An example wave elevation time trace for the Quintrex Freedom Sport 470 is shown below.

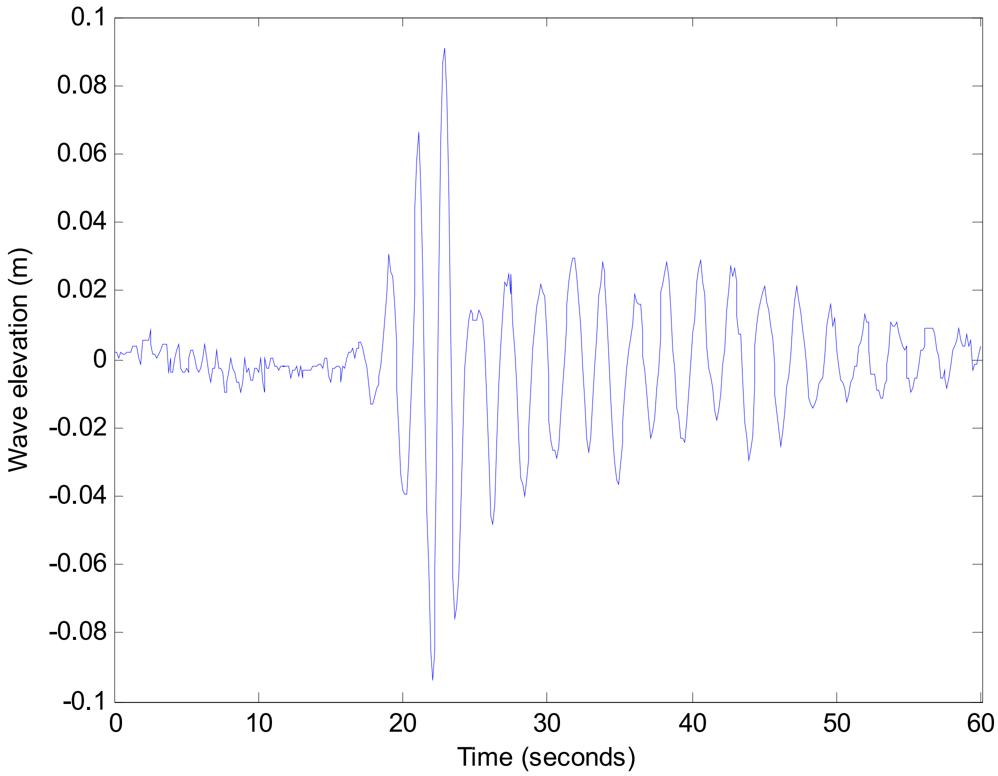

Figure 11: Measured wave elevation for Quintrex Freedom Sport 470 example case (largest wave height): 6.7 knots at 07:06

3.4 Quintrex Freedom Sport 570

The Quintrex Freedom Sport 570 was tested at Ashfield Parade on 3rd February 2010, from 09:30 to 11:05. The wind conditions measured at Melville Water at the time were SE, 10 – 15 knots. The mean water depth at the waverecorder during the trial was approximately 1.9m.

The hull displacement in the tested condition was approximately 1000kg (hull 620kg, 115hp outboard 180kg, 95l fuel tank ¾ full = 50kg, 2pax = 150kg).

Results are shown below.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 200m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
09:32:27	17.2	5.0	2.1	0.037	1.00	1	3
09:35:31	21.4	5.0	1.9	0.033	1.25	1	3
09:39:19	20.0	6.1	1.2	0.075	1.50	9	25
09:41:13	18.8	5.9	1.9	0.066	1.50	6	19
09:44:24	20.4	7.1	1.8	0.237	1.75	101	333
09:46:01	17.9	7.2	1.6	0.252	2.00	137	476
09:53:24	21.6	7.9	2.1	0.240	2.00	124	431
09:54:58	21.2	8.2	4.2	0.213	2.25	115	415
09:57:57	23.7	9.0	4.4	0.159	1.75	45	149
09:59:28	20.1	8.7	10.5	0.165	2.00	59	206
10:02:18	25.7	10.0	5.6	0.132	1.75	31	103
10:03:41	23.0	9.4	11.7	0.138	2.25	48	173
10:06:38	20.1	11.1	7.1	0.151	1.75	41	134
10:08:08	20.8	10.5	9.4	0.140	2.00	42	147
10:10:58	23.1	11.6	10.3	0.136	1.75	33	109
10:12:52	20.9	12.2	5.3	0.137	1.50	28	83
10:16:48	40.2	4.9	2.1	0.023	1.25	1	2
10:19:01	38.2	5.1	2.9	0.030	1.00	1	2
10:23:32	43.1	6.1	1.1	0.053	1.25	4	9
10:25:55	43.5	5.9	2.9	0.047	1.75	4	13
10:30:23	39.5	7.1	1.5	0.184	1.75	61	199
10:32:21	40.5	7.0	6.3	0.166	1.75	49	163
10:35:40	45.2	8.1	2.9	0.164	2.00	58	203
10:37:33	42.1	8.1	3.2	0.164	2.50	79	292
10:40:07	46.9	9.0	6.8	0.108	1.75	21	69
10:41:42	43.1	9.4	19.5	0.123	2.00	32	113
10:44:50	45.6	10.3	6.8	0.110	2.00	26	91
10:46:14	43.3	10.1	9.5	0.120	2.50	42	155
10:51:10	44.4	10.8	2.0	0.103	1.75	19	63
10:52:29	39.9	11.2	7.1	0.104	2.25	27	99
10:58:44	41.5	11.6	5.1	0.091	1.50	12	36
11:00:14	43.4	11.9	3.8	0.105	1.75	20	65
11:04:01	39.7	24.8	85.9	0.037	1.50	2	6

Table 5: Wake trials results for Quintrex Freedom Sport 570 at Ashfield Parade

An example wave elevation time trace, together with corresponding photo, are shown below.

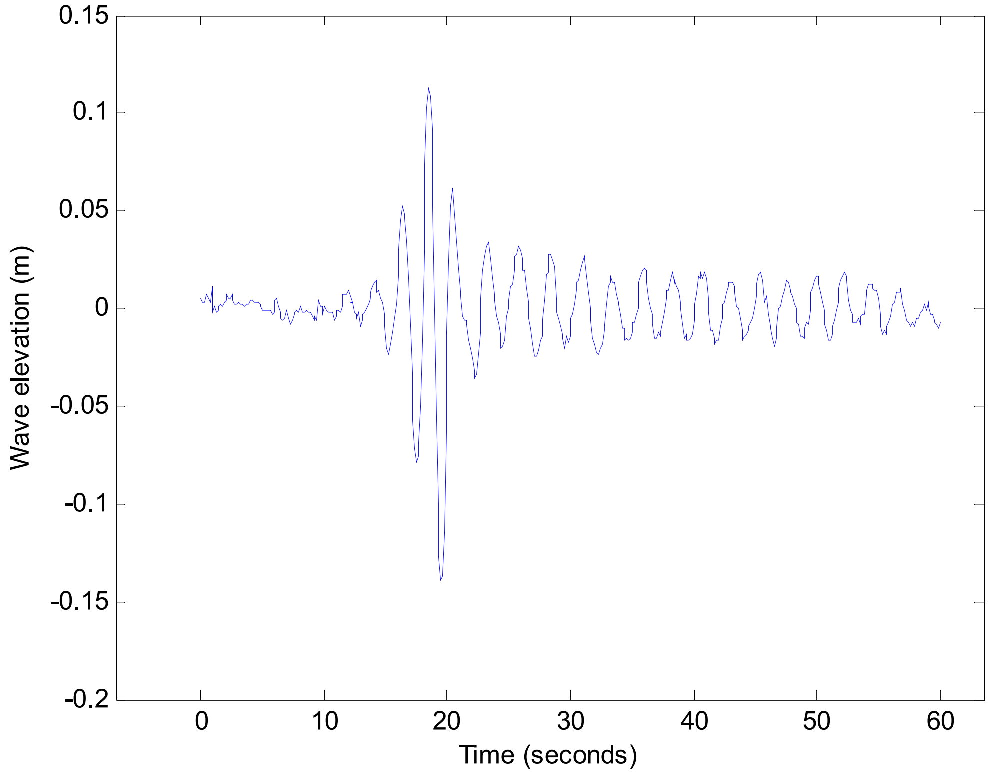

Figure 12: Measured wave elevation for Quintrex Freedom Sport 570 example case (largest wave height): 7.2 knots at 09:46

Figure 13: Photo of Quintrex Freedom Sport 570 example case (largest wave height): 7.2 knots at 09:46

3.5 Captain Cook River Lady

The wake of the Captain Cook River Lady was measured during her standard morning upriver run (to the east of Ron Courtney Island) and afternoon downriver run (to the west of Ron Courtney Island). These measurements were made on the 2nd and 3rd February 2010.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 200m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
2nd Feb 2010							
10:50:56	74.5	6.3	7.6	0.094	2.00	19	66
15:27:21	45.9	8.2	4.6	0.128	2.50	47	176
3rd Feb 2010							
10:56:23	67.9	6.7	9.7	0.103	2.25	27	97
15:41:38	43.0	7.7	3.4	0.133	2.25	45	161

Table 6: Wake trials results for River Lady at Ashfield Parade

An example wave elevation time trace from the River Lady is shown below, together with a corresponding photo. We see that the wave pattern is quite different to that of the smaller vessels at a similar speed. The wave pattern is characterized by a very long period wave of small amplitude, before the familiar wave pattern.

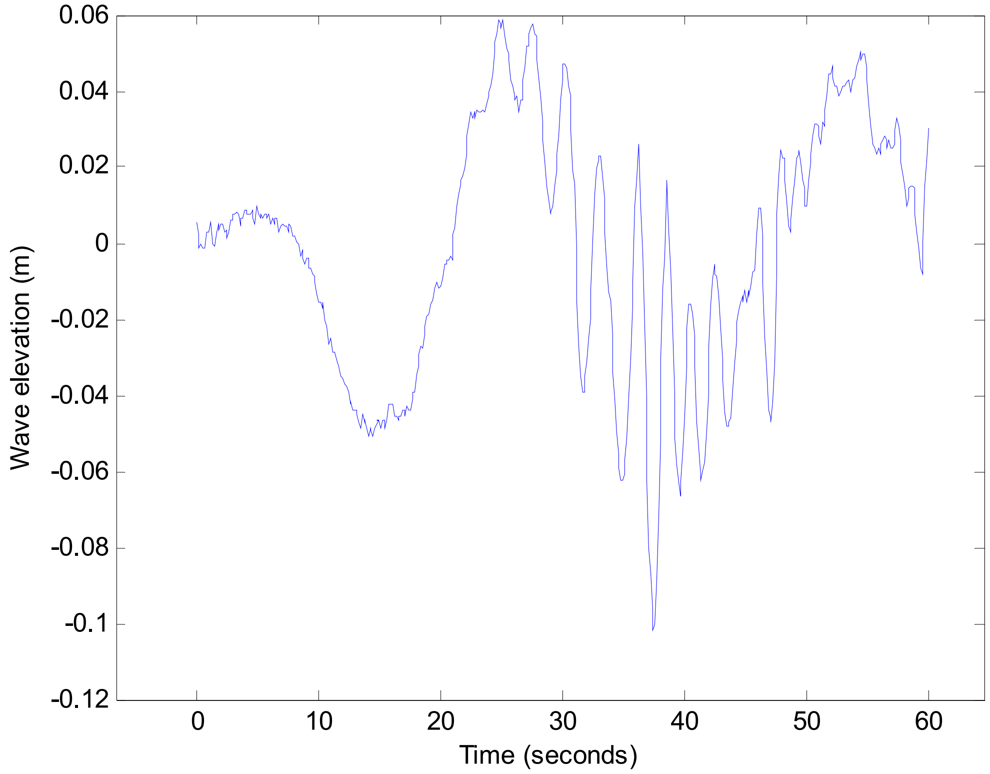

Figure 14: Measured wave elevation for River Lady on 2nd Feb 2010, passing waverecorder at 15:27:21

Figure 15: Photo of River Lady on 2nd Feb 2010, passing waverecorder at 15:27:21

3.6 Comparison between all vessels at Ashfield Parade

The results from the preceding tables will now be plotted for all vessels at Ashfield Parade, in order to see the effect of speed for each vessel size, and compare different vessel sizes. The graphs are shown for the two different transverse distances: close approach (inside the buoys) and distant approach (outside the buoys). Close approach trials were all in the range 16 – 28m, while distant approach trials were all in the range 35 – 52m. Therefore, grouping all close approach results together on the same graph will inevitably produce some scatter in the results, and similarly for distant-approach results. However the scatter due to varying transverse distance still allows the underlying effects of vessel speed and vessel size to be seen.

As well as the measured results for each vessel, the predicted extreme wind waves at Ashfield Parade are also plotted. These were calculated using the methods described in the initial report (CMST – AMC 2009), which have been checked using the wind wave measurements described here in Section 7.

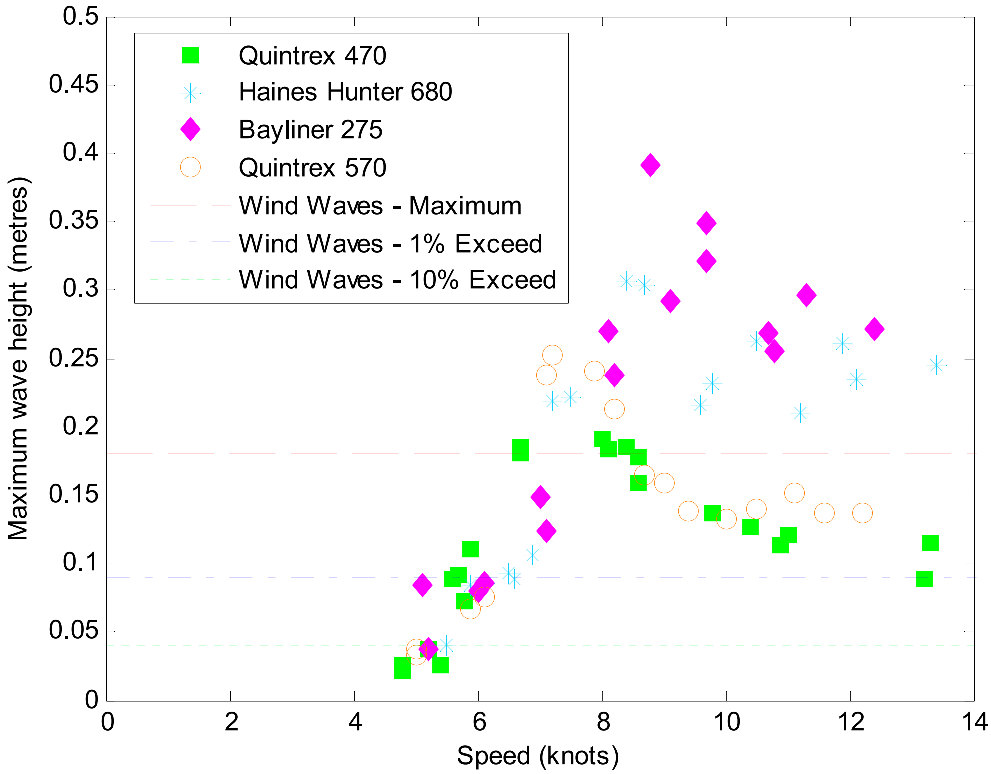

Figure 16: Measured maximum wave height for all close-approach trials at Ashfield Parade

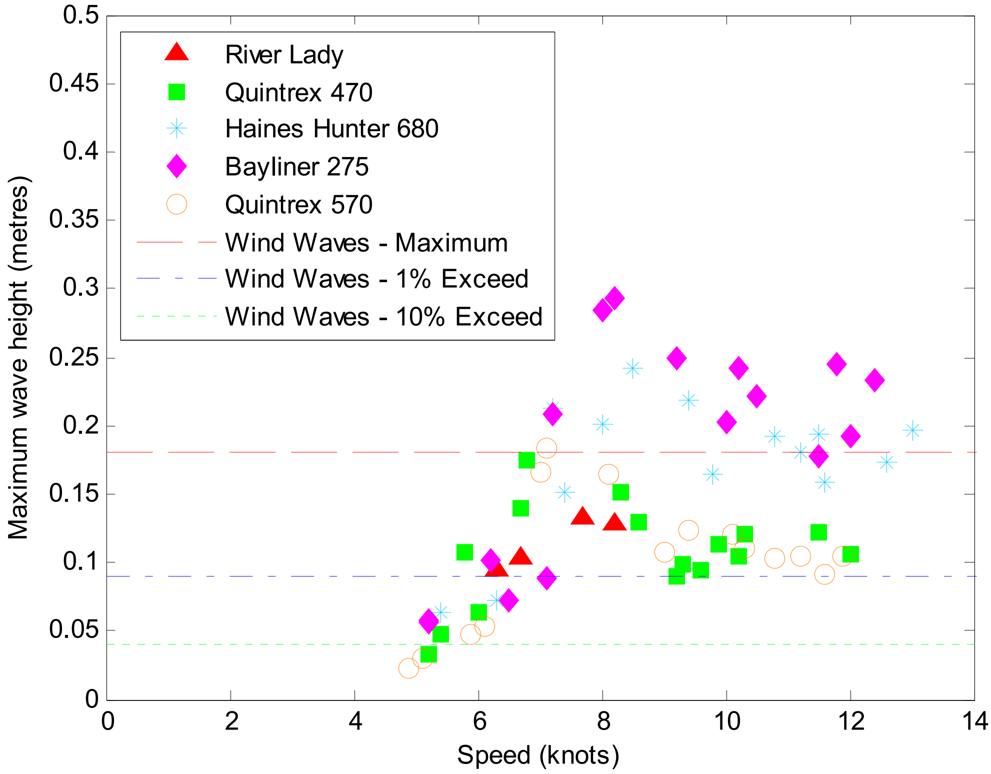

Figure 17: Measured maximum wave height for all distant-approach trials at Ashfield Parade

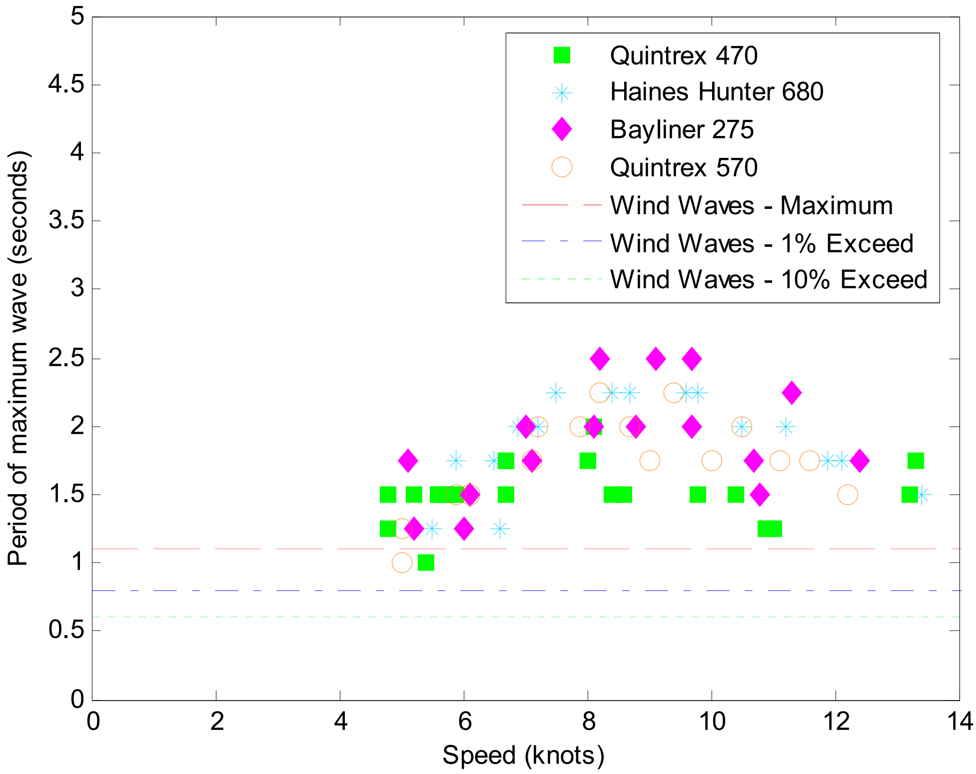

Figure 18: Measured period of maximum wave for all close-approach trials at Ashfield Parade

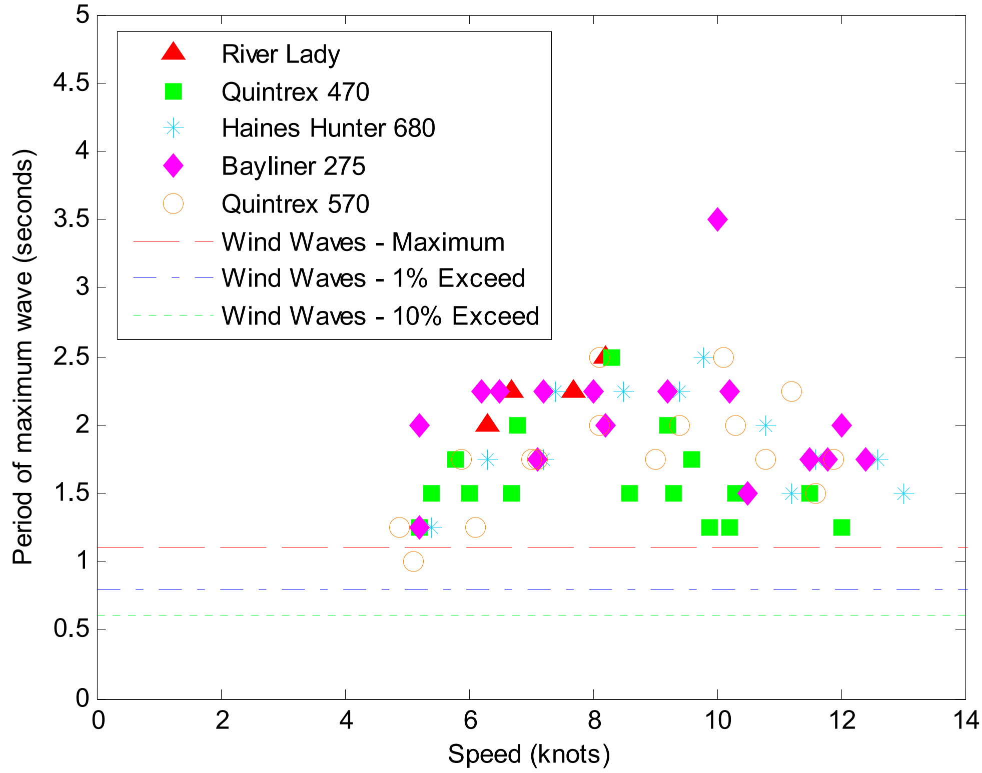

Figure 19: Measured period of maximum wave for all distant-approach trials at Ashfield Parade

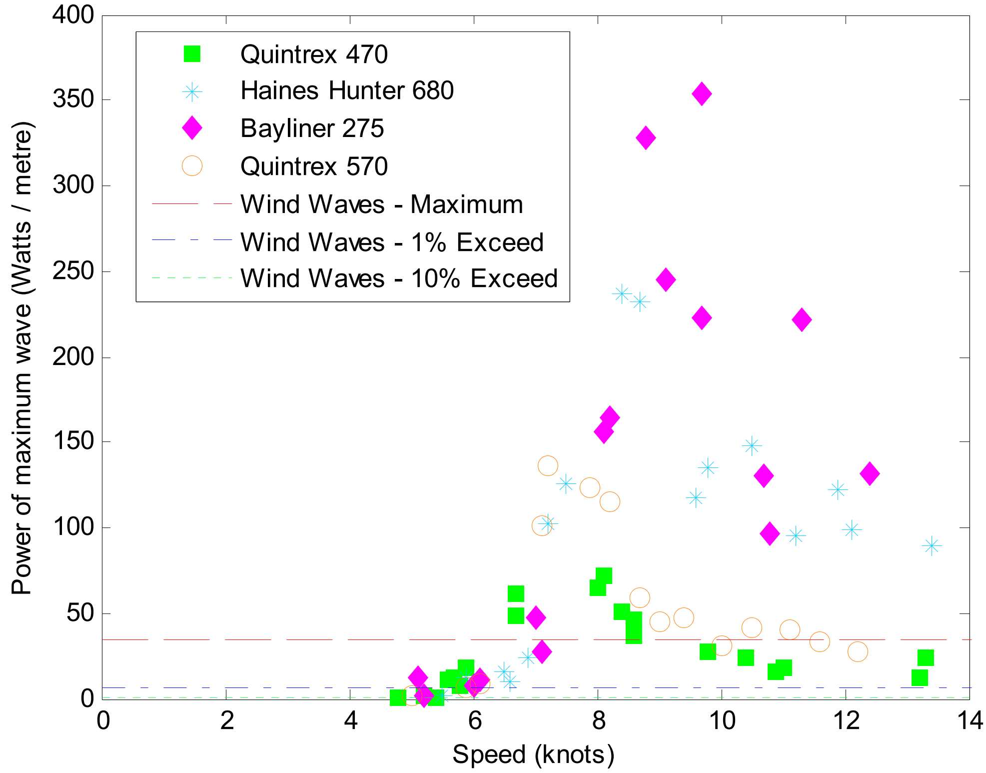

Figure 20: Measured power of maximum wave for all close-approach trials at Ashfield Parade

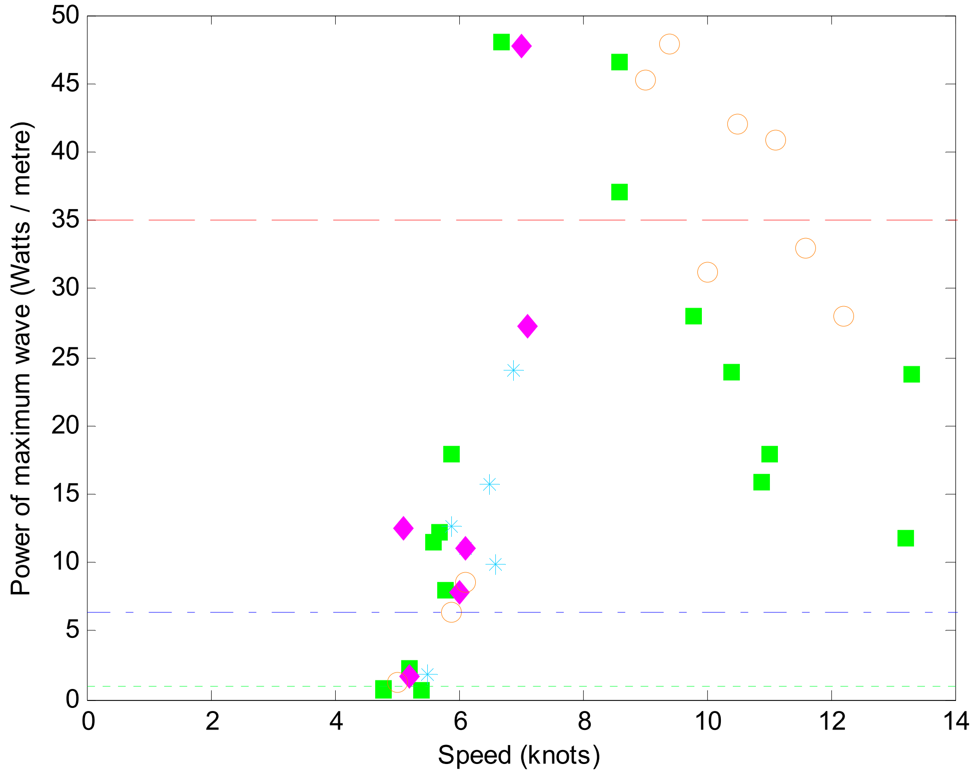

Figure 21: Measured power of maximum wave for all close-approach trials at Ashfield Parade: zoomed in

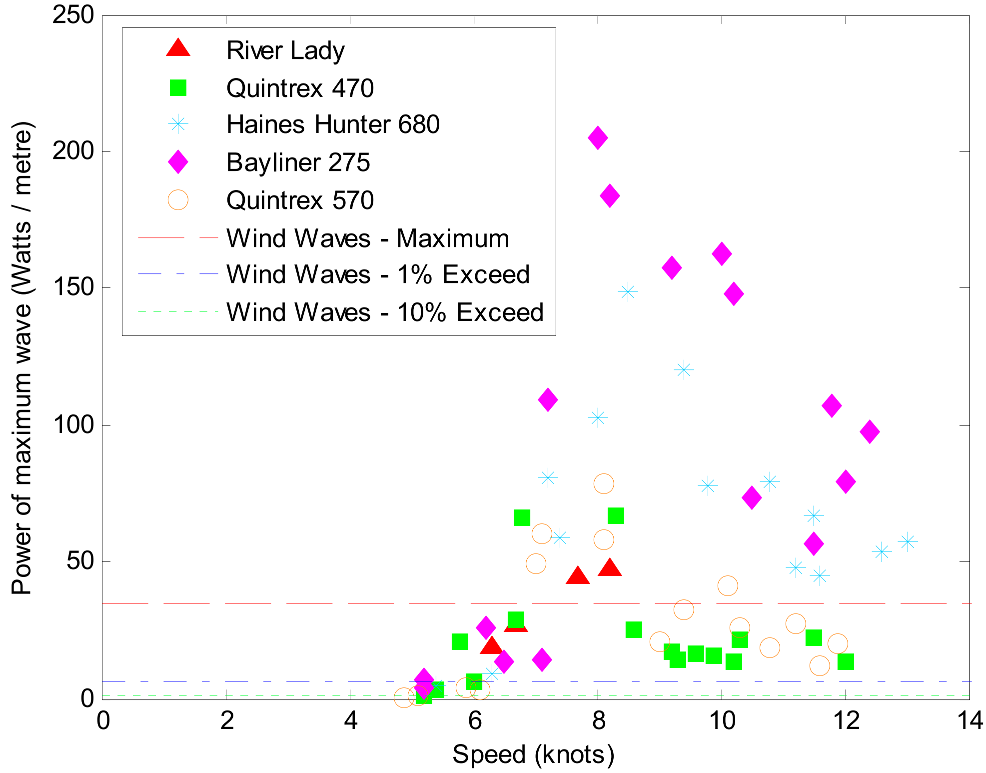

Figure 22: Measured power of maximum wave for all distant-approach trials at Ashfield Parade

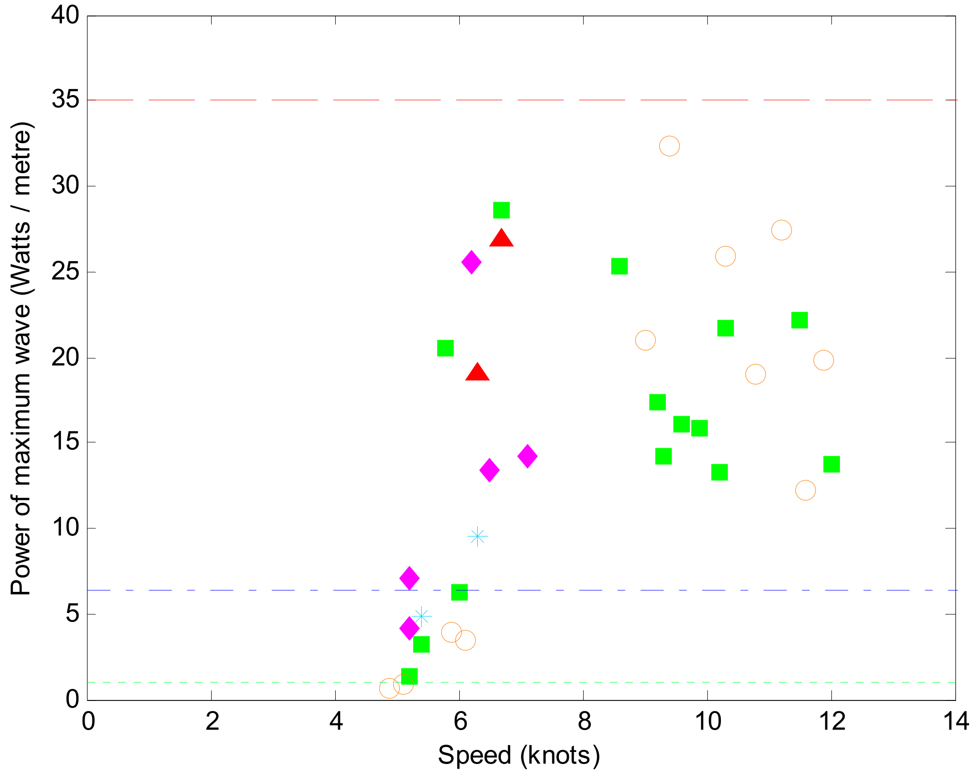

Figure 23: Measured power of maximum wave for all distant-approach trials at Ashfield Parade: zoomed in

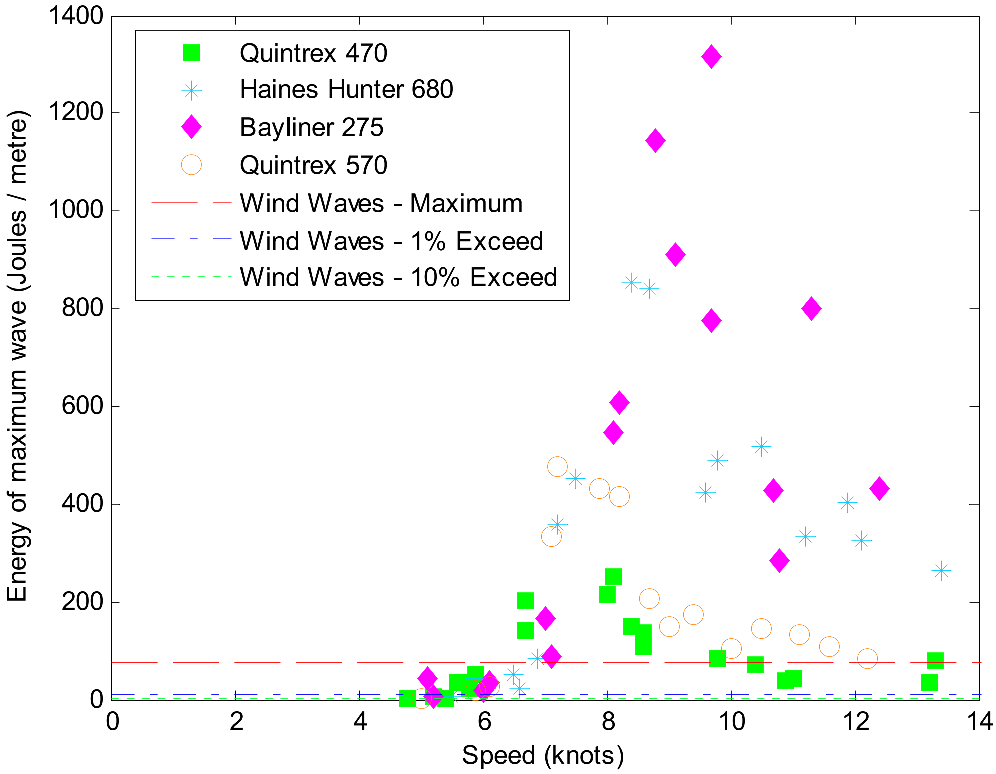

Figure 24: Measured energy of maximum wave for all close-approach trials at Ashfield Parade

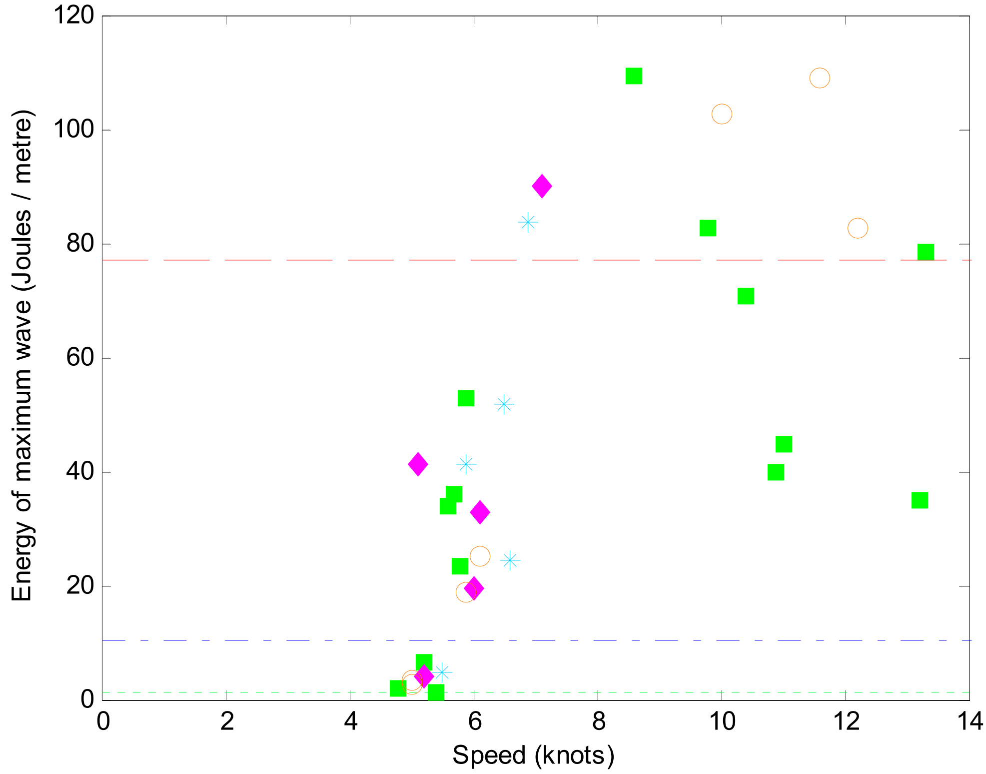

Figure 25: Measured energy of maximum wave for all close-approach trials at Ashfield Parade: zoomed in

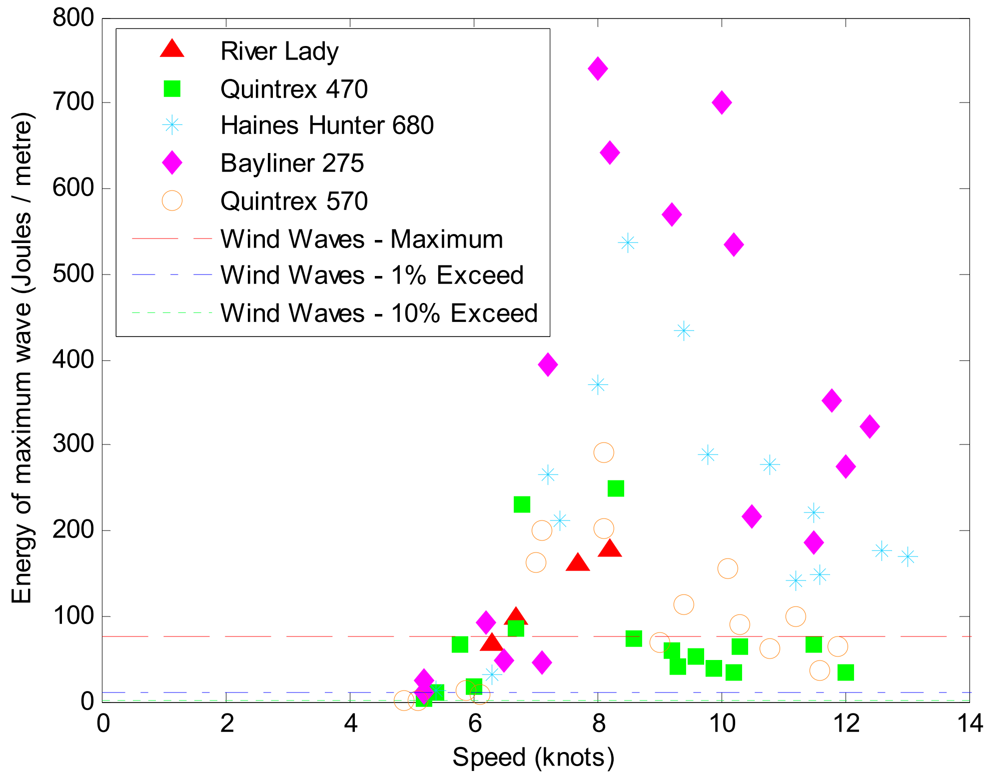

Figure 26: Measured energy of maximum wave for all distant-approach trials at Ashfield Parade

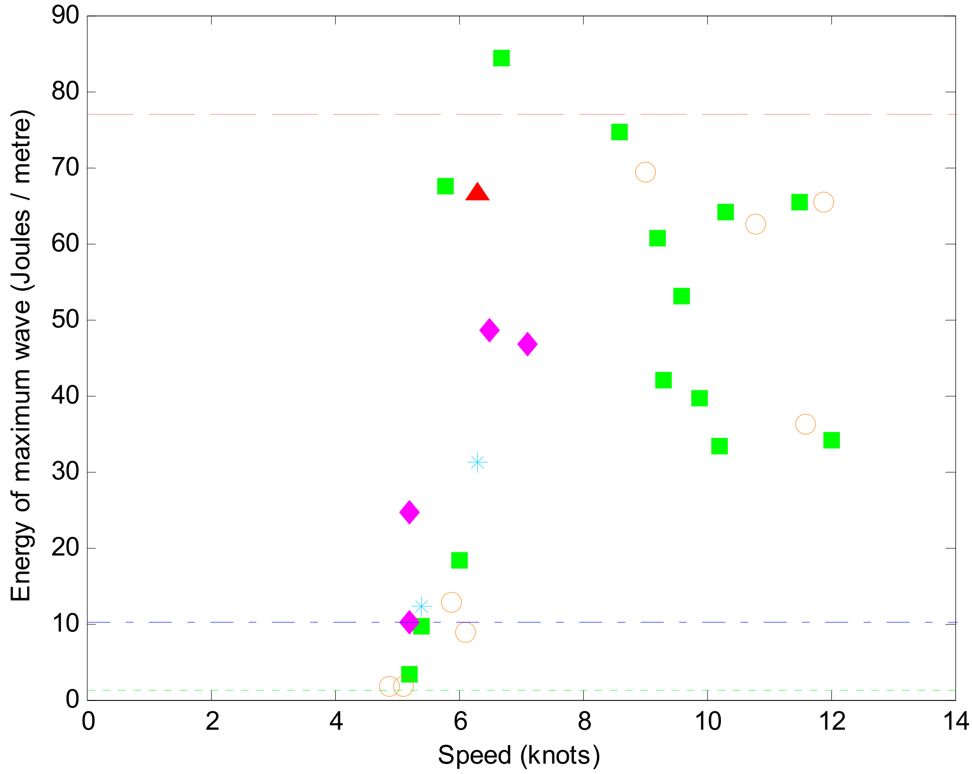

Figure 27: Measured energy of maximum wave for all distant-approach trials at Ashfield Parade: zoomed in

Points of note from the graphs include:

1. The present speed limit of 8 knots roughly corresponds to the worst speed in terms of wave height, power and energy, for all of the smaller boats tested. The larger River Lady however would most likely produce its largest wake at higher speeds.
2. At higher speeds, the wave height dropped off slightly, although the period remained long. Therefore at 12 knots the larger vessels (Bayliner 275 and Haines Hunter Patriot 680) still produced more wave energy than the extreme wind waves.
3. The above conclusions were for both close approach and distant approach; however it was noted that the distant-approach wave energy was around 30 – 40% less than the close approach at similar speed.

3.7 Comparison with deep-water predictions

Of the boats tested at Ashfield Parade, only the Haines Hunter Patriot 680 and River Lady were similar to the vessels modelled in the initial report (AMC – CMST 2009). Comparisons will now be made between these measured and predicted results.

The measured Haines Hunter Patriot 680 had a displacement of 2.1 tonnes, slightly different to the modelled displacement of 2.4 tonnes for the Haines Hunter Prowler 680, although the length and beam are the same. Since the measured speeds were slightly different to those modelled, comparisons are best made graphically by plotting results as a function of speed. Only results obtained at similar transverse distances to the modelled results are shown.

A comparison between the predicted and measured maximum wave height for the Haines Hunter 680 is shown below.

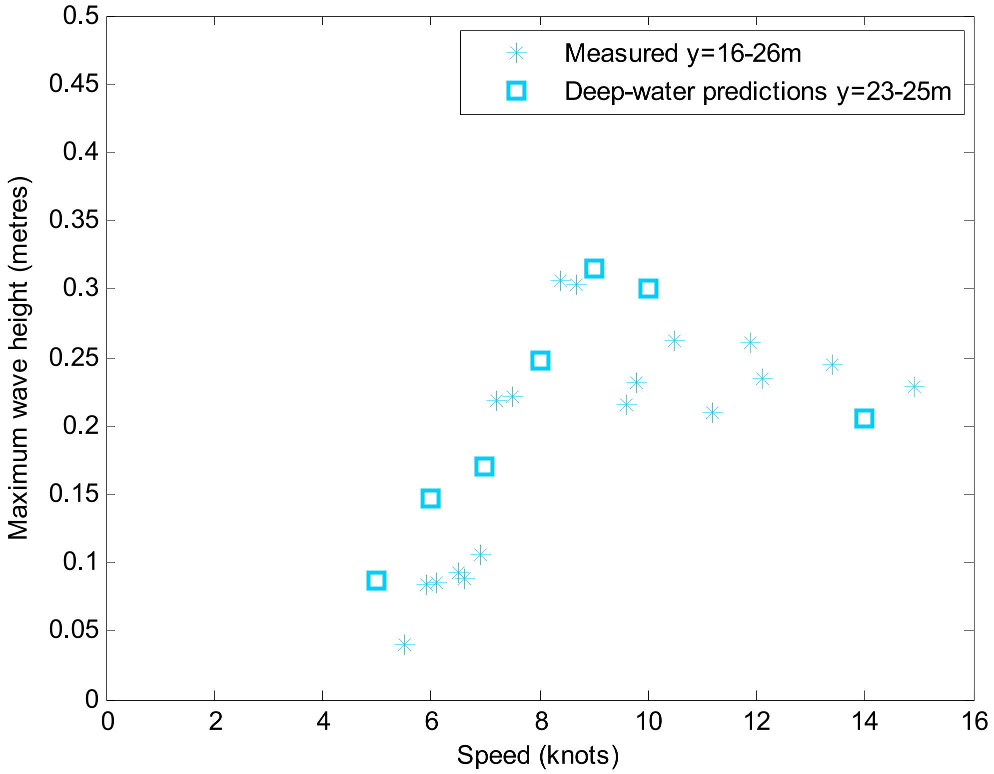

Figure 28: Comparison between measured wave heights and deep-water predictions for close-approach trials of Haines Hunter 680 at Ashfield Parade

A comparison between the predicted and measured period of the maximum wave is shown below for the Haines Hunter 680.

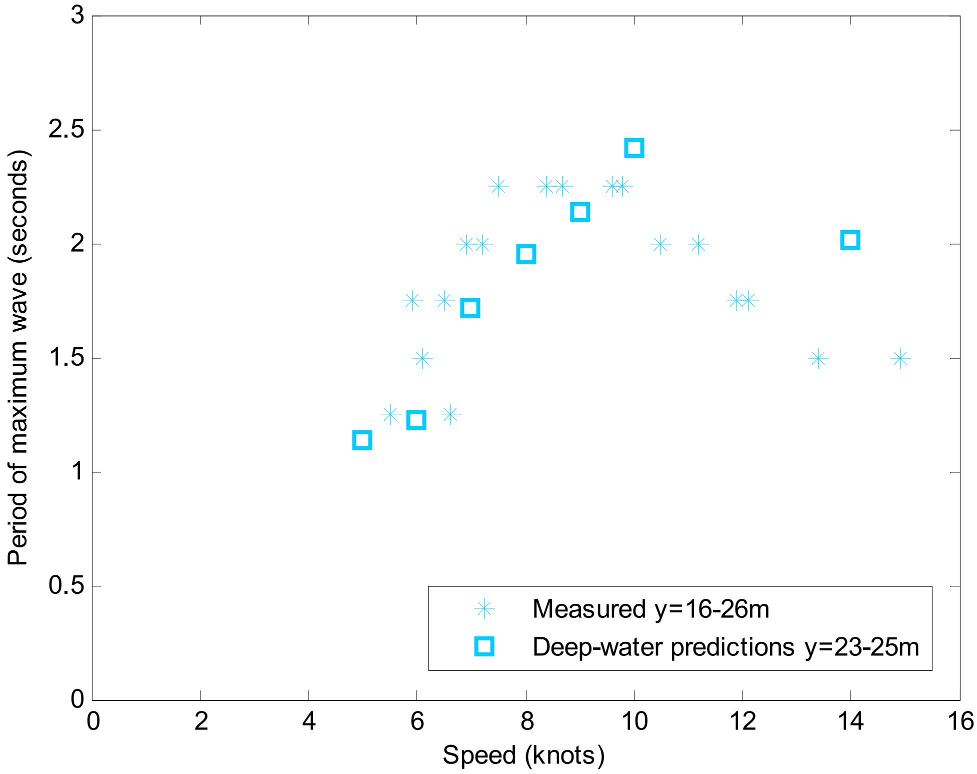

Figure 29: Comparison between measured wave periods and deep-water predictions for close-approach trials of Haines Hunter 680 at Ashfield Parade

We see that the predicted and measured results agree fairly closely for the Haines Hunter 680.

The River Lady results can also be compared with predictions, as shown in the following graphs. Since no predictions were made at the same transverse distance as in the measurements, the predicted results at 23m and 100m are shown.

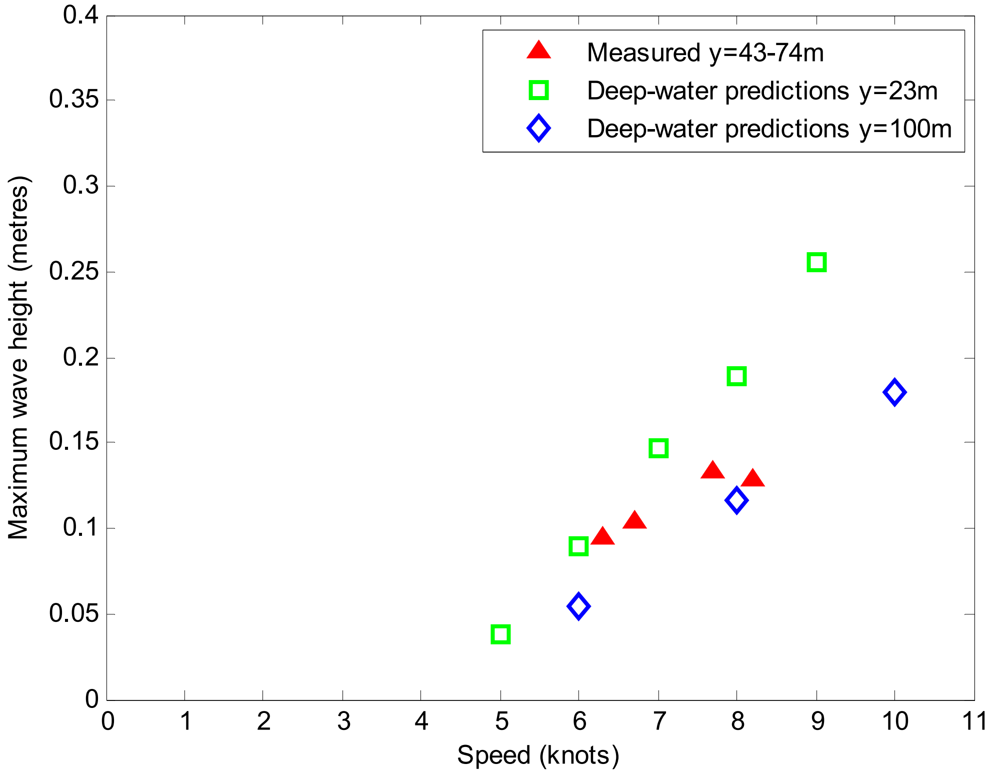

Figure 30: Comparison between measured wave heights and deep-water predictions for River Lady at Ashfield Parade

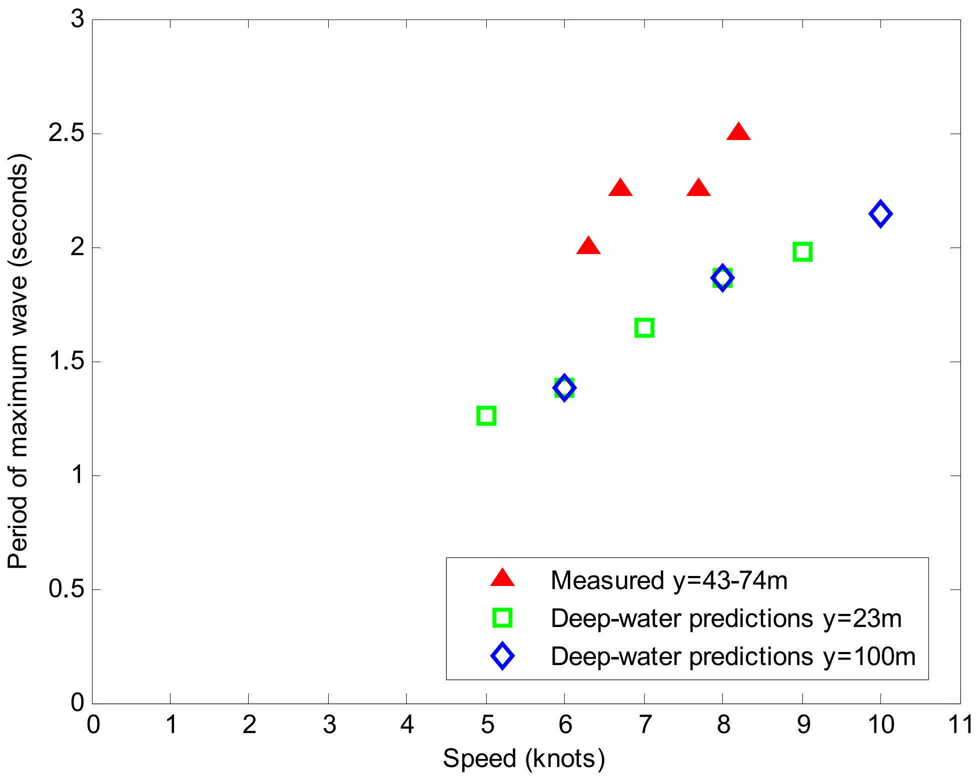

Figure 31: Comparison between measured wave periods and deep-water predictions for River Lady at Ashfield Parade

We see that the maximum wave height corresponds well with the predictions based on deep-water model tests, but the period is slightly longer in the measured results. It is thought that this may be partly due to the shallow water, the effects of which become increasingly important for boats with large waterline length such as the River Lady.

4 DEDICATED TRIALS AT QUARRY POINT

The Quarry Point trials were undertaken near the Quarry Point pilon off Mounts Bay Road, running parallel to the 2m depth contour at headings of 38º and 218º. The waverecorder was attached to the Quarry Point pilon as shown in Figure 2, and located at 31º58.2699'S, 115º50.2920'E. GPS waypoints were set up on each boat so that the trials followed as well as possible a similar track on each run. Two sets of runs were performed, one close to the pilon (at 25 – 50m from the pilon) and one midway between the pilon and the shore (at 70 – 140m from the pilon). The exact transverse distance was measured in each case with GPS.

A chart extract showing the trials location and position of the waverecorder is shown below. The datum depth at the waverecorder is 1.9m.

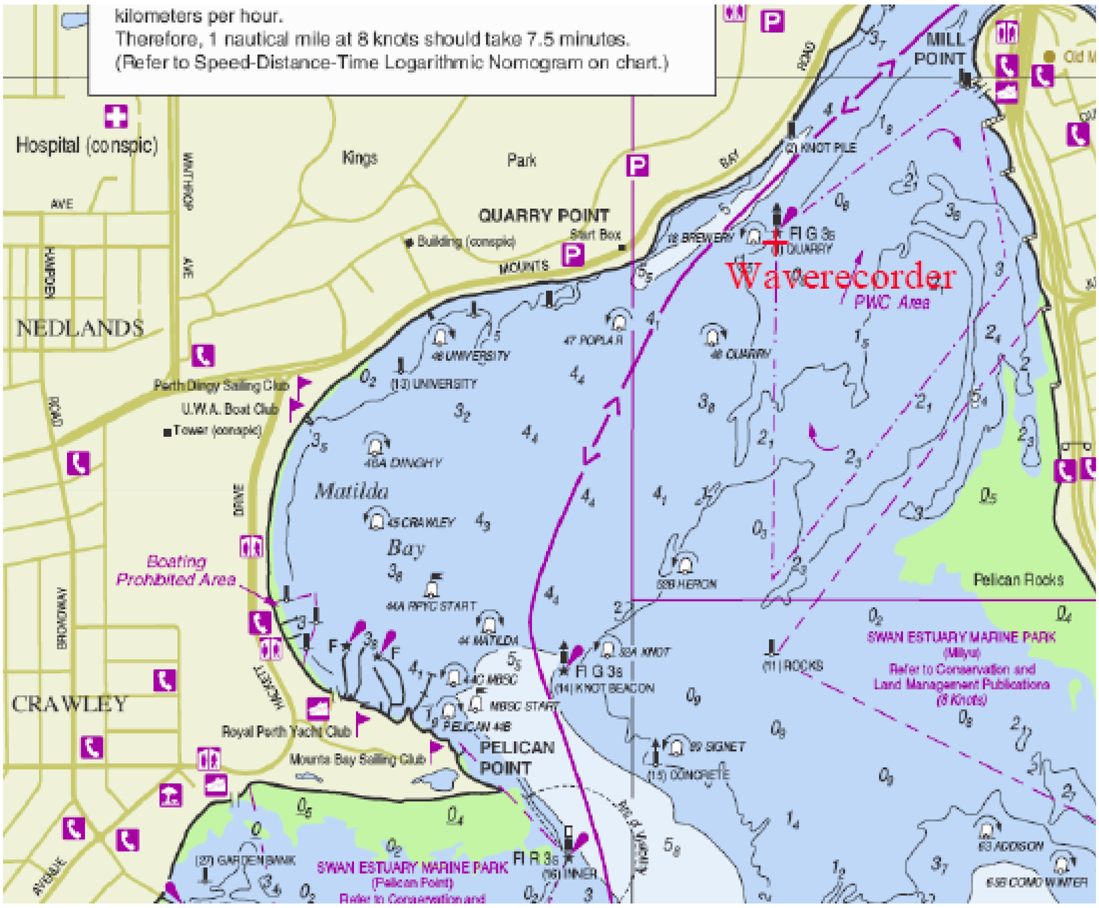

Figure 32: Extract from chart of Quarry Point trials location. Waverecorder position shown as red cross.

An example GPS trace from one of the dedicated trials at Quarry Point is shown below. Positions are shown relative to the waverecorder at (0,0). The early runs (blue colour) are close to the waverecorder, while the later runs (red colour) are further off.

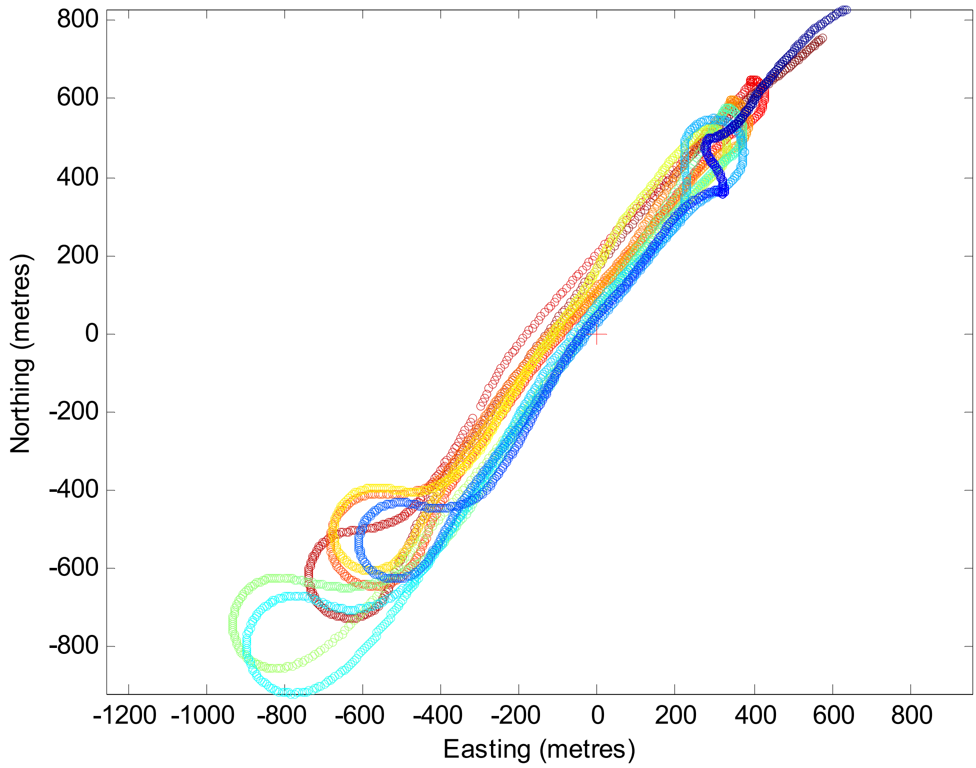

Figure 33: Example GPS trace from Quarry Point, for Star Flyte Express. GPS positions shown relative to waverecorder (red cross). Colours show times, from blue (start) to red (end).

The runs were made long enough so that the wake had time to be measured by the waverecorder and then die down before the next run. It was attempted to keep the boat speed constant during each run, though this was not always possible, especially at close to hump speed.

An "up and back" run was done at each speed, before moving up to the next speed.

The GPS position and speed of the boat were recorded by the recordable GPS brought onto each boat. These results were later processed to determine the transverse distance from the waverecorder (at the closest point in each run) and the speed. The stated speeds are averaged over a run length of 150m each side of the waverecorder, and the amount of variability is also given.

Currents were negligible for all of the dedicated trials at Quarry Point.

The dedicated trials results for each vessel at Quarry Point will now be described.

4.1 Haines Hunter Patriot 680

The Haines Hunter Patriot 680 was tested at Quarry Point on 10th February 2010, from 09:50 to 11:05. Wind conditions measured at Melville Water at the time were WSW, 5 – 8 knots. The tide height measured at Barrack St was 0.61m at the beginning of the trial, 0.64m midway through and 0.66m at the end.

The displacement in the tested condition was approximately 2.1 tonnes (bare hull 1500kg, Honda 225 outboard 270kg, 350l fuel tank ⅓ full 90kg, 3pax 210kg).

Measured wake results for the Haines Hunter Patriot 680 are shown below.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 300m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
09:53:34	22.7	5.9	19.8	0.108	1.50	17	52
09:55:08	13.7	5.7	9.7	0.062	1.50	6	17
09:57:25	16.8	7.6	25.1	0.359	2.00	264	998
10:05:13	20.5	8.0	10.5	0.318	2.00	207	782
10:07:00	19.4	10.2	7.6	0.294	2.00	177	669
10:11:35	18.4	10.0	5.8	0.270	1.50	108	322
10:12:52	19.7	12.0	32.0	0.237	1.75	98	337
10:16:39	18.2	12.0	5.6	0.259	1.75	117	402
10:18:19	18.0	14.2	4.6	0.265	1.75	122	419
10:19:36	20.9	13.8	13.0	0.252	1.75	110	380
10:21:04	19.7	15.9	32.6	0.247	1.50	90	269
10:22:11	22.6	15.0	36.0	0.158	1.75	43	148
10:23:32	18.4	17.7	19.9	0.251	2.00	129	486
10:24:30	21.8	17.7	21.0	0.233	1.50	80	240
10:25:59	18.4	19.6	22.5	0.221	1.75	85	291
10:27:01	18.4	19.1	25.9	0.163	2.00	54	204
10:29:03	72.1	6.0	8.0	0.086	1.75	13	45
10:33:34	98.6	6.2	4.9	0.059	1.75	6	21
10:36:27	82.0	8.2	4.9	0.280	2.25	188	753
10:38:19	75.8	8.2	8.3	0.191	2.25	87	348
10:40:26	94.1	9.8	8.6	0.133	2.00	36	137
10:43:43	77.1	9.9	10.9	0.213	2.25	108	434
10:45:50	92.9	11.8	8.2	0.141	2.00	41	154
10:48:12	80.9	12.0	4.8	0.157	2.00	50	189
10:50:27	91.0	14.0	5.3	0.143	1.75	35	122
10:52:20	88.8	14.0	4.4	0.130	1.75	30	102
10:54:16	88.8	15.6	6.6	0.123	2.00	31	118
10:55:51	70.3	16.4	48.6	0.128	1.75	28	97
10:57:32	75.3	16.7	11.0	0.118	2.50	39	159
10:59:01	76.2	17.9	5.3	0.160	1.75	45	154
11:00:48	69.5	19.6	6.4	0.172	2.00	60	229
11:02:22	72.2	19.6	4.2	0.126	2.00	33	123

Table 7: Wake trials results for Haines Hunter Patriot 680 at Quarry Point

An example wave elevation time trace and corresponding photo are shown below, for the largest wave height case.

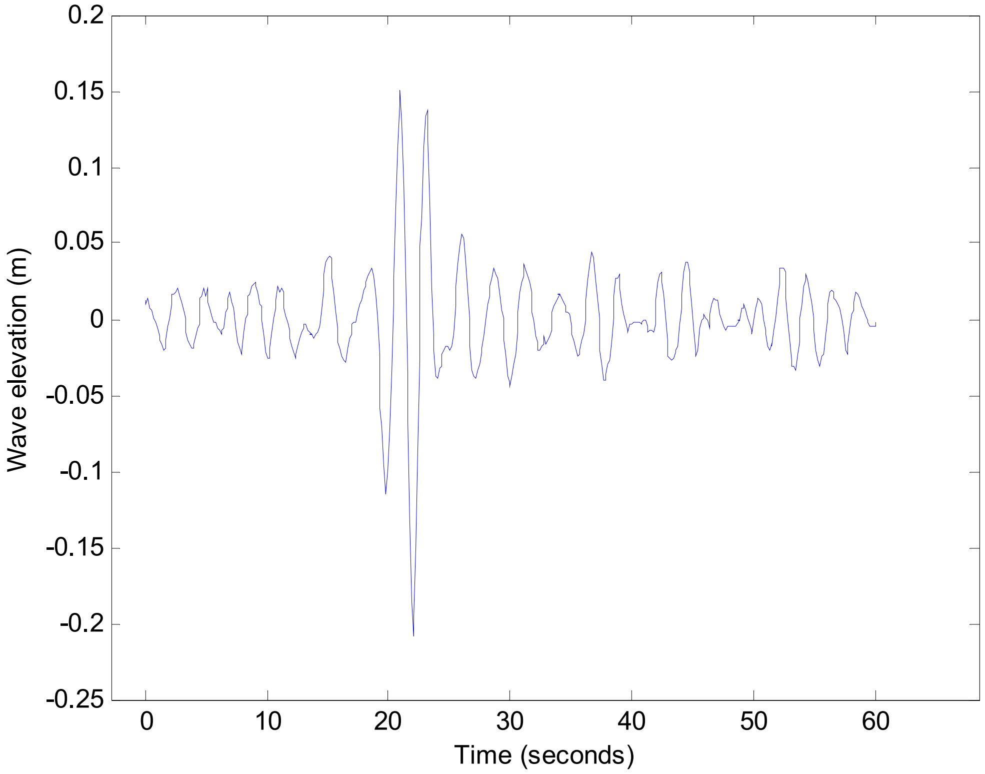

Figure 34: Wave elevation for Haines Hunter Patriot 680 example case (largest wave height): 7.6 knots at 09:57

Figure 35: Photo of Haines Hunter Patriot 680 example case (largest wave height): 7.6 knots at 09:57

4.2 Star Flyte Express

The Star Flyte Express was tested at Quarry Point on 11th February 2010, from 06:00 to 07:00. Wind conditions measured at Melville Water at the time were S – SE, 3 – 6 knots. The tide height measured at Barrack St was 0.59m at the beginning of the trial, 0.58m midway through and 0.56m at the end.

The displacement in the tested condition was 85.3 tonnes, with draft 1.1m.

Measured wake results for the Star Flyte Express are shown below.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 300m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
06:01:41	30.2	9.9	7.2	0.377	4.75	713	3930
06:07:52	19.4	9.5	9.4	0.376	3.75	613	2920
06:12:17	47.1	16.0	9.6	0.444	8.00	1140	9620
06:18:54	30.1	14.4	16.9	0.555	3.25	1180	5230
06:22:54	39.8	23.1	4.5	0.466	7.25	1240	9560
06:28:00	31.2	23.2	1.4	0.599	2.00	736	2770
06:32:10	92.3	10.9	4.9	0.218	3.50	194	891
06:38:16	73.6	10.6	3.7	0.298	2.50	246	1010
06:43:13	88.5	12.7	5.4	0.602	7.00	2050	15400
06:48:25	69.2	12.0	2.1	0.765	7.00	3310	24800
06:53:22	136.8	23.7	2.2	0.320	4.75	513	2820
06:57:37	102.8	23.4	1.1	0.383	5.25	767	4550

Table 8: Wake trials results for Star Flyte Express at Quarry Point

An example wave elevation time trace and corresponding photo are shown below, for the largest wave height case.

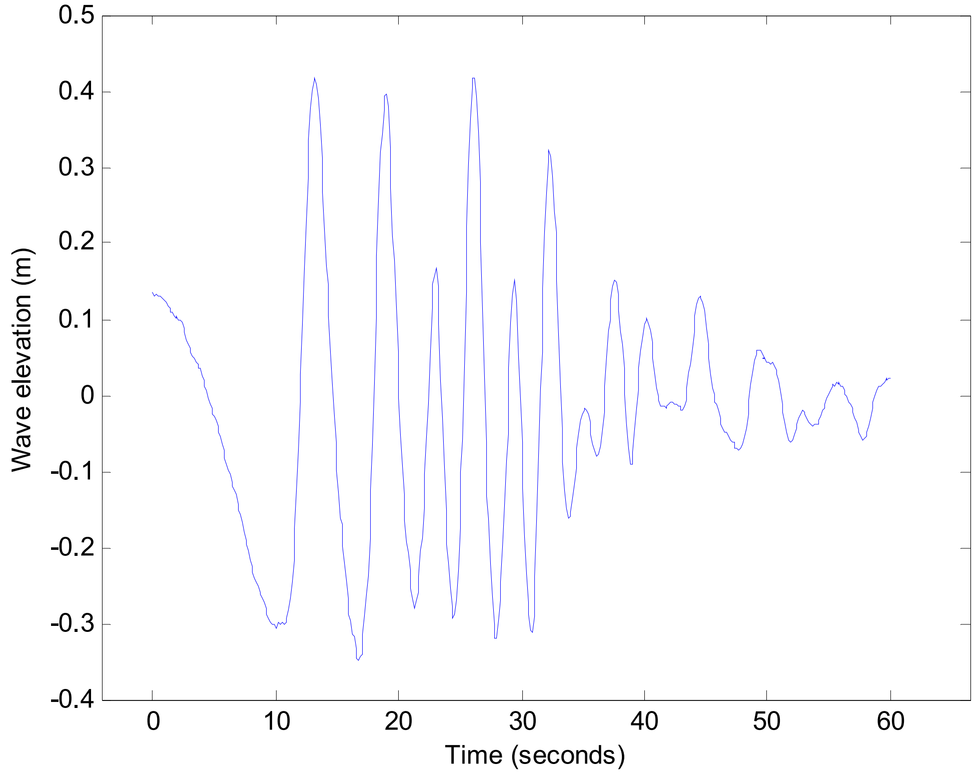

Figure 36: Wave elevation for Star Flyte Express example case (largest wave height): 12.0 knots at 06:48

Figure 37: Photo of Star Flyte Express example case (largest wave height): 12.0 knots at 06:48

Figure 38: Photo of Star Flyte Express wake hitting Mounts Bay Rd shoreline, for 14.4 knot case at 06:18

4.3 Riviera Offshore Express 48

The Riviera Offshore Express 48 was tested at Quarry Point on 11th February 2010, from 09:05 to 10:35. Wind conditions measured at Melville Water at the time were SSW, 0 – 5 knots. The tide height measured at Barrack St was 0.58m at the beginning of the trial, 0.60m midway through and 0.63m at the end.

The displacement in the tested condition was approximately 20.3 tonnes (19.5t dry weight, 800l fuel = 0.6t, 3pax = 0.2t).

Measured wake results for the Riviera Offshore Express 48 are shown below.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 300m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
09:10:18	63.3	6.5	3.2	0.067	1.50	7	20
09:15:08	16.3	6.5	4.3	0.088	1.25	10	24
09:18:27	31.3	8.2	3.0	0.394	1.75	269	926
09:21:57	18.0	8.1	11.5	0.316	1.75	173	596
09:25:30	29.7	9.9	4.7	0.660	3.25	1670	7420
09:28:19	22.0	9.8	5.7	0.807	4.00	2960	14600
09:31:42	31.7	10.2	17.0	0.548	4.00	1370	6730
09:34:39	22.1	12.9	11.1	0.578	3.50	1370	6280
09:36:59	28.1	14.3	3.9	0.464	3.00	753	3260
09:39:07	26.1	14.3	2.6	0.551	3.50	1240	5720
09:41:22	22.1	18.1	2.6	0.562	2.50	877	3600
09:43:25	22.9	17.2	4.9	0.541	2.25	703	2790
09:45:10	24.8	21.9	3.0	0.629	2.50	1100	4520
09:46:49	23.2	21.3	19.4	0.463	2.50	596	2440
09:49:38	87.7	6.5	6.7	0.139	1.75	33	115
09:53:42	77.5	8.4	2.3	0.252	2.00	130	492
09:59:18	103.8	8.3	4.3	0.290	2.00	172	647
10:01:59	83.7	6.6	5.8	0.110	1.75	21	72
10:05:35	93.7	10.3	3.2	0.263	3.25	264	1180
10:08:17	76.0	10.3	3.6	0.296	3.25	335	1490
10:14:38	98.4	12.0	4.7	0.457	3.50	854	3920
10:17:01	87.9	11.9	7.5	0.352	5.00	633	3620
10:19:24	98.7	14.5	8.0	0.291	2.25	204	810
10:21:21	79.5	14.1	11.0	0.429	5.75	990	6290
10:23:35	99.5	18.1	3.0	0.315	2.25	238	945
10:25:27	72.9	18.0	5.4	0.355	2.00	258	971
10:28:49	102.0	22.0	7.4	0.443	2.00	401	1510
10:30:20	87.4	21.7	7.4	0.397	2.25	378	1500

Table 9: Wake trials results for Riviera Offshore Express 48

An example wave elevation time trace and corresponding photo are shown below, for the largest wave height case.

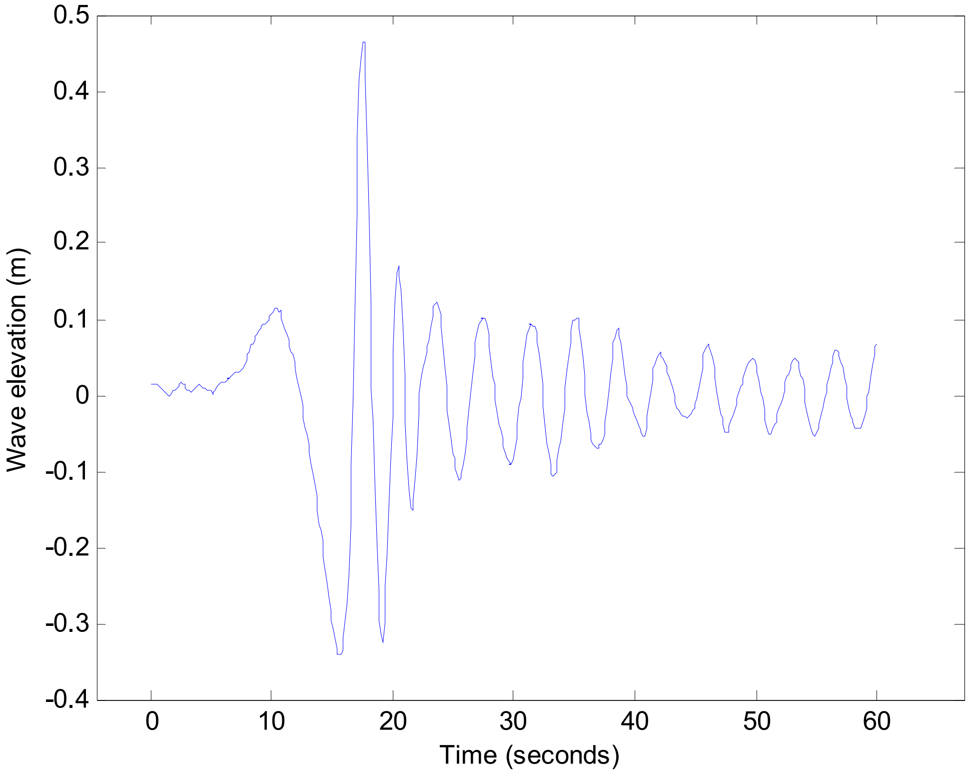

Figure 39: Wave elevation for Riviera Offshore Express 48 example case (largest wave height): 9.8 knots at 09:28

Figure 40: Photo of Riviera Offshore Express 48 example case (largest wave height): 9.8 knots at 09:28

4.4 LeisureCat Mako 9000

The LeisureCat Mako 9000 was tested at Quarry Point on 12th February 2010, from 09:10 to 10:35. Wind conditions measured at Melville Water at the time were SW, 4 – 14 knots (building towards the end of the trial). The tide height measured at Barrack St was 0.59m at the beginning of the trial, 0.60m midway through and 0.64m at the end.

The displacement in the tested condition was approximately 3.0 tonnes.

Measured wake results for the LeisureCat Mako 9000 are shown below.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 300m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
09:15:09	19.6	6.0	7.3	0.126	1.50	24	70
09:19:17	37.5	6.0	3.6	0.121	1.50	22	64
09:23:36	23.3	7.9	2.8	0.193	2.50	104	426
09:26:34	41.5	7.8	5.6	0.166	2.50	77	315
09:29:47	30.9	9.6	9.2	0.355	2.50	351	1440
09:32:48	52.2	9.8	8.6	0.237	2.25	135	535
09:35:46	32.4	12.5	20.6	0.392	2.25	369	1470
09:42:41	35.5	12.3	12.1	0.198	2.25	94	375
09:46:42	28.1	14.0	6.4	0.200	2.25	96	383
09:49:34	40.9	14.1	2.6	0.187	2.00	72	270
09:54:28	32.6	16.0	2.6	0.199	2.25	95	378
09:56:31	50.0	15.8	2.2	0.174	2.00	62	234
09:59:06	36.8	18.1	6.4	0.147	1.50	32	95
10:03:36	33.8	17.8	1.4	0.184	2.25	81	322
10:05:38	33.7	20.2	3.6	0.156	2.00	50	189
10:07:39	31.9	19.4	1.4	0.177	2.25	75	300
10:10:33	68.2	6.2	3.1	0.123	1.50	23	67
10:18:05	79.6	5.9	5.1	0.100	1.50	15	44
10:22:33	74.7	10.2	29.3	0.194	2.00	77	291
10:25:31	78.1	10.0	3.9	0.211	1.75	78	267
10:28:03	75.2	14.0	8.0	0.188	2.00	72	273
10:30:32	86.0	14.1	2.5	0.169	2.25	69	272
10:32:47	74.3	17.8	6.5	0.164	1.75	47	162

Table 10: Wake trials results for LeisureCat Mako 9000

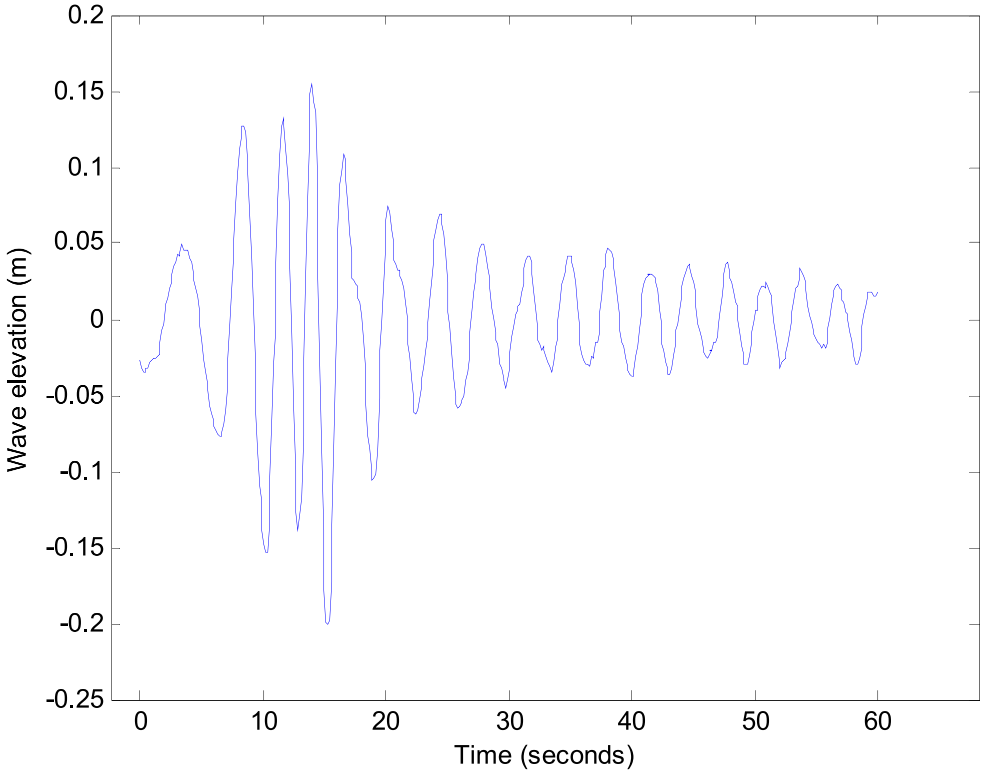

Figure 41: Wave elevation for LeisureCat Mako 9000 example case (largest wave height): 9.6 knots at 09:29

Figure 42: Photo of LeisureCat Mako 9000 example case (largest wave height): 9.6 knots at 09:29

4.5 Comparison between all vessels at Quarry Point

Comparisons of wave height, period, energy and power will now be made between the different vessel trials at Quarry Point. The corresponding values for the extreme wind waves will also be shown for comparison. These have been modified from the initial report (AMC – CMST 2009) in accordance with the findings from Section 7.4.

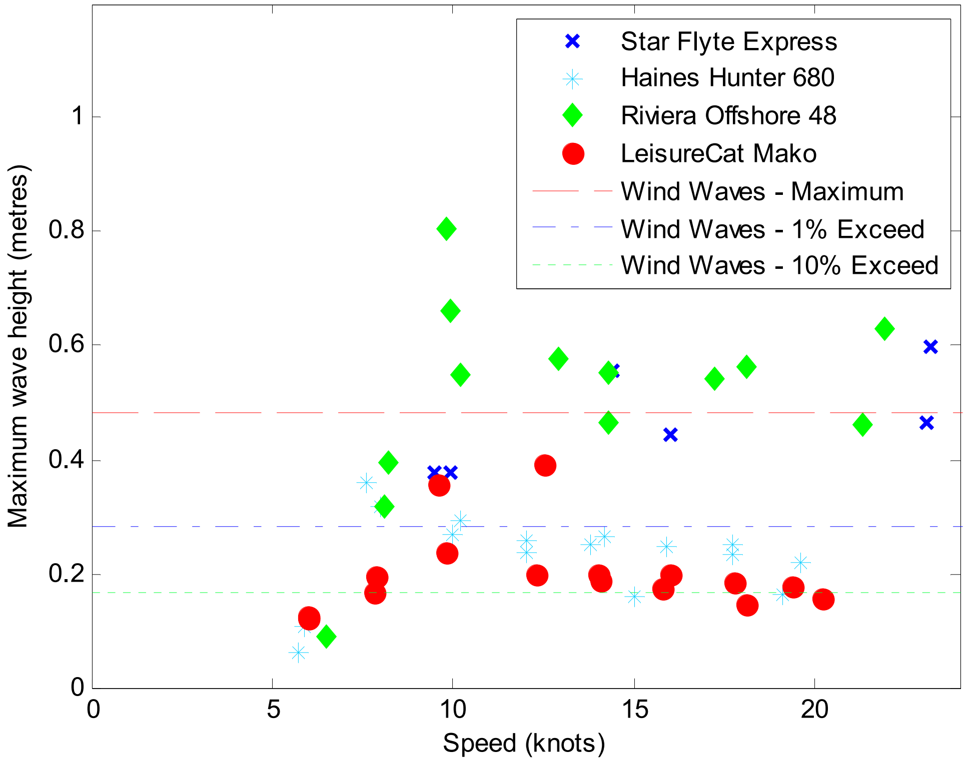

Figure 43: Measured maximum wave height for all close-approach trials at Quarry Point

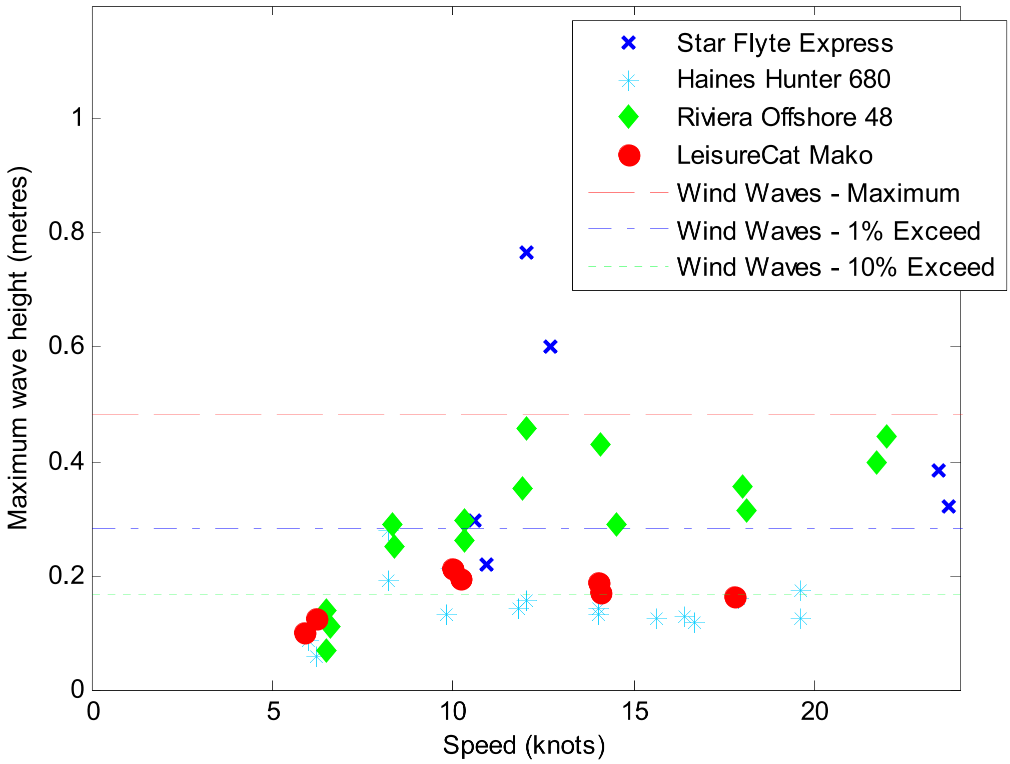

Figure 44: Measured maximum wave height for all distant-approach trials at Quarry Point

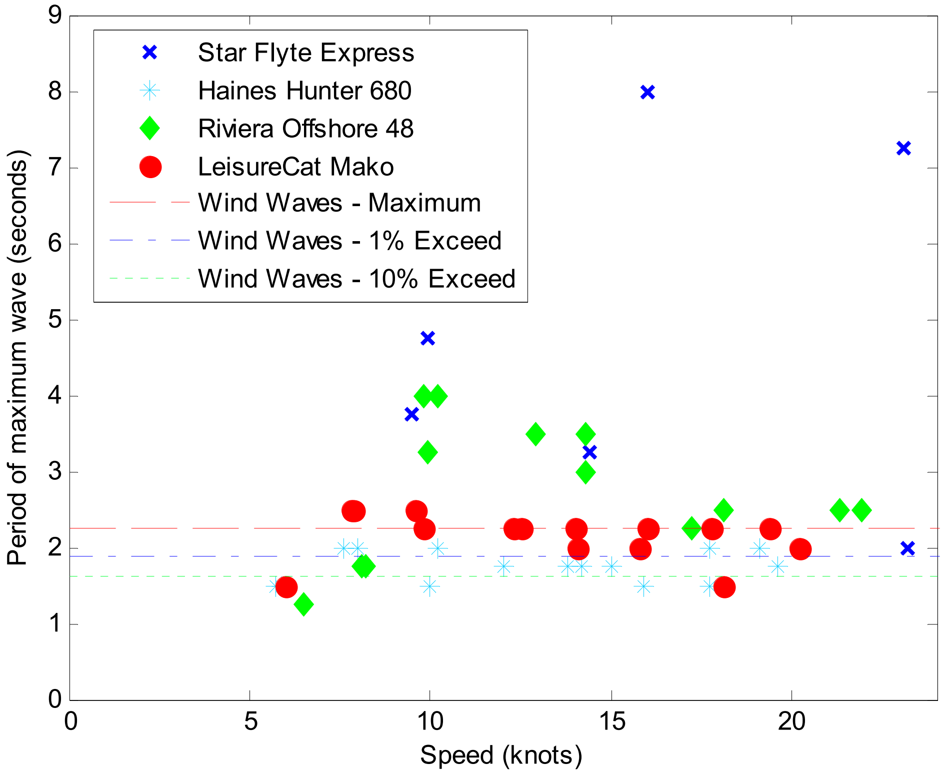

Figure 45: Measured period of maximum wave for all close-approach trials at Quarry Point

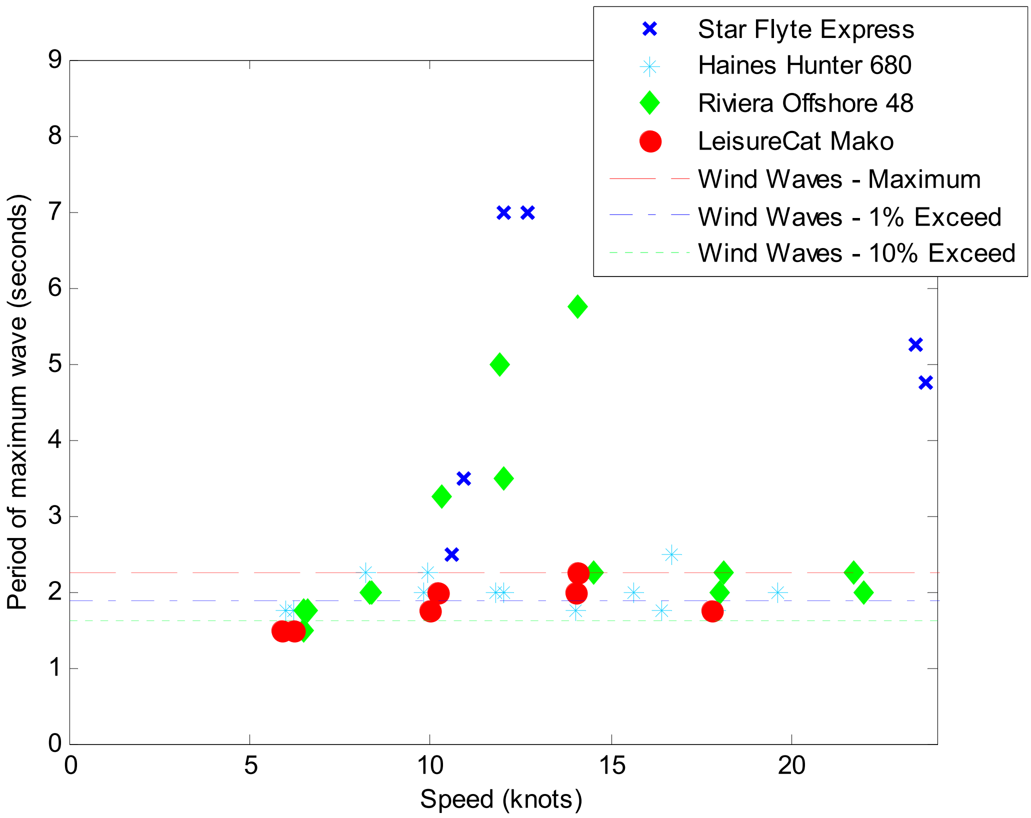

Figure 46: Measured period of maximum wave for all distant-approach trials at Quarry Point

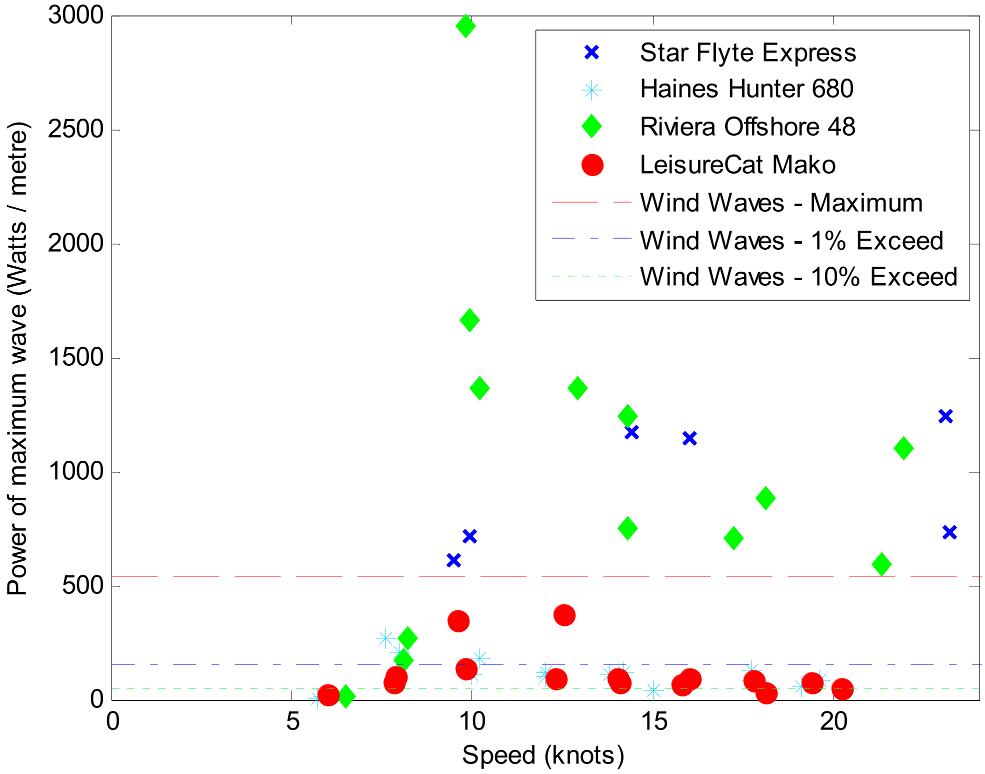

Figure 47: Measured power of maximum wave for all close-approach trials at Quarry Point

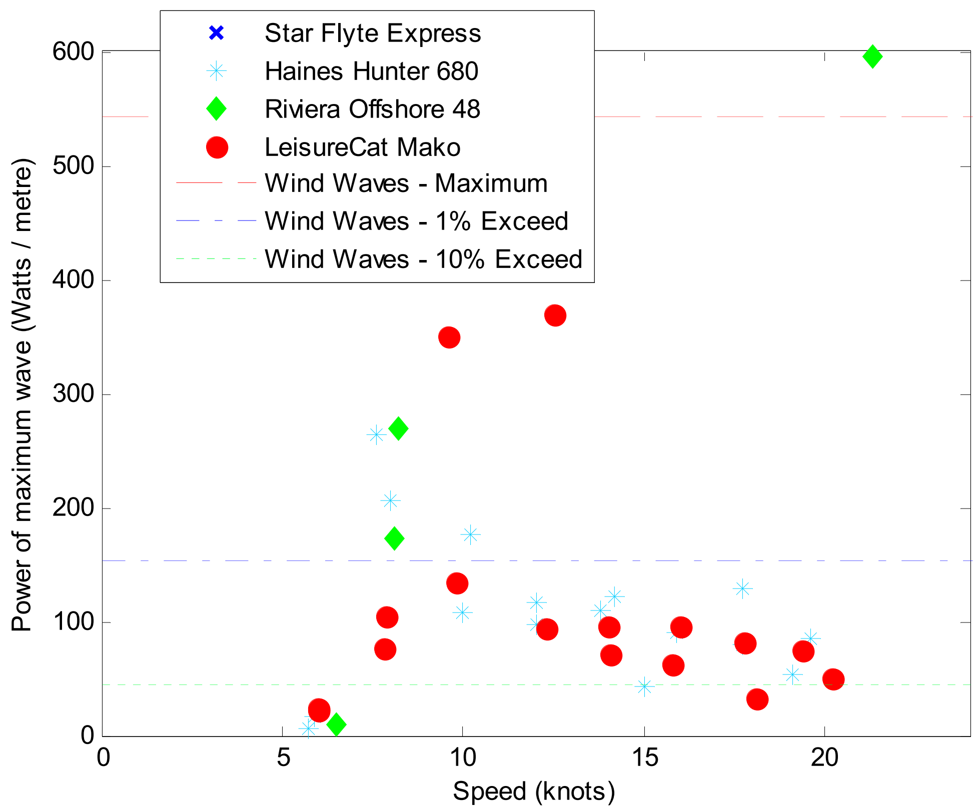

Figure 48: Measured power of maximum wave for all close-approach trials at Quarry Point: zoomed in

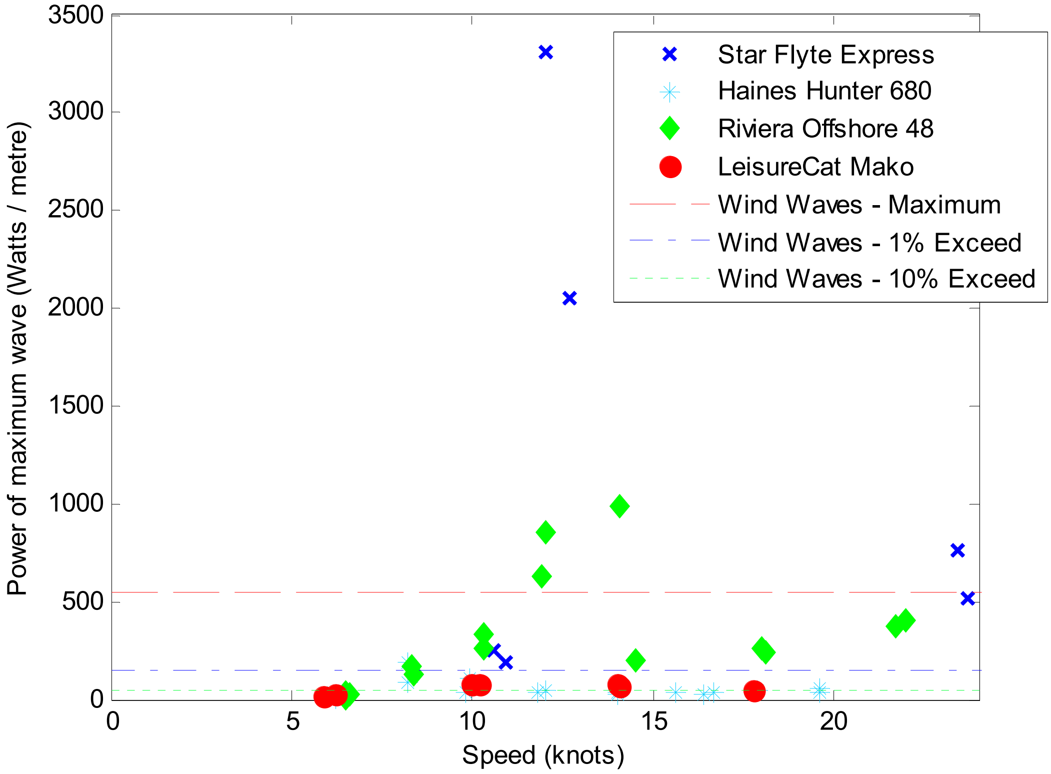

Figure 49: Measured power of maximum wave for all distant-approach trials at Quarry Point

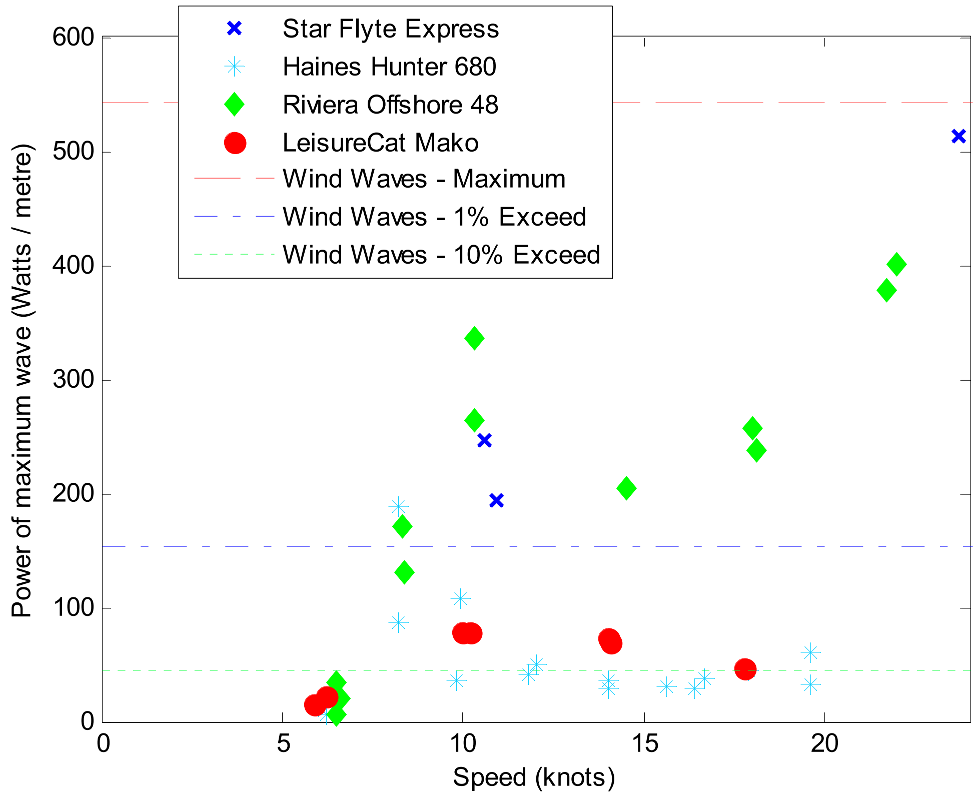

Figure 50: Measured power of maximum wave for all distant-approach trials at Quarry Point: zoomed in

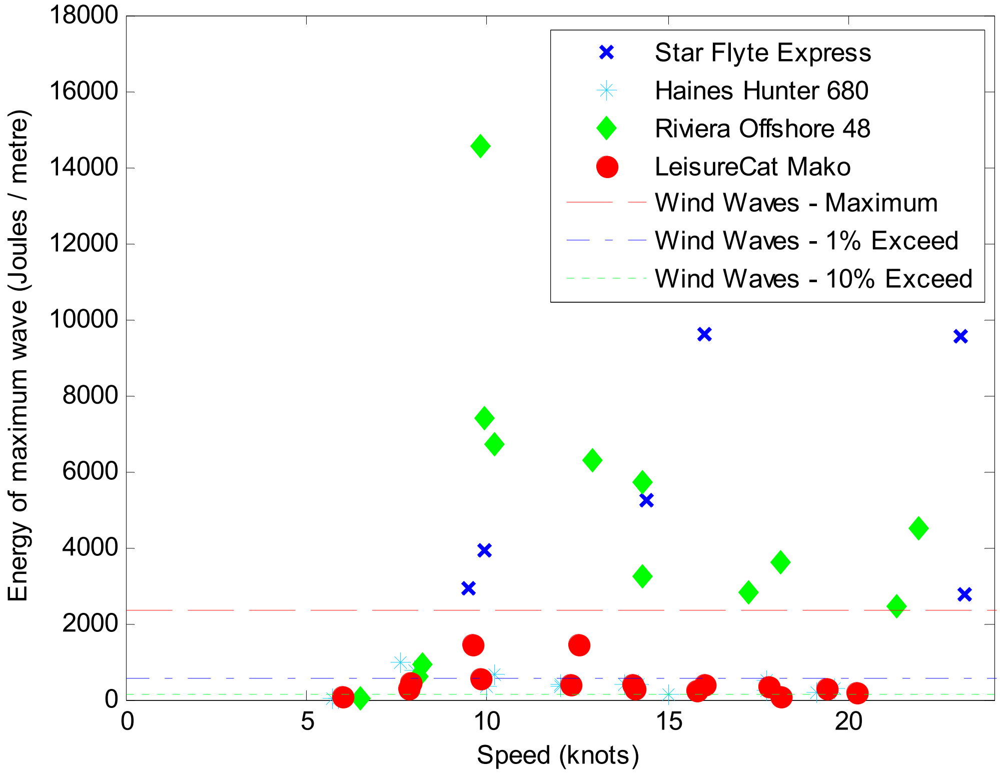

Figure 51: Measured energy of maximum wave for all close-approach trials at Quarry Point

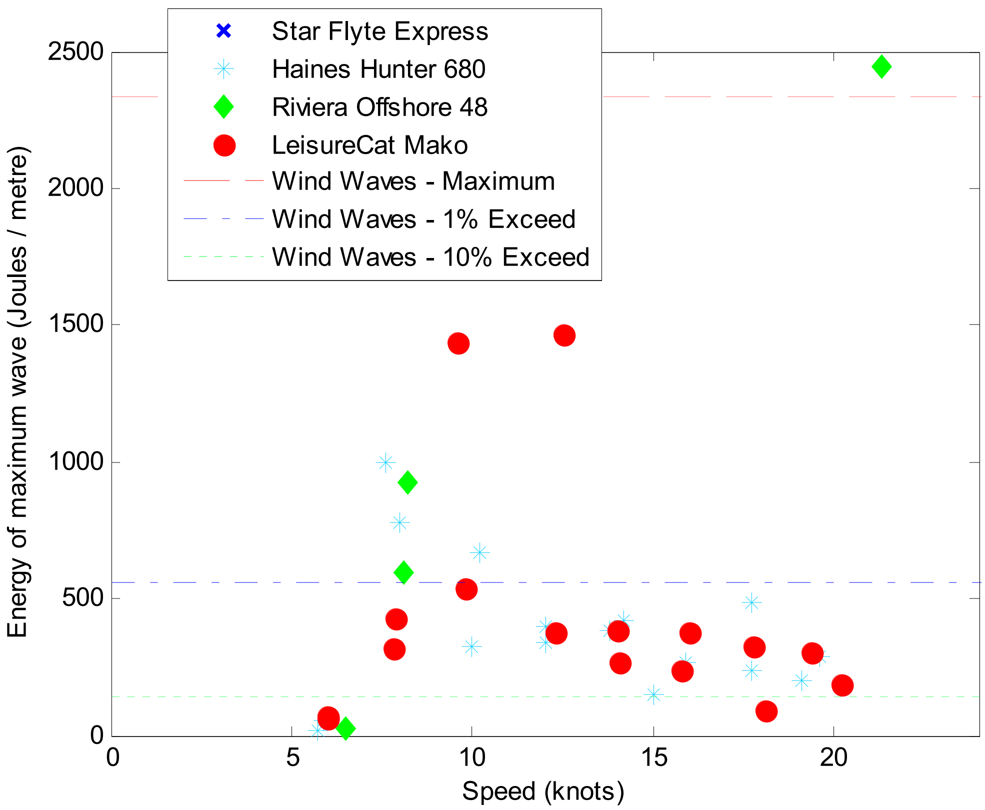

Figure 52: Measured energy of maximum wave for all close-approach trials at Quarry Point: zoomed in

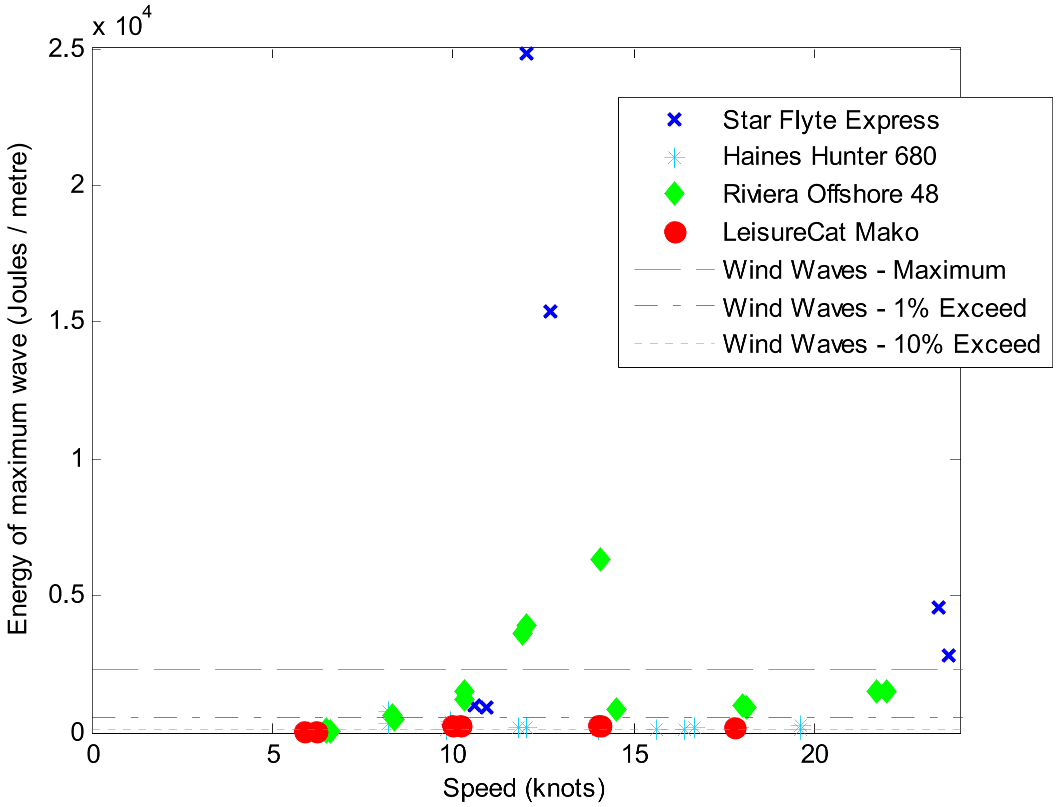

Figure 53: Measured energy of maximum wave for all distant-approach trials at Quarry Point

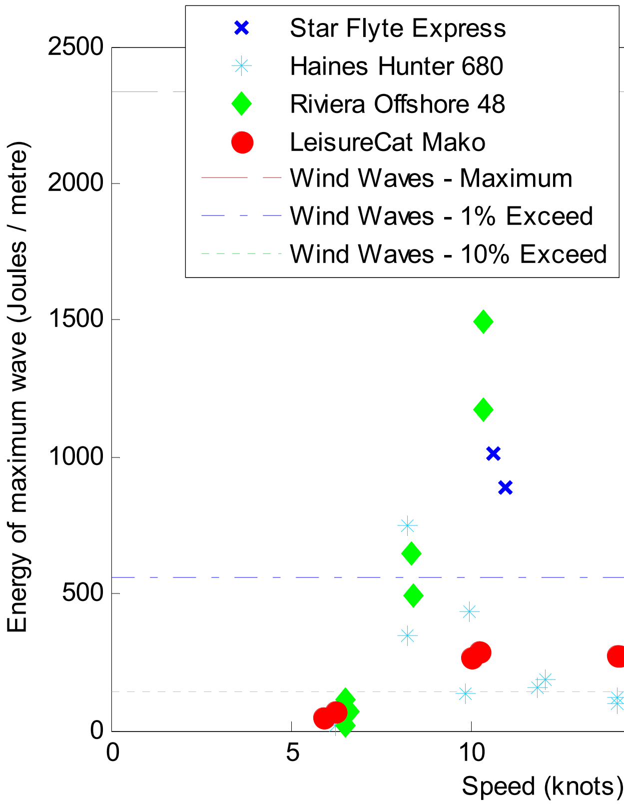

Figure 54: Measured energy of maximum wave for all distant-approach trials at Quarry Point: zoomed in

Points to note from the graphs include:

1. The smaller vessels tested (Haines Hunter and LeisureCat) produced smaller wave heights than the extreme wind waves over most of the speed range, and similar wave periods.
2. The larger vessels (Riviera and Star Flyte Express) produced similar wave heights to the extreme wind waves over most of the speed range, and much longer wave periods.
3. The smaller vessels tested (Haines Hunter and LeisureCat) produced the largest wave energy near their hump speed, for both close approach and distant approach. The hump speed is 3.0 times the square root of the waterline length, i.e. around 7.5 knots for the Haines Hunter and 9 knots for the LeisureCat. The smaller vessels were only marginally affected by water depth.
4. For the close approach trials, the larger vessels (Riviera and Star Flyte Express) produced their largest wave energy near their hump speed, being 11 knots for the Riviera and 18 knots for the Star Flyte Express.
5. The larger vessels are more affected by the shallow water, having a larger (shiplength / water depth) ratio.
6. For the distant approach trials, both of the larger vessels (Riviera and Star Flyte Express) produced their largest wave energy at close to the shallow-water critical speed (around 12 – 14 knots in a mean water depth of 4 – 5m). This is partly influenced by the fact that the critical speed wave pattern decays only slowly with transverse distance. The varying bathymetry will also have played a part, with the seabed relatively flat under the hull for the distant approach trials, which is more conducive to a defined critical speed.

4.6 Comparison with deep-water predictions

Of the boats tested at Quarry Point, only the Haines Hunter Patriot 680 and Star Flyte Express were similar to the vessels modelled in the initial report (AMC – CMST 2009). Comparisons will now be made between these measured and predicted results.

The measured Haines Hunter Patriot 680 had a displacement of 2.1 tonnes, slightly different to the modelled displacement of 2.4 tonnes for the Haines Hunter Prowler 680, although the length and beam are the same. Since the measured speeds were slightly different to those modelled, comparisons are best made graphically by plotting results as a function of speed. Only results obtained at similar transverse distances to the modelled results are shown.

Comparisons between the predicted and measured wave height and period for the Haines Hunter 680 at close approach are shown below. The results for the same boat at Ashfield Parade (at close approach) are also shown again for comparison.

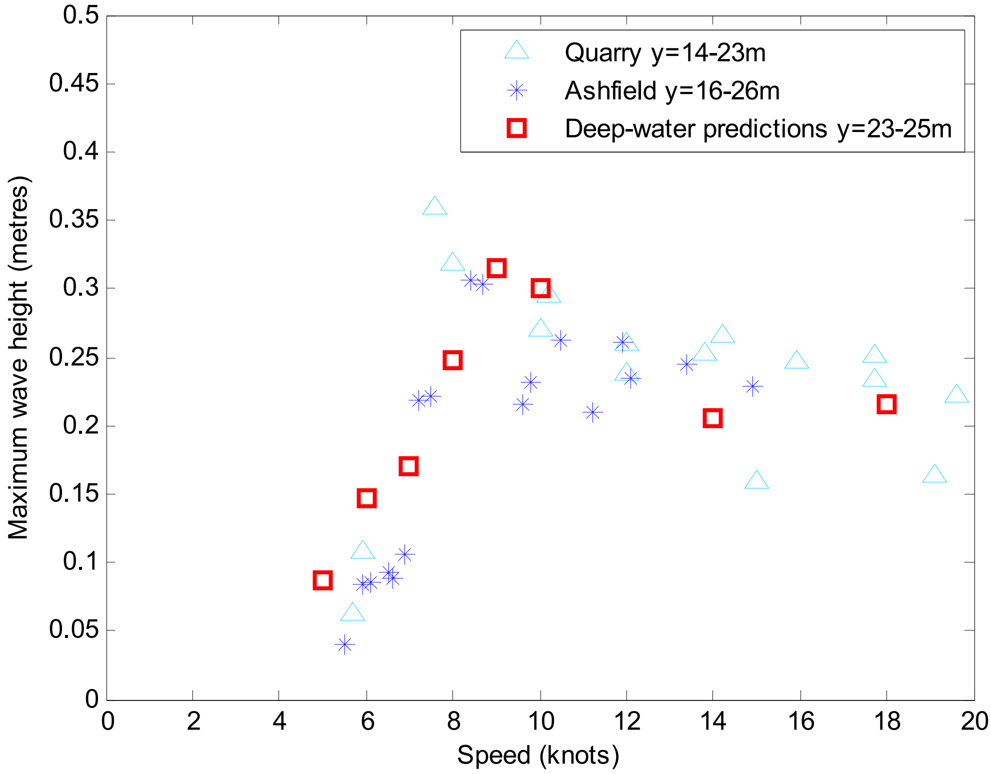

Figure 55: Comparison between measured wave heights and deep-water predictions for close-approach trials of Haines Hunter 680 at Quarry Point. Ashfield Parade results for Haines Hunter 680 also shown.

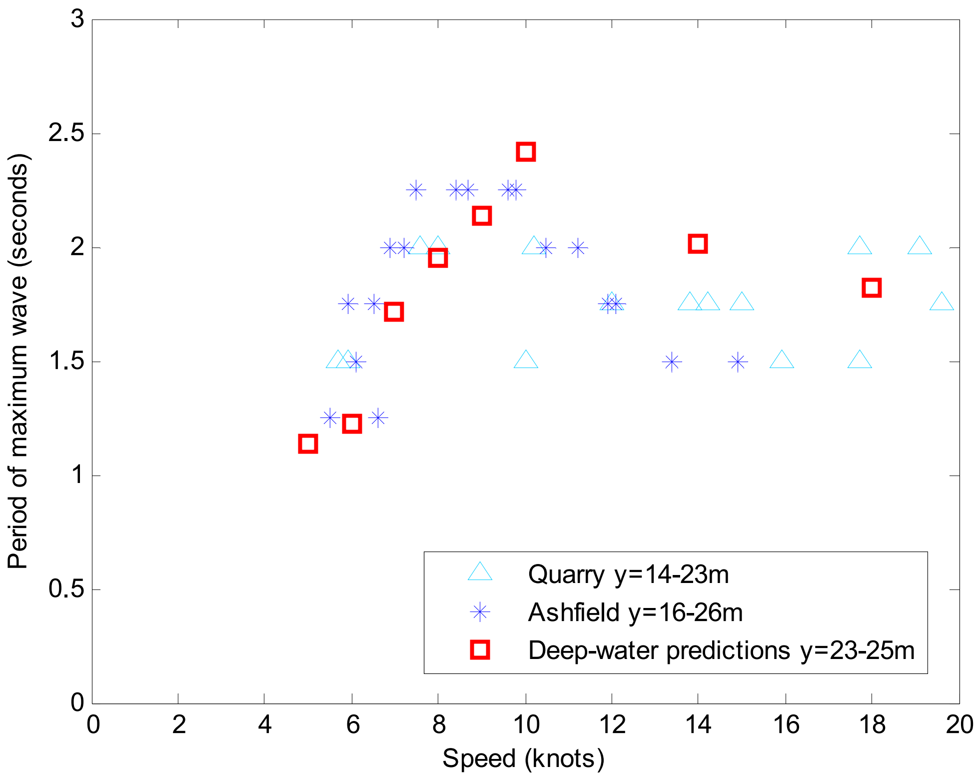

Figure 56: Comparison between measured wave periods and deep-water predictions for close-approach trials of Haines Hunter 680 at Quarry Point. Ashfield Parade results for Haines Hunter 680 also shown.

We see that the measured and predicted wave height and period agree fairly well for the Haines Hunter 680 at close approach, and these are also similar to the results obtained at Ashfield Parade. There is some scatter due to the varying transverse distances from the waverecorder.

Comparisons for wave height and period at distant approach are shown below.

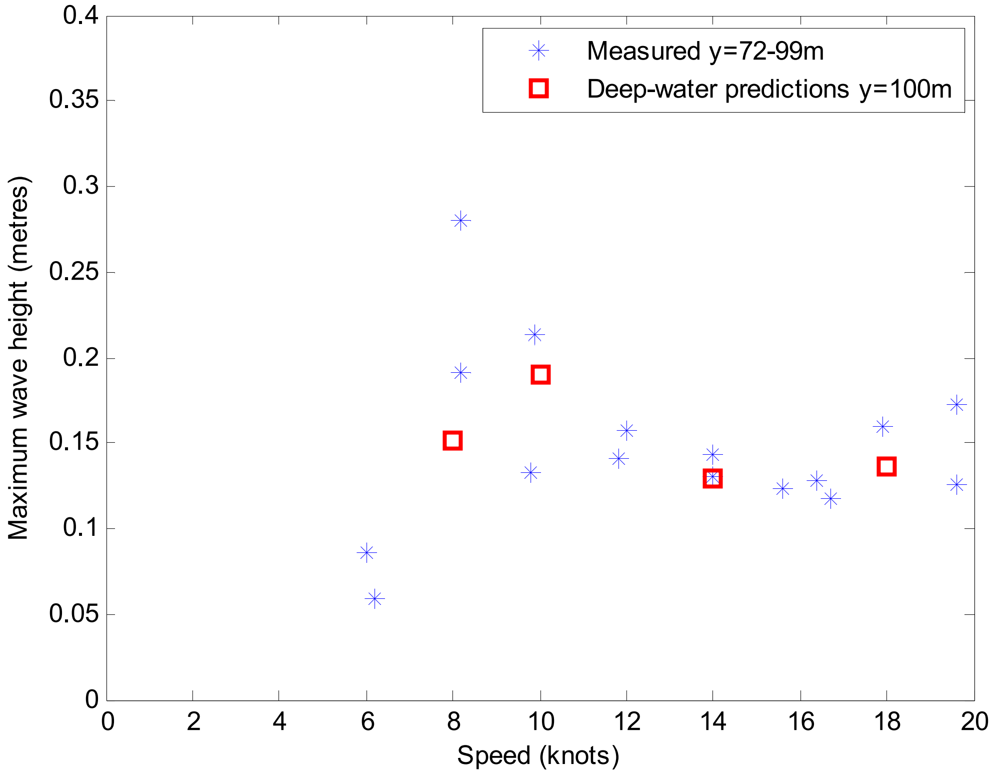

Figure 57: Comparison between measured wave heights and deep-water predictions for distant-approach trials of Haines Hunter 680 at Quarry Point

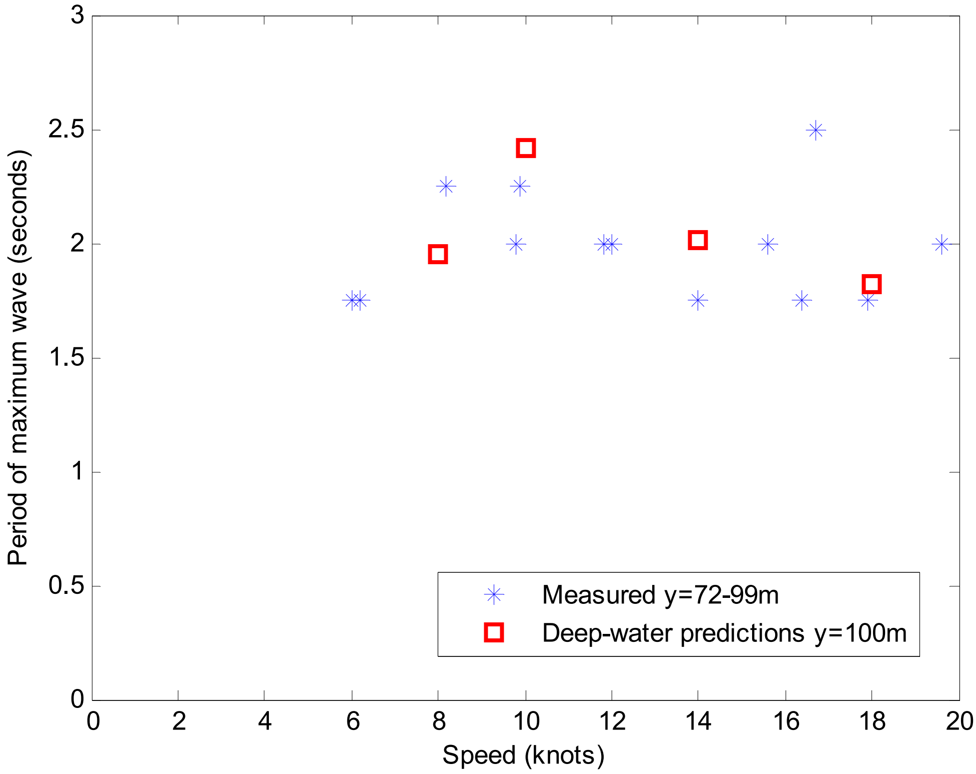

Figure 58: Comparison between measured wave periods and deep-water predictions for distant-approach trials of Haines Hunter 680 at Quarry Point

The measured results are slightly larger than predicted around hump speed, partly because of the smaller transverse distance to that modelled. At higher speeds the results are quite similar. The periods are also similar between the measured and predicted results.

The Star Flyte Express “close approach” runs varied between 19 – 47m from the waverecorder. The predicted results for both 25m and 50m are shown in the following graphs of wave height and period for close approach runs.

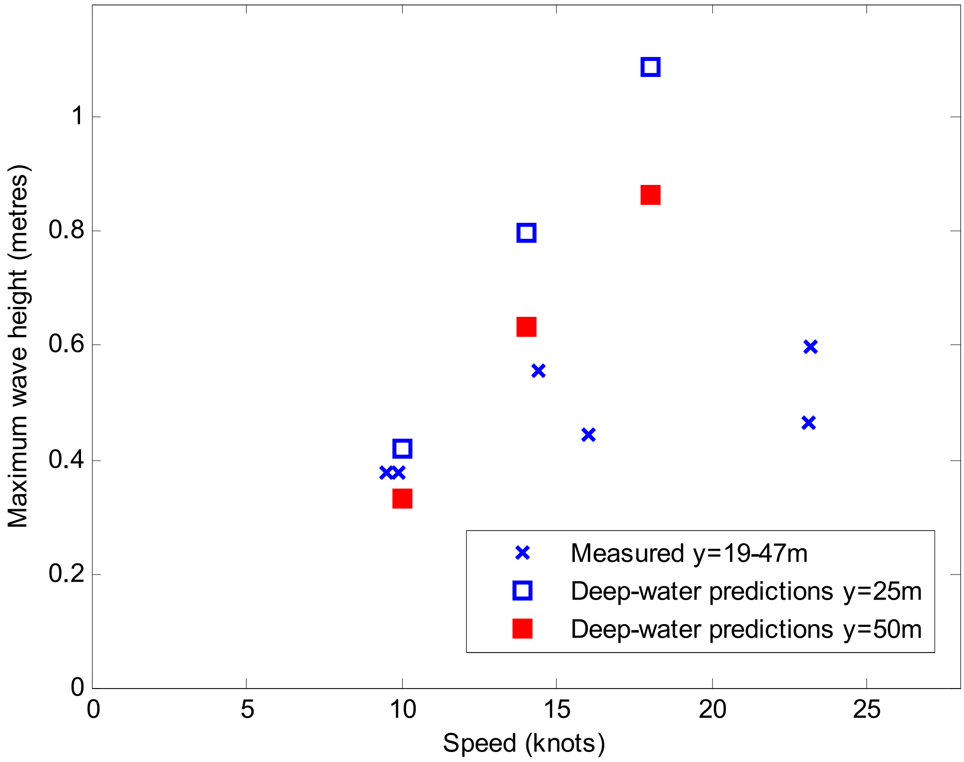

Figure 59: Comparison between measured wave heights and deep-water predictions for close-approach trials of Star Flyte Express at Quarry Point

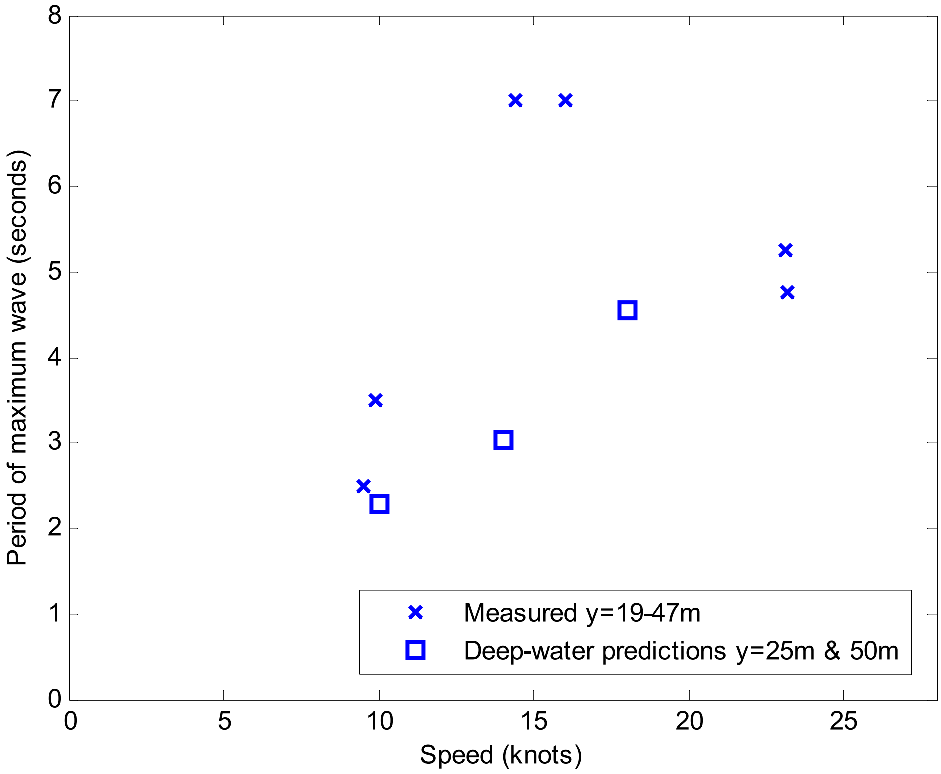

Figure 60: Comparison between measured wave periods and deep-water predictions for close-approach trials of Star Flyte Express at Quarry Point

The graphs of measured and predicted wave height and period are shown in the following graphs for distant-approach runs.

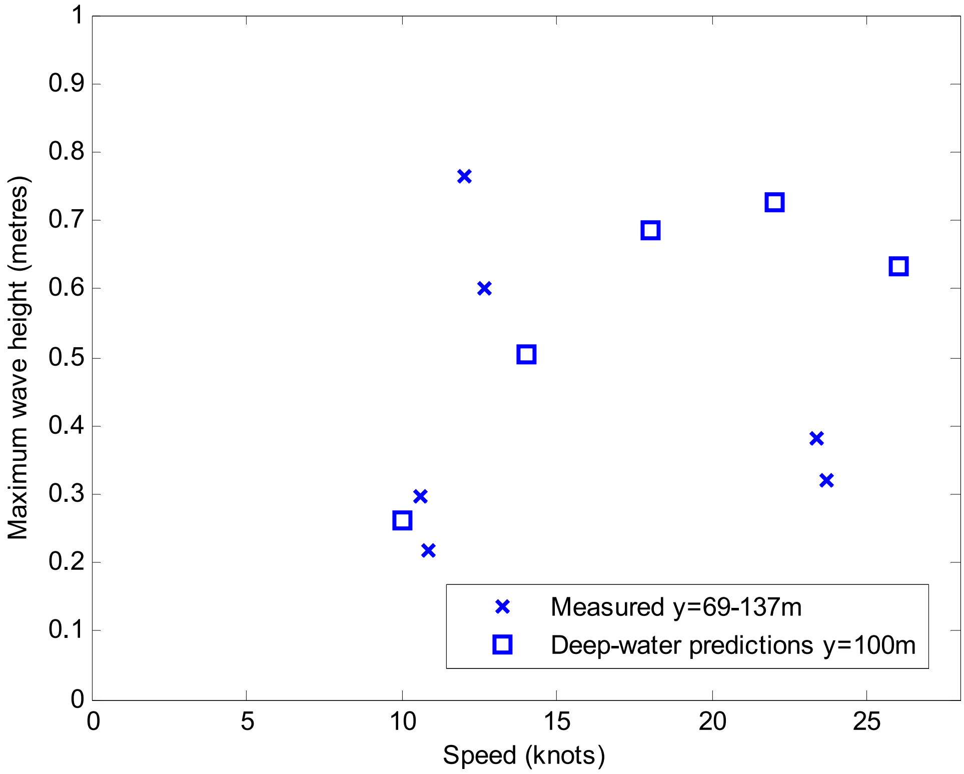

Figure 61: Comparison between measured wave heights and deep-water predictions for distant-approach trials of Star Flyte Express at Quarry Point

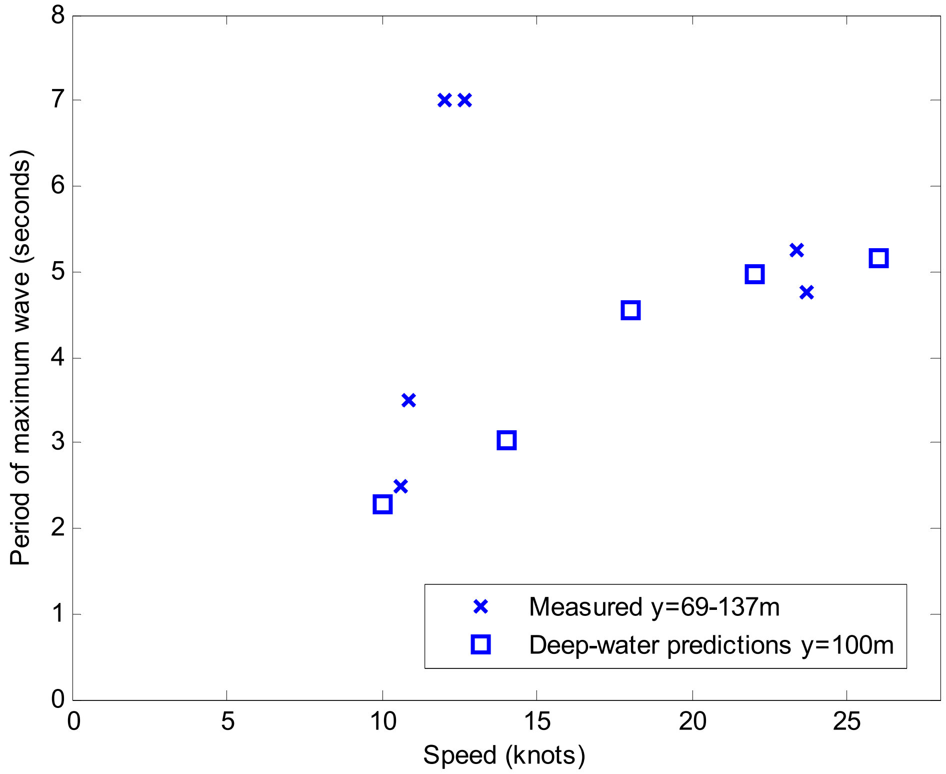

Figure 62: Comparison between measured wave periods and deep-water predictions for distant-approach trials of Star Flyte Express at Quarry Point

As mentioned previously, water depth was an important factor for the Star Flyte, due to its large length as compared to the water depth. The predicted results are based on deep-water model tests, so do not include this effect. The effect of water depth becomes most important at the critical speed, around 12 – 15 knots in this region. This speed range is where the most discrepancy between the measured results and the deep-water predictions occurs. Of particular note is the long period waves produced at the critical speed.

5 DEDICATED TRIALS AT ELLAM ST, SOUTH PERTH

5.1 SRT Noel Robins

The Swan River Trust vessel "Noel Robins" was tested near their Ellam St depot in South Perth, on 10th February 2010 from 12:50 to 14:15. The waverecorder was mounted on the disused jetty as shown in Figure 3, at position 31º58.2231'S,115º52.7987'E. Runs were done parallel to the jetty, at headings 73º and 253º.

The wind conditions measured at Melville Water during the Noel Robins trials were SSW, 8 – 13 knots. Datum depth at the waverecorder was approximately 1.0m. The tide height measured at Barrack St was 0.75m at the beginning of the trial, 0.77m midway through and 0.80m at the end. Currents were negligible during the trials.

Two sets of runs were performed, one set close to the jetty (at 3 – 9m from the waverecorder) and one set at 73 – 89m from the waverecorder. For the distant-approach runs, GPS waypoints were set up on the boat so that the trials followed as well as possible a similar track on each run. The actual transverse distance for each run was measured with GPS. A time trace of the GPS position of the boat is shown below.

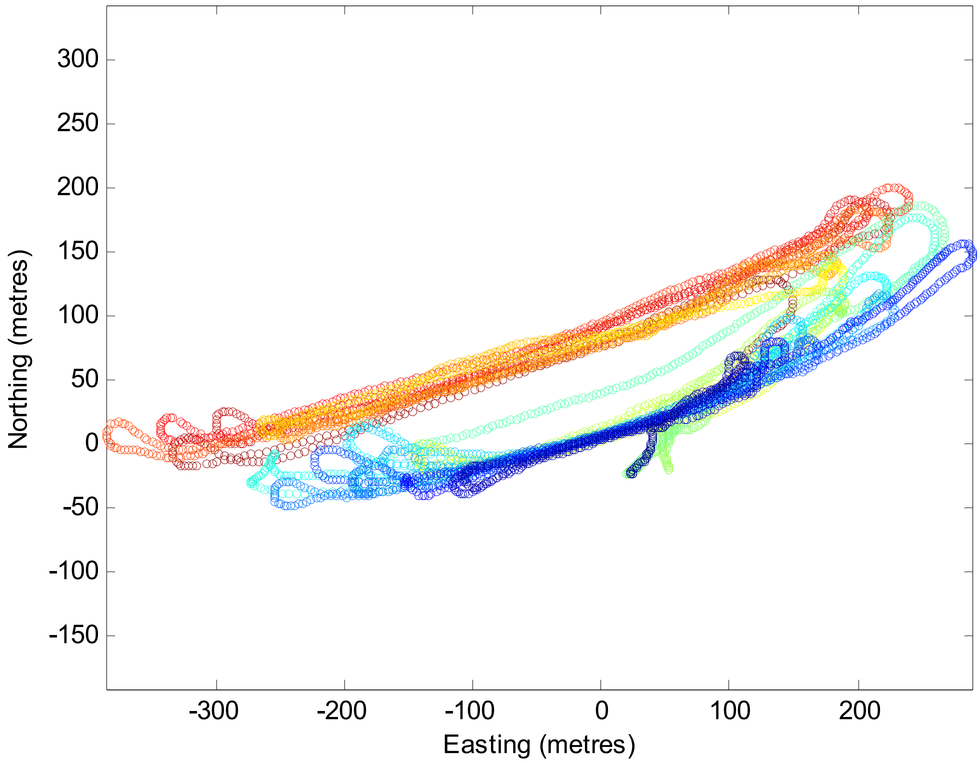

Figure 63: GPS trace from SRT Noel Robins at Ellam St. GPS positions shown relative to waverecorder at (0,0). Colours show times, from blue (start) to red (end).

Measured wake results for the Noel Robins are shown in the following table.

Time boat passes level with waverecorder	Transverse distance from waverecorder (m)	Average boat speed over 300m run (knots)	Speed variation over 200m run (%)	Maximum wave height (m)	Period of maximum wave (s)	Power of maximum wave (W/m)	Energy of maximum wave (J/m)
12:50:30	5.4	5.1	12.1	0.080	1.50	9	28
12:52:03	3.0	5.5	17.3	0.063	1.25	5	12
12:53:42	6.4	6.1	10.3	0.140	1.25	24	60
12:55:11	5.0	6.2	7.3	0.143	1.75	37	120
12:57:07	6.6	6.8	8.2	0.191	2.00	79	272
12:58:55	4.7	7.5	36.7	0.179	1.75	58	188
13:02:38	4.4	7.8	14.8	0.387	3.25	561	2290
13:04:46	8.0	7.6	20.1	0.399	2.25	407	1440
13:06:36	5.8	8.5	25.3	0.367	3.00	472	1850
13:09:27	7.3	7.6	22.7	0.404	2.50	476	1740
13:11:50	4.7	8.4	18.2	0.454	2.75	665	2510
13:13:19	6.3	8.4	37.3	0.453	2.75	664	2510
13:14:58	6.3	8.1	18.4	0.374	3.00	489	1920
13:16:34	7.6	10.4	21.7	0.309	2.50	278	1020
13:17:55	7.9	11.0	42.2	0.331	2.50	319	1160
13:19:02	8.2	12.4	31.6	0.270	2.00	158	542
13:20:56	8.7	11.2	46.1	0.289	2.50	243	888
13:23:16	6.2	14.8	65.2	0.314	1.50	147	434
13:25:24	9.2	15.1	26.8	0.315	2.00	216	741
13:26:51	38.3	6.8	10.1	0.131	1.50	26	76
13:36:42*	12.8	7.0	9.0	0.211	2.75	144	544
13:38:11*	3.4	7.0	10.9	0.146	1.50	32	93
13:39:36*	9.4	7.9	5.9	0.481	3.00	812	3180
13:40:57*	3.4	7.8	9.9	0.389	2.50	442	1610
13:43:48	79.8	4.9	12.2	0.043	1.75	3	11
13:47:16	87.2	5.0	23.5	0.040	1.25	2	5
13:50:13	74.8	6.0	4.9	0.033	1.00	1	2
13:53:01	77.2	6.0	12.0	0.056	1.50	5	14
13:56:00	72.7	6.8	6.9	0.042	2.50	5	19
13:59:42	89.4	7.0	6.4	0.088	1.25	9	24
14:02:25	87.2	7.8	12.2	0.144	2.25	53	189
14:05:20	84.3	8.0	8.2	0.132	2.75	56	212
14:07:30	76.4	9.0	7.1	0.142	5.75	96	596
14:09:52	83.3	8.8	10.4	0.176	2.25	79	280
14:11:49	72.8	12.1	23.3	0.124	2.50	45	162
14:13:53	73.6	11.9	13.1	0.147	6.00	103	663

Table 11: Wake trials results for SRT vessel Noel Robins. Runs with a (*) indicate engine trimmed fully down, otherwise engine trim neutral.

An example wave elevation time trace and corresponding photo are shown below, for the largest wave height case.

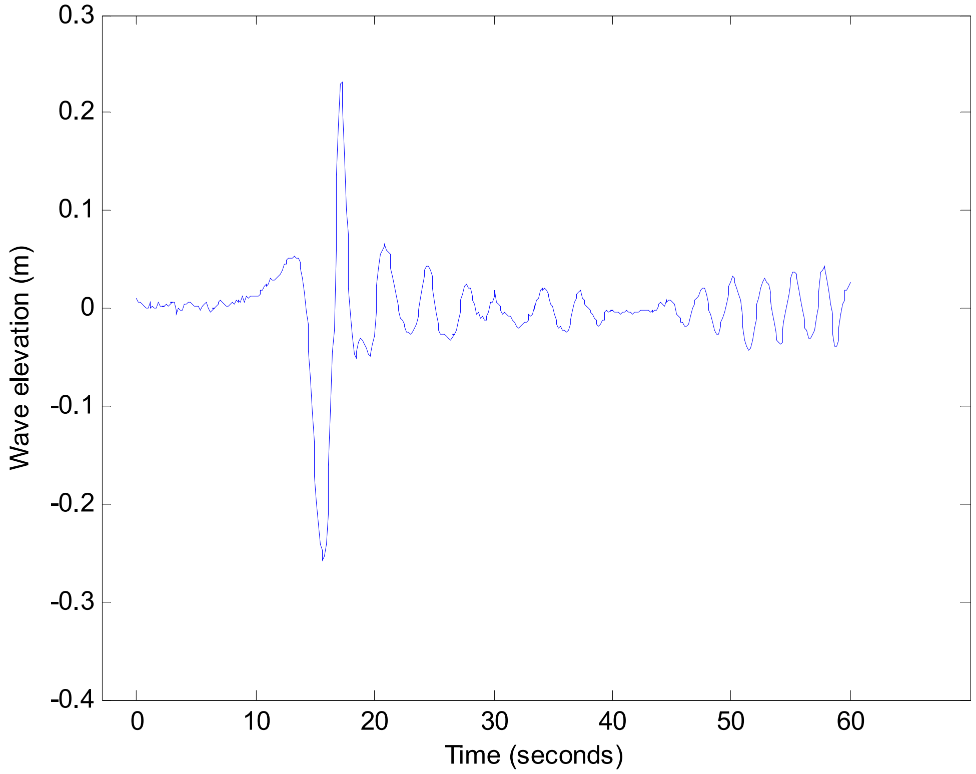

Figure 64: Wave elevation for Noel Robins example case (largest wave height): 7.9 knots at 13:39

Figure 65: Photo of Noel Robins example case (largest wave height): 7.9 knots at 13:39

When comparing the Noel Robins results to the other vessels at Ashfield Parade or Quarry Point, it should be borne in mind that the close-approach trials of the Noel Robins were at smaller transverse distances than at the other sites. Comparing the distant-approach results for the Noel Robins with the distant-approach results for the Haines Hunter 680 and LeisureCat

Mako 9000 at Quarry Point (which are all at similar transverse distances), it can be seen that the maximum wave heights are slightly smaller for the Noel Robins, and wave periods are similar to the other vessels.

6 TOTAL WAVE WAKE – VARIOUS SITES

6.1 Trials description

Measurements were made of the combined wave wake produced at various sites along the Swan River during normal busy periods. These sites are shown below, together with trials times.

Site name	Trial date and time	Sensor location
Quarry Point	Sunday 31st January 2010, 10:00 – 14:00	Quarry Point pilon (Figure 2) Datum depth 1.9m Mean tide height 0.4m Mean water depth 2.3m
Chidley Point	Saturday 13th February 2010, 07:45 – 11:45	Chidley Point pilon (Figure 4) Datum depth ~1.2m Mean tide height ~0.6m Mean water depth ~1.8m
Goodwood Parade	Sunday 14th February 2010, 09:45 – 13:45	"Under Water Hazard" pilon (Figure 5), 300m NW of boat ramp Mean water depth ~2.0m

Table 12: Sites for total combined boat wake trials

6.2 Comparative results for all sites

The total wave energy received at each site over a 4-hour period is shown below. Note that all cumulative wave energy trials were undertaken with minimal wind waves present, and a large amount of vessel traffic, so that the measured wave energy can be attributed primarily to boat wakes in these cases.

Site name	Cumulative boat wake energy in 4-hour period (per metre of transverse distance)	Maximum recorded boat wake energy per wavelength (per metre of wave crest)	Number of passing boats (in both directions) in 4-hour period. Excludes jetskis, kayaks and rowing boats.
Quarry Point	226 kJ/m	7730 J/m	~140 (based on 89 boats measured from 09:57 to 12:30)
Chidley Point	281 kJ/m	10300 J/m	128
Goodwood Parade	116 kJ/m	911 J/m	~420 (based on 53 boats headed upstream from 10:05 to 11:05)

Table 13: Comparative results for total wave energy trials at all sites

We see that Chidley Point had the largest wave energy produced by an individual vessel. It also had the largest cumulative boat wake energy, despite having the smallest number of passing boats. This was due to the generally large size and high speed of passing recreational vessels at Chidley Point.

Goodwood Parade waterski area, despite having over 400 passing boats during the 4-hour period, had around half the cumulative boat wake energy of Quarry Point and Chidley Point.

6.3 Largest boat wake results for Quarry Point

The most extreme boat wakes measured at Quarry Point during the 4-hour interval of normal vessel traffic are as shown in the following table and photographs. The cases are ordered by maximum boat wake energy.

Time	Energy per wavelength, per metre of wave front	Wave height	Wave period	Wave power per metre of wave front
12:19	7730 J/m	0.514m	5.0s	1350 W/m
11:15	3360 J/m	0.329m	5.25s	567 W/m
12:33	2780 J/m	0.457m	2.75s	659 W/m
11:52	2560 J/m	0.369m	3.5s	557 W/m
12:10	2350 J/m	0.394m	3.0s	543 W/m

Table 14: Largest wave energy cases measured at Quarry Point during normal vessel traffic

Photographs of the cases tabled above are shown below.

Figure 66: Boat passing Quarry Point pilon at 12:19

Figure 67: Boat passing Quarry Point pilon at 11:15

Figure 68: Boat passing Quarry Point pilon at 12:33

Figure 69: Golden Sun “Jetaway” passing Quarry Point pilon at 11:52

Figure 70: Boat passing Quarry Point pilon at 12:10

The ferries Captain Cook, James Stirling and Oceanic Seacat also passed Quarry Point pilon during the measurement period, but were not among the boats producing the largest wake energy.

6.4 Largest boat wake results for Chidley Point

The most extreme boat wakes measured at Chidley Point during the 4-hour interval of normal vessel traffic are as shown in the following table and photographs. The cases are ordered by maximum boat wake energy.

Time	Energy per wavelength, per metre of wave front	Wave height	Wave period	Wave power per metre of wave front
09:33	10300 J/m	0.699m	4.25s	2120 W/m
09:31	7160 J/m	0.583m	4.25s	1480 W/m
08:42	6610 J/m	0.526m	4.75s	1250 W/m
09:21	5850 J/m	0.652m	3.0s	1490 W/m
10:40	5510 J/m	0.720m	2.5s	1510 W/m

Table 15: Largest wave energy cases measured at Chidley Point during normal vessel traffic

Photographs of the cases described above are shown below.

Figure 71: Boat passing Chidley Point pilon at 09:33

Figure 72: Wake produced by boat passing Chidley Point pilon at 09:33

Figure 73: Boat passing Chidley Point pilon at 09:31

Figure 74: Boat passing Chidley Point pilon at 08:42

Figure 75: Boat passing Chidley Point pilon at 09:21

Figure 76: Boats passing Chidley Point pilon at 10:40 (combined waves due to all 3 boats)

The ferries Star Flyte Express, Captain Cook and Oceanic Rivercat also passed Chidley Point pilon during the measurement period, but were not among the boats producing the largest wake energy.

6.5 Largest boat wake results for Goodwood Parade

The largest boat wakes measured at Goodwood Parade during the 4-hour interval of normal vessel traffic are as shown in the following table. The cases are ordered by maximum boat wake energy.

Time	Energy per wavelength, per metre of wave front	Wave height	Wave period	Wave power per metre of wave front
10:29	911 J/m	0.314m	2.25s	248 W/m
13:15	598 J/m	0.281m	2.0s	169 W/m
10:10	596 J/m	0.254m	2.25s	162 W/m
11:15	568 J/m	0.274m	2.0s	160 W/m
10:40	501 J/m	0.291m	1.75s	151 W/m

Table 16: Largest wave energy cases measured at Goodwood Parade during normal vessel traffic

Photographs of the 1st, 3rd and 5th highest energy wave cases are shown below.

Figure 77: Captain Cook "River Lady" and recreational boat passing Goodwood Parade waverecorder at 10:29 (combined effect from both boats)

Figure 78: Boat passing Goodwood Parade waverecorder at 10:10 (pilon with waverecorder in foreground)

Figure 79: Boat passing Goodwood Parade waverecorder at 10:40

7 WIND WAVE MEASUREMENTS

Wind wave measurements were made at Ashfield Parade and Quarry Point, to check the validity of the wind wave modelling equations used for these sites in the initial report (AMC – CMST 2009). In that report, the wind wave modelling equations were combined with 7 years of measured wind data on Melville Water, to predict the properties of the largest wind waves likely to be encountered at Ashfield Parade and Quarry Point.

Cumulative wind wave energy was also measured during the trials.

The location of the waverecorder at Ashfield Parade during the wind wave trials was similar to in the dedicated trials, but 1 – 2m closer to shore. The location of the waverecorder at Quarry Point during the wind wave trials was on the Quarry Point pilon, in the same location as for the dedicated trials and total wave wake trials.

For all wind wave measurements, quoted wind conditions were as measured at Melville Water's Inner Dolphin Pilon.

7.1 Ashfield Parade 2nd Feb 2010

Wind waves were measured at Ashfield Parade from 14:10 to 15:40 on 2nd Feb 2010. The mean water depth at waverecorder during the trials was 1.7m. The wind strength measured at Melville Water over the duration of the trial is shown below.

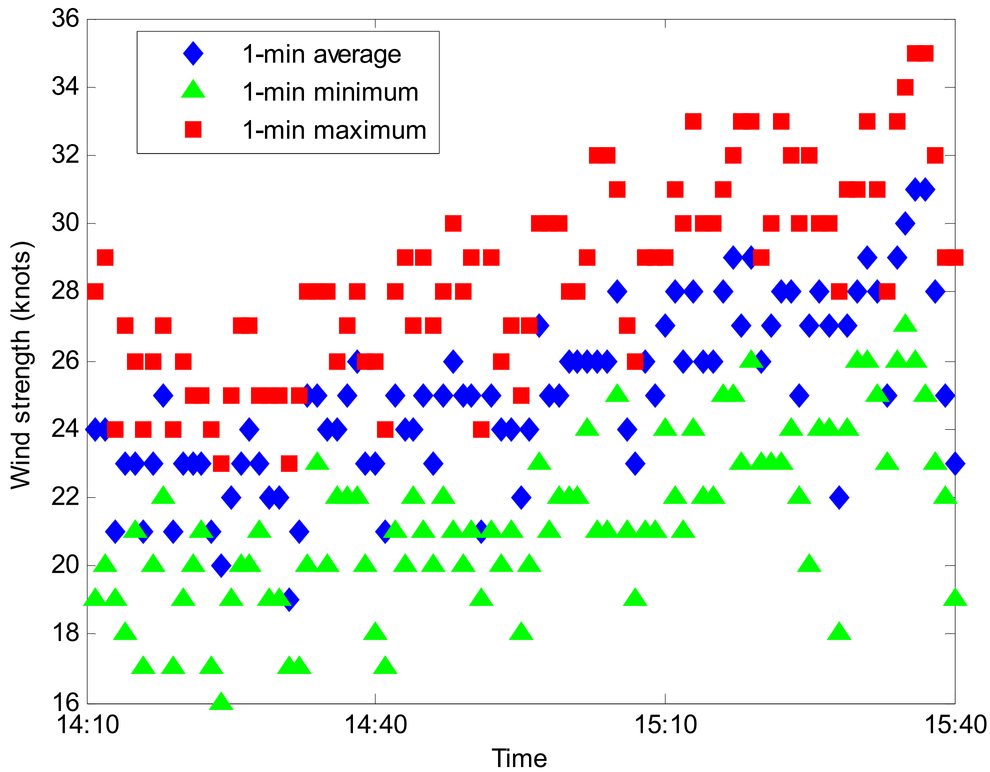

Figure 80: Measured wind strength at Melville Water during wind wave trials at Ashfield Parade on 2nd Feb 2010

The observed wind strength on the river at Ashfield Parade during the trial was significantly less than that measured at Melville Water, due to Ashfield Parade's sheltered nature.

The wind direction measured at Melville Water over the duration of the trial is shown below.

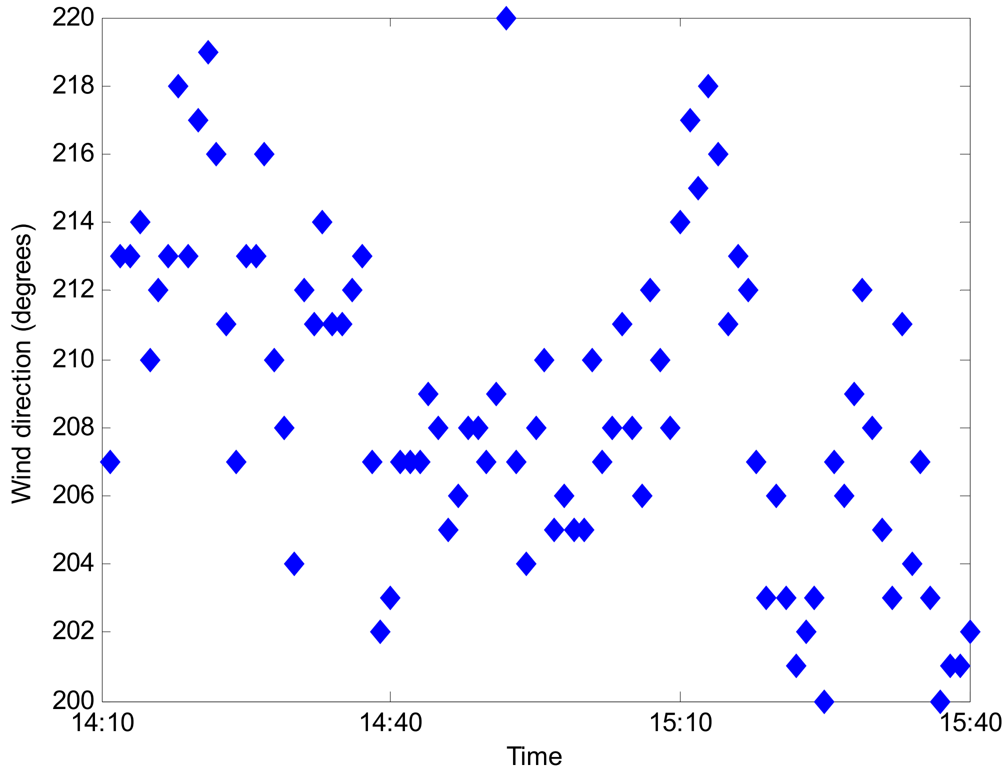

Figure 81: Measured wind direction at Melville Water during wind wave trials at Ashfield Parade on 2nd Feb 2010

The wind direction had an offshore component (wind direction > 195°) during the entire measurement period on 2nd Feb, so that the fetch was zero, and no wind waves could travel directly toward the waverecorder in the direction of the wind. Instead, the only wind waves encountered at the waverecorder were the result of wave refraction. This means that the measured wind waves were very small, and the wind wave prediction method is not valid for cases with zero fetch. Therefore, measurements of wind waves are given for 2nd Feb, but no predictions.

The measured wave heights of all individual wind waves during the measurement period are shown below.

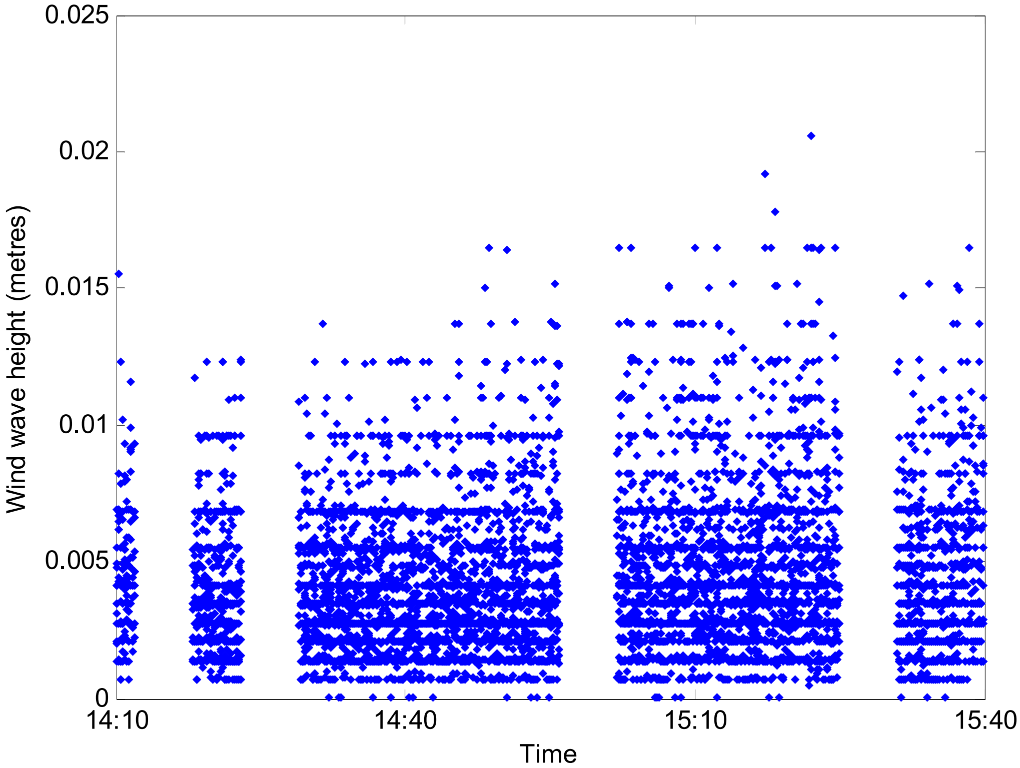

Figure 82: Measured individual wind wave heights during wind wave trials at Ashfield Parade on 2nd Feb 2010

During the trials, the time of any passing boats was noted. The data was then cropped to remove the period 2 minutes before and 4 minutes after each passing boat at Ashfield Parade. This ensures that the waves shown are only due to wind and not passing boats.

We see that wind waves were generally less than 0.02m during these measurements.

By breaking the data into 30-minute intervals, the maximum wave height over each time interval, as well as the average height of the largest 1% of waves, can be found. These results are plotted below.

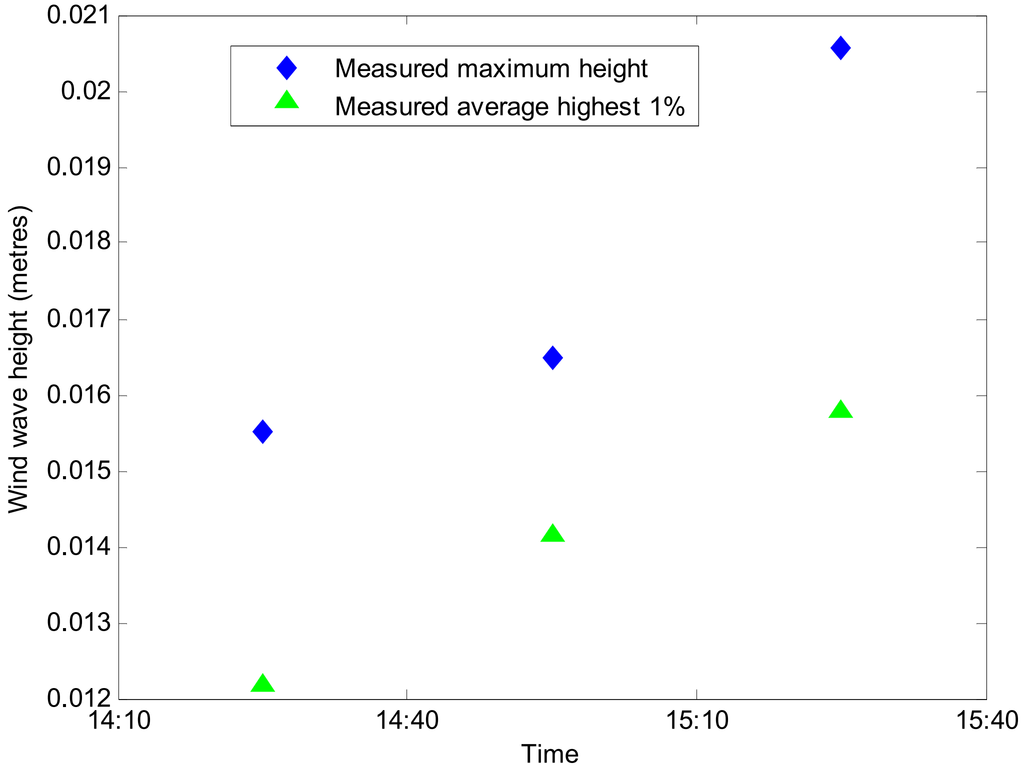

Figure 83: Measured wind wave heights over 30-minute intervals during wind wave trials at Ashfield Parade on 2nd Feb 2010

The period of the maximum wave can be found in the same way as for the boat wake trials (see Appendix A). These results are plotted below.

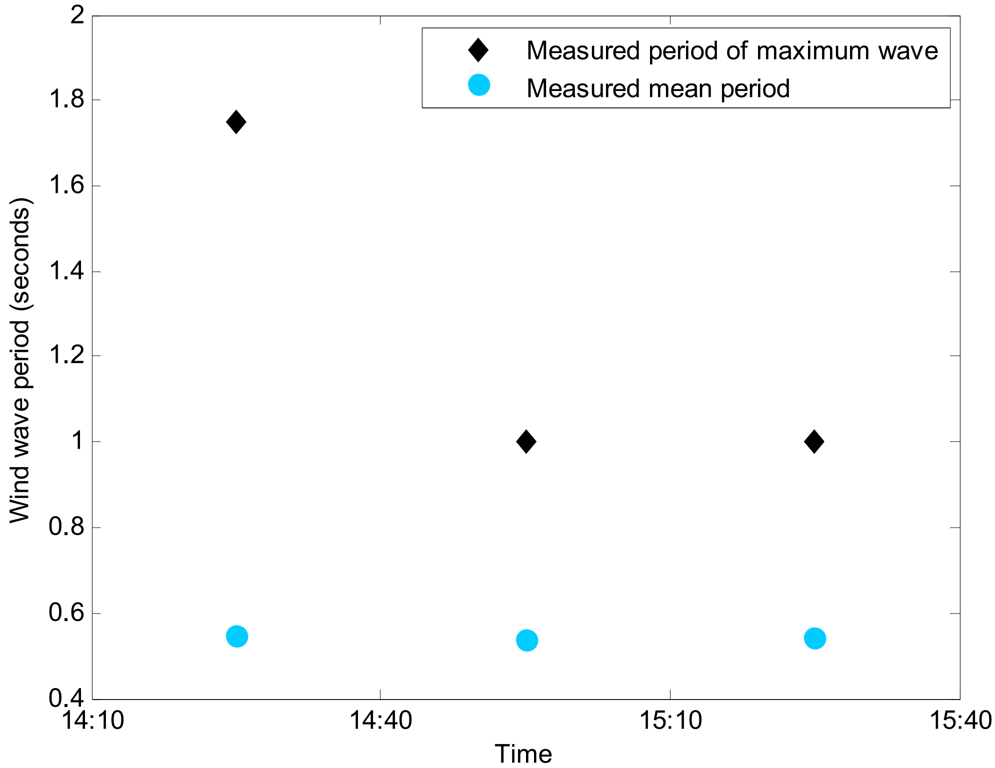

Figure 84: Measured wind wave periods over 30-minute intervals during wind wave trials at Ashfield Parade on 2nd Feb 2010

We see that the periods of these waves are relatively long (1 – 1.8s) because only the longest-period components of the wave spectrum refract back in towards the shore. As seen above, however, these waves are less than 0.02m in height.

7.2 Ashfield Parade 3rd Feb 2010, including comparison with predictions

Wind waves were measured at Ashfield Parade from 13:40 to 15:40 on 3rd Feb 2010. The mean water depth at the waverecorder during the trials was 1.7m. The wind strength and direction measured at Melville Water over the duration of the trial are shown below.

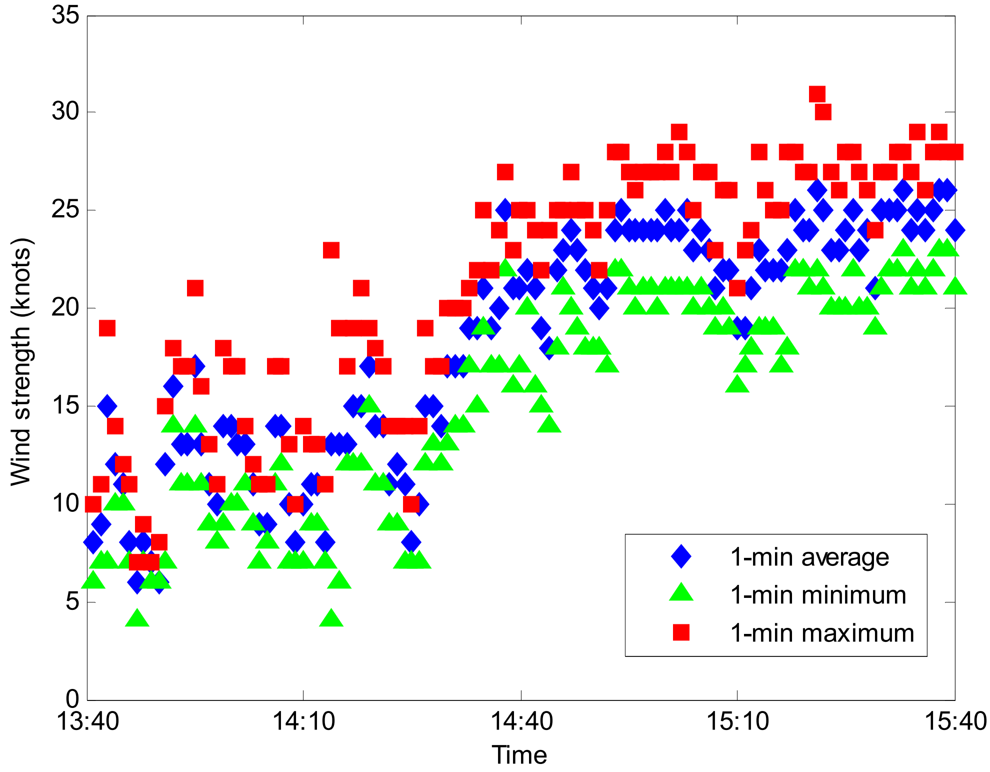

Figure 85: Measured wind strength at Melville Water during wind wave trials at Ashfield Parade on 3rd Feb 2010

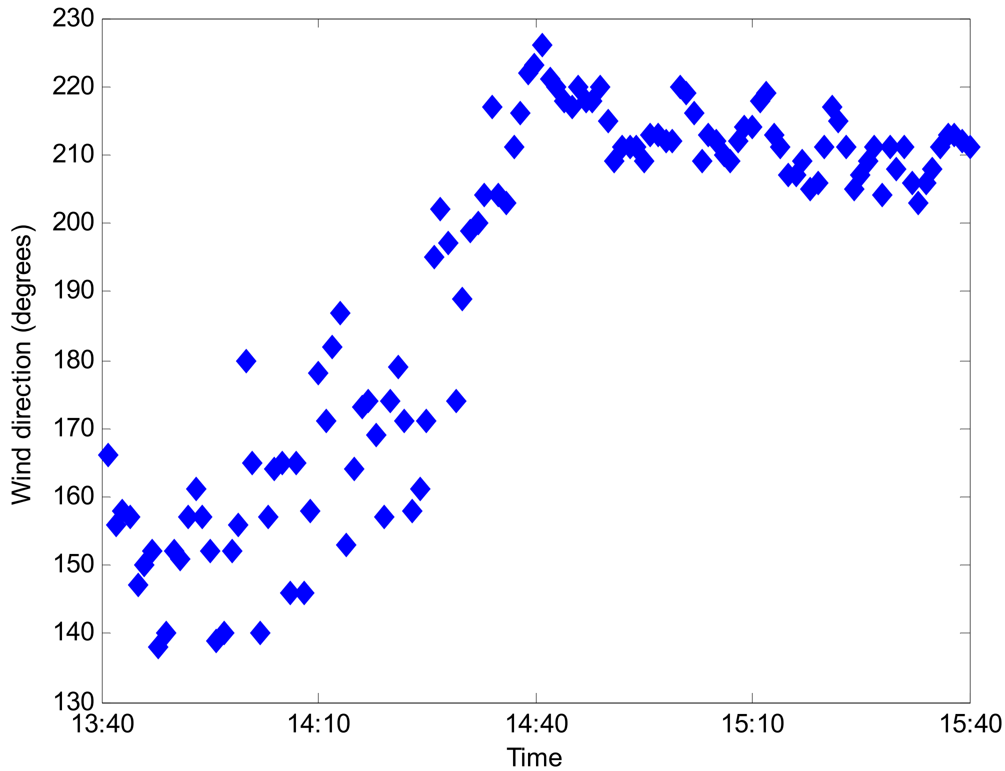

Figure 86: Measured wind direction at Melville Water during wind wave trials at Ashfield Parade on 3rd Feb 2010

The measured individual wave heights, as well as wave heights and periods over 30-minute intervals, are shown below.

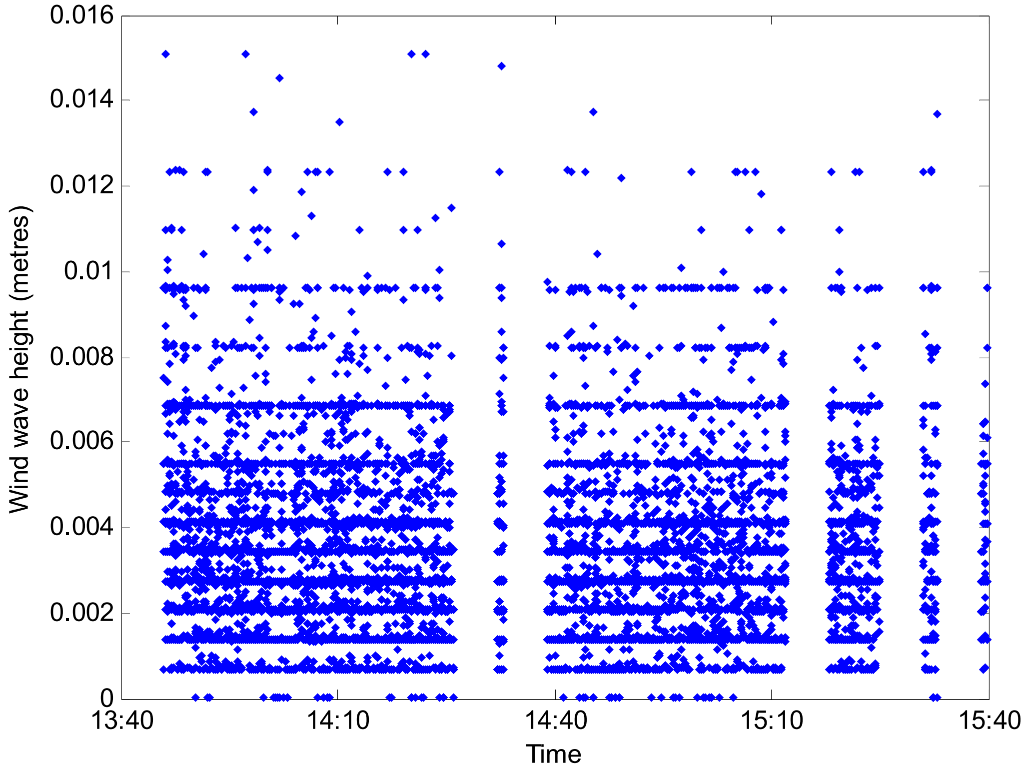

Figure 87: Measured individual wind wave heights during wind wave trials at Ashfield Parade on 3rd Feb 2010

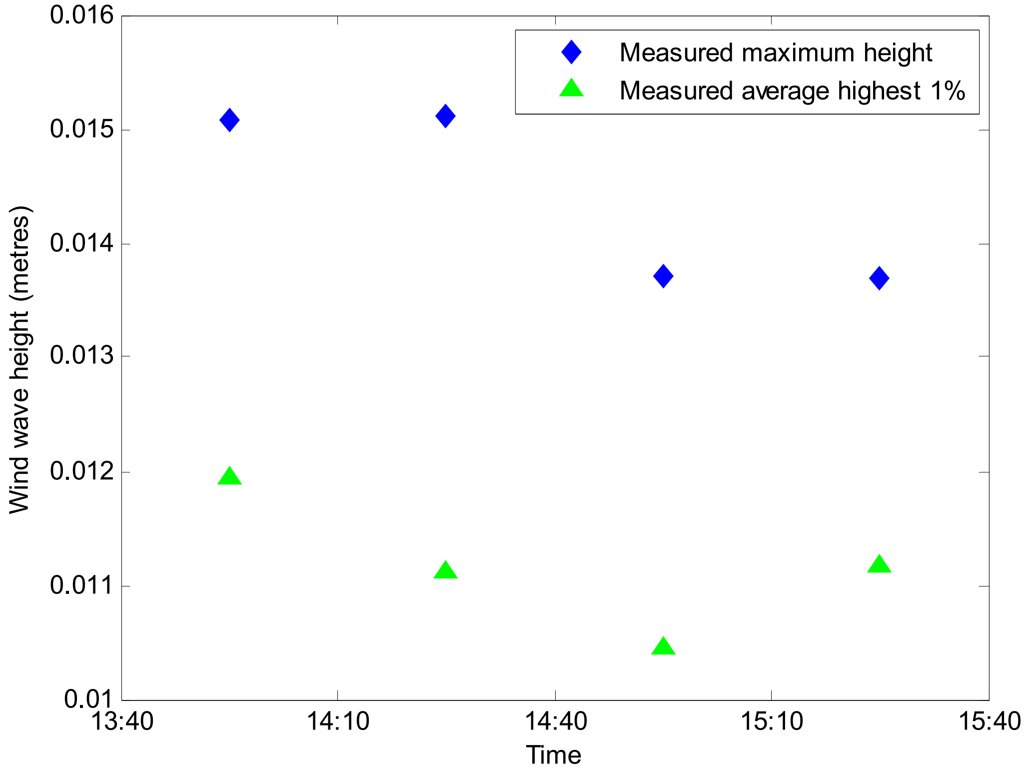

Figure 88: Measured wind wave heights over 30-minute intervals during wind wave trials at Ashfield Parade on 3rd Feb 2010

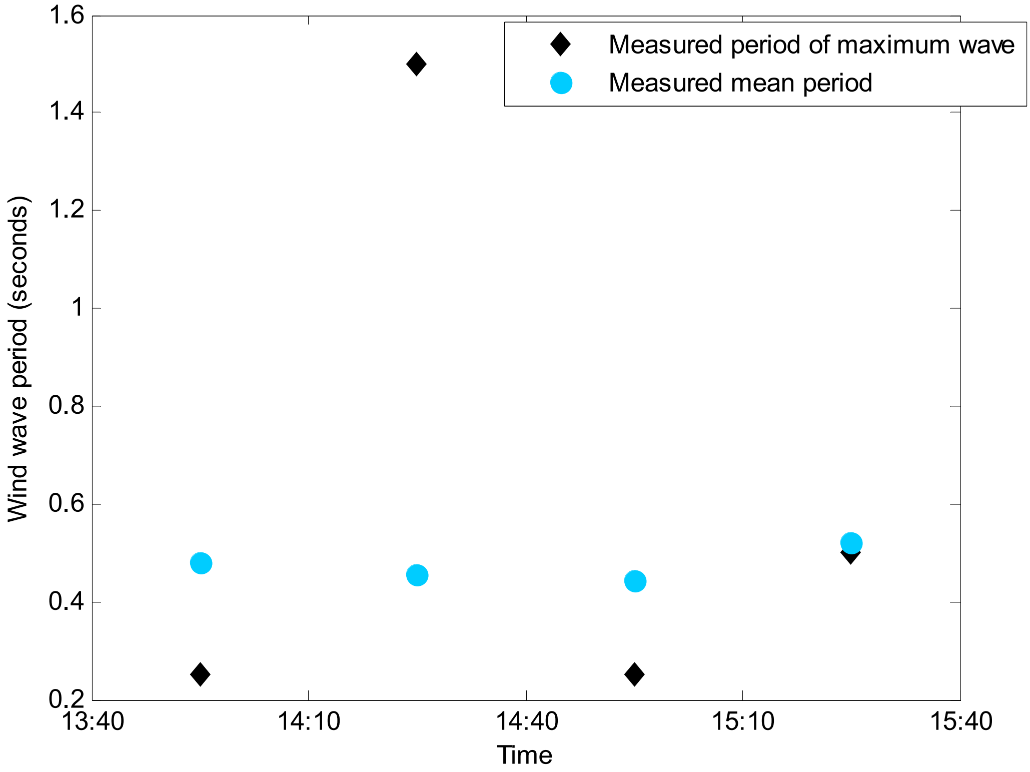

Figure 89: Measured wind wave periods over 30-minute intervals during wind wave trials at Ashfield Parade on 3rd Feb 2010

Again, we see that all of the measured wind waves were tiny, being less than 0.015m in this case.

The wind direction had an onshore component (wind direction < 195°) only for the first part of the measurement period, so that the prediction method is only valid for this period. Comparisons between measured and predicted wind waves for the first part of the measurement period are shown below.

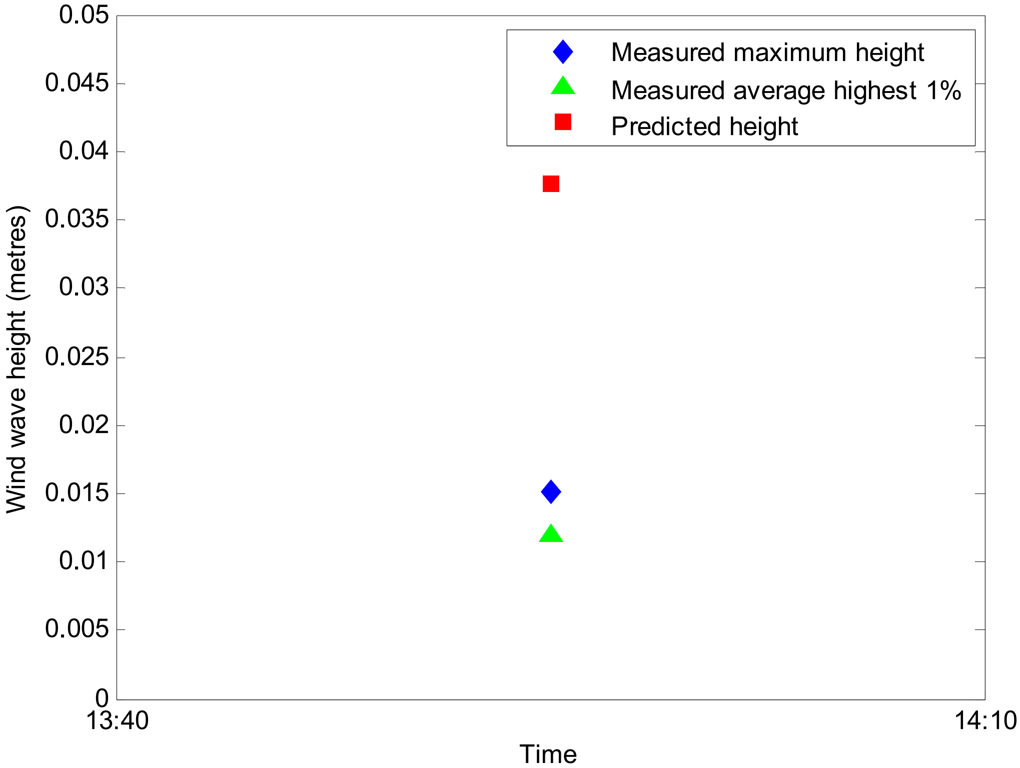

Figure 90: Measured and predicted wind wave heights over 30-minute interval during wind wave trials at Ashfield Parade on 3rd Feb 2010

We see that the measured wind wave heights are much less than those predicted. This is most likely due to the sheltered location at Ashfield Parade, meaning that the average wind strength is significantly less than at Melville Water.

The measured period of the maximum wave, as well as the measured mean period, are shown below, together with the predicted period. Note that the predicted period as defined in the USACERC1977 method is a representative value, which would most likely approximate the mean wave period, rather than the period of the maximum wave.

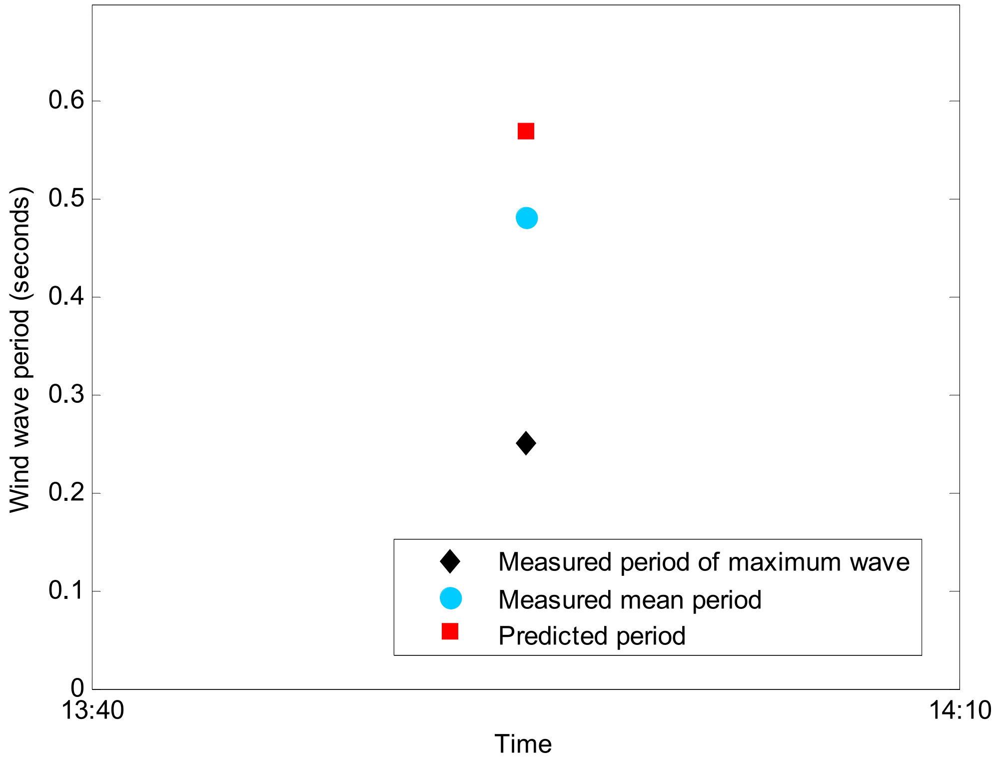

Figure 91: Measured and predicted wind wave periods over 30-minute interval during wind wave trials at Ashfield Parade on 3rd Feb 2010

The measured mean period is slightly less than the predicted value. The measured period of the maximum wave is small in this case, but is quite erratic (see previous graphs) due to the finite resolution of the waverecorder making it difficult to pick out peaks and troughs for tiny waves such as those measured here.

There is insufficient data to draw solid conclusions about the applicability of the wind wave prediction method at Ashfield Parade. However, from the data shown, it appears that the prediction method over-predicts the wind wave heights when using Melville Water wind data, due to the much lighter wind conditions at Ashfield Parade. Therefore the wind wave prediction method remains unchanged from the initial report (AMC – CMST 2009) at Ashfield Parade, with the understanding that the extreme wind waves at this location are probably somewhat less than the predicted values given.

7.3 Quarry Point 11th Feb 2010

Wind waves were measured at Quarry Point from 12:00 to 14:00 on 11th Feb 2010. The tide height measured at Barrack St was 0.69m at the beginning of the trial, 0.73m at the middle and 0.77m at the end. The wind strength and direction measured at Melville Water over the duration of the trial are shown below. For both plots, a zero reading represents missing data.

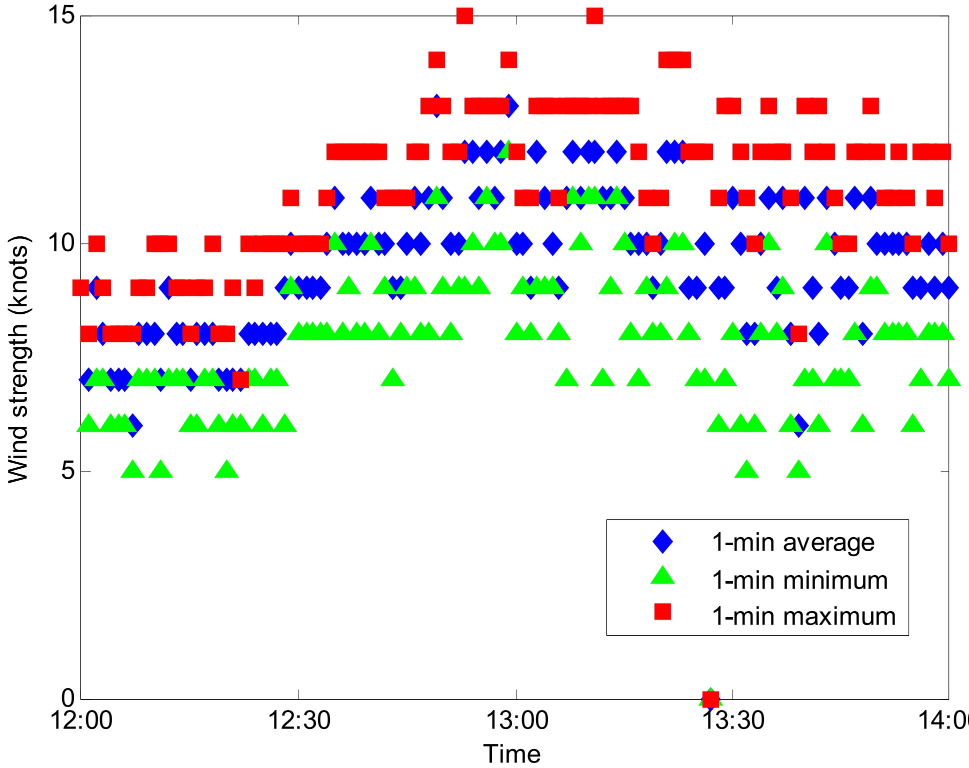

Figure 92: Measured wind strength at Melville Water during wind wave trials at Quarry Point on 11th Feb 2010

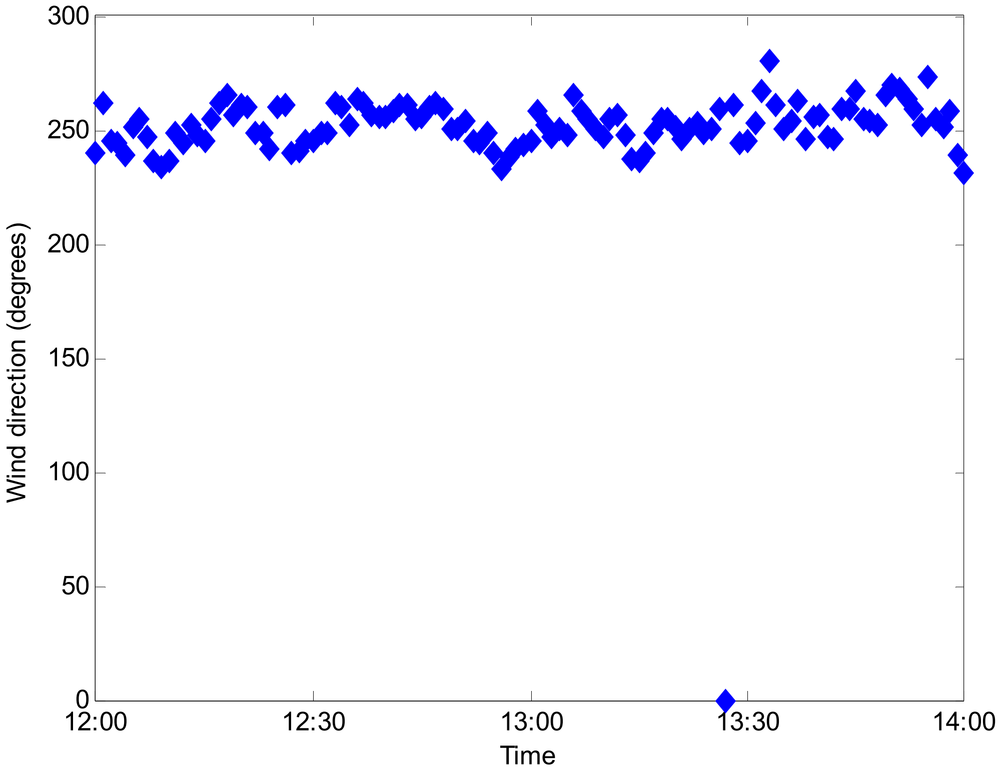

Figure 93: Measured wind direction at Melville Water during wind wave trials at Quarry Point on 11th Feb 2010

The wind direction had an offshore component (wind direction > 240°) for most of the measurement period on 11th Feb, and the wind wave prediction method is not valid in this case. Therefore, measurements of wind waves are given for 11th Feb, but no predictions.

The measured individual wave heights are shown below.

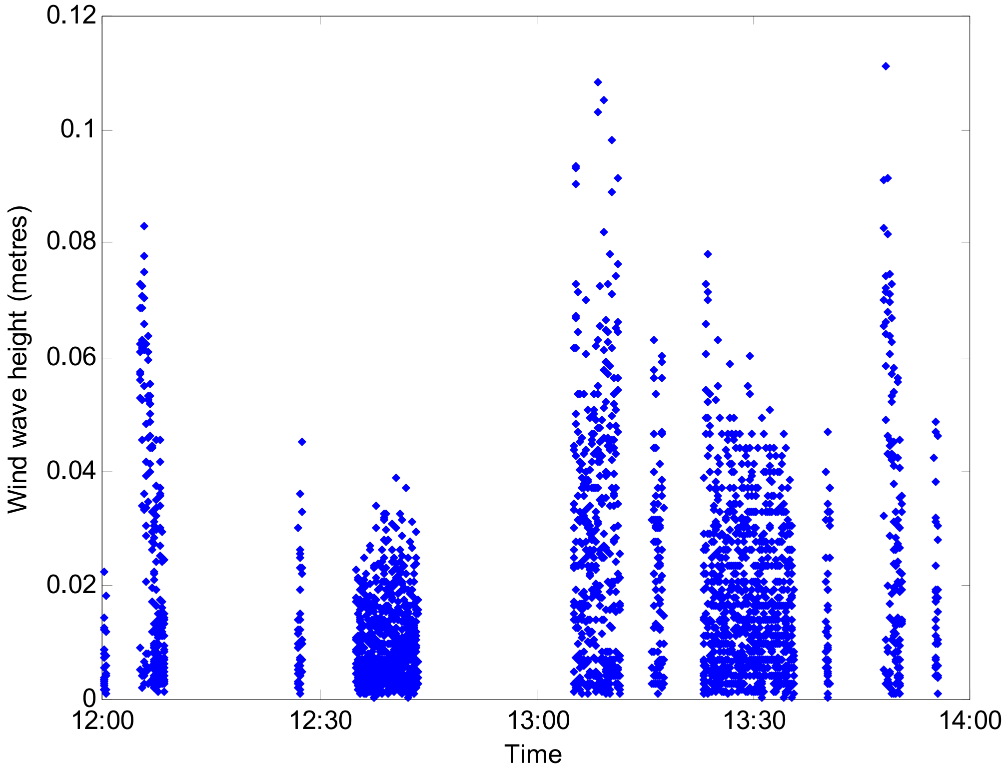

Figure 94: Measured individual wind wave heights during wind wave trials at Quarry Point on 11th Feb 2010

During the trials, the time of any passing boats was noted. The data was then cropped to remove the period 1.5 minutes before and 3 minutes after each passing boat at Quarry Point. This ensures that the waves shown are only due to wind and not passing boats.

The measured wave heights and periods over 30-minute intervals are shown below.

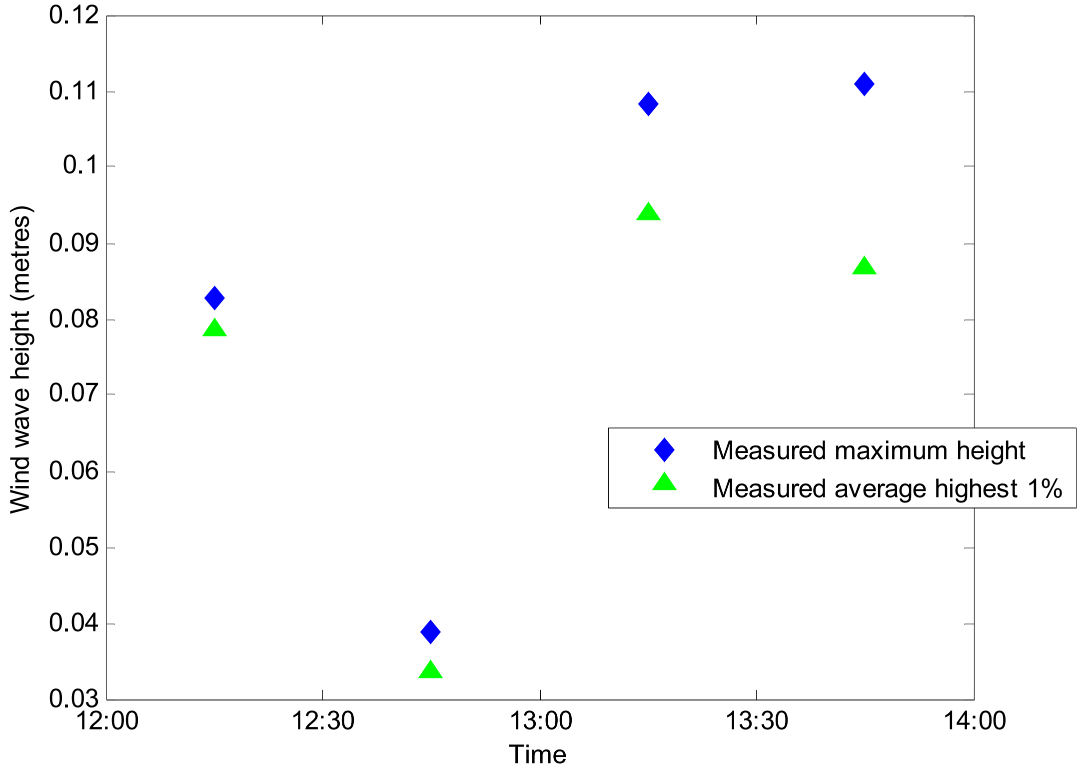

Figure 95: Measured wind wave heights over 30-minute intervals during wind wave trials at Quarry Point on 11th Feb 2010

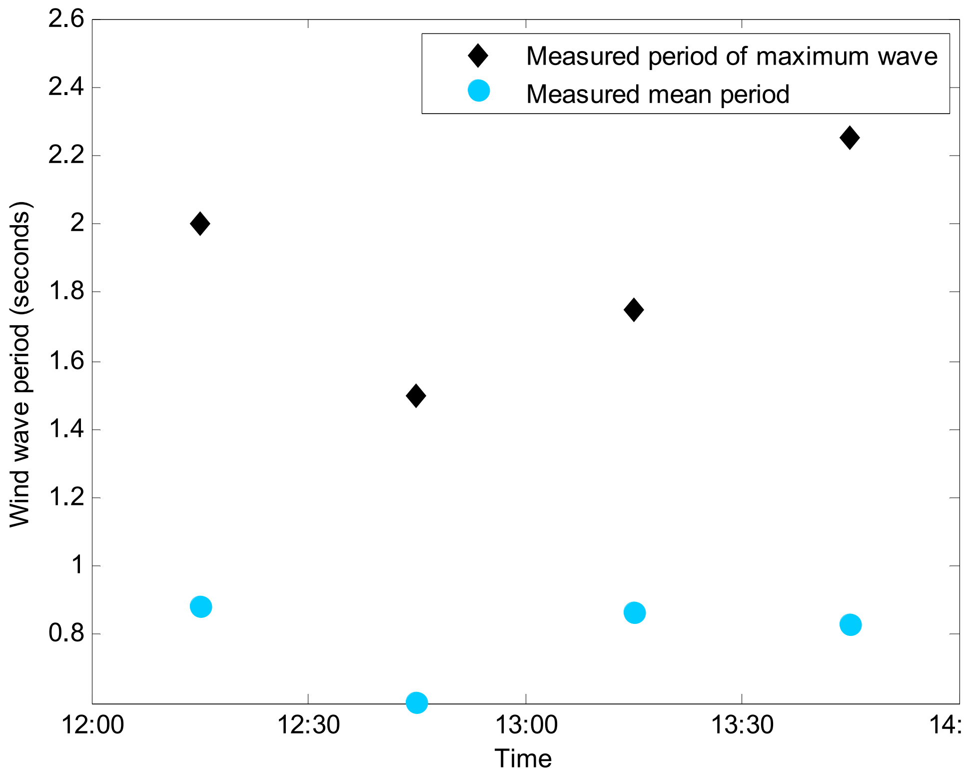

Figure 96: Measured wind wave periods over 30-minute intervals during wind wave trials at Quarry Point on 11th Feb 2010

7.4 Quarry Point 12th Feb 2010, including comparison with predictions

Wind waves were measured at Quarry Point from 12:45 to 15:45 on 12th Feb 2010. The tide height measured at Barrack St was 0.72m at the beginning of the trial, 0.77m at the middle and 0.78m at the end. The wind strength and direction measured at Melville Water over the duration of the trial are shown below. For both plots, a zero reading represents missing data.

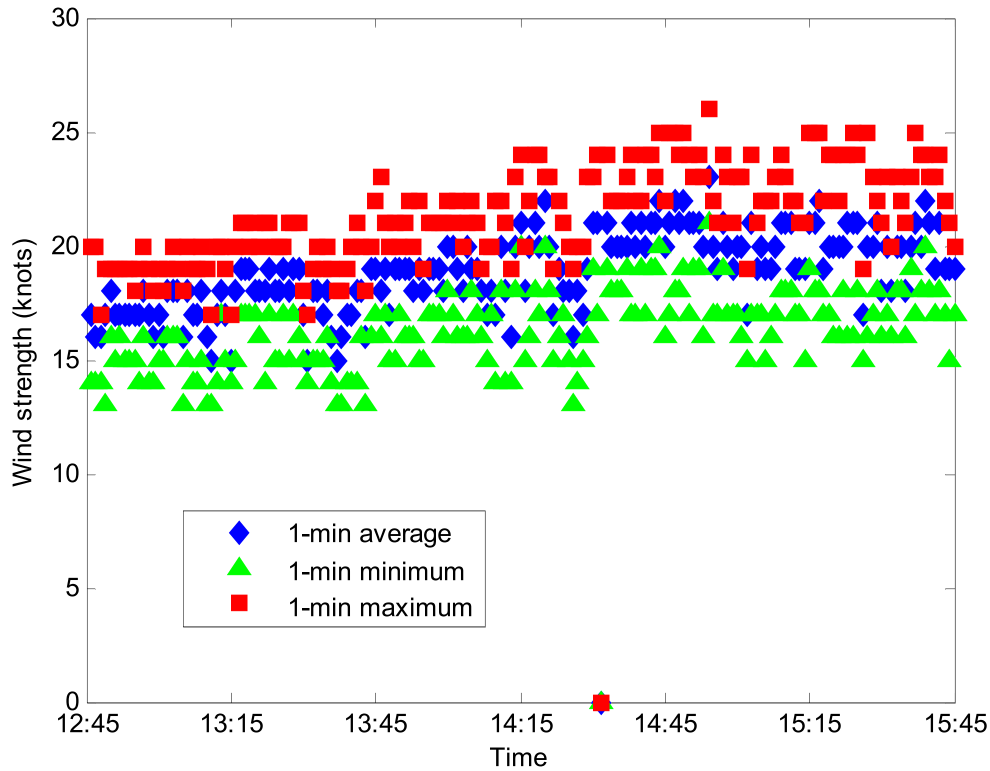

Figure 97: Measured wind strength at Melville Water during wind wave trials at Quarry Point on 12th Feb 2010

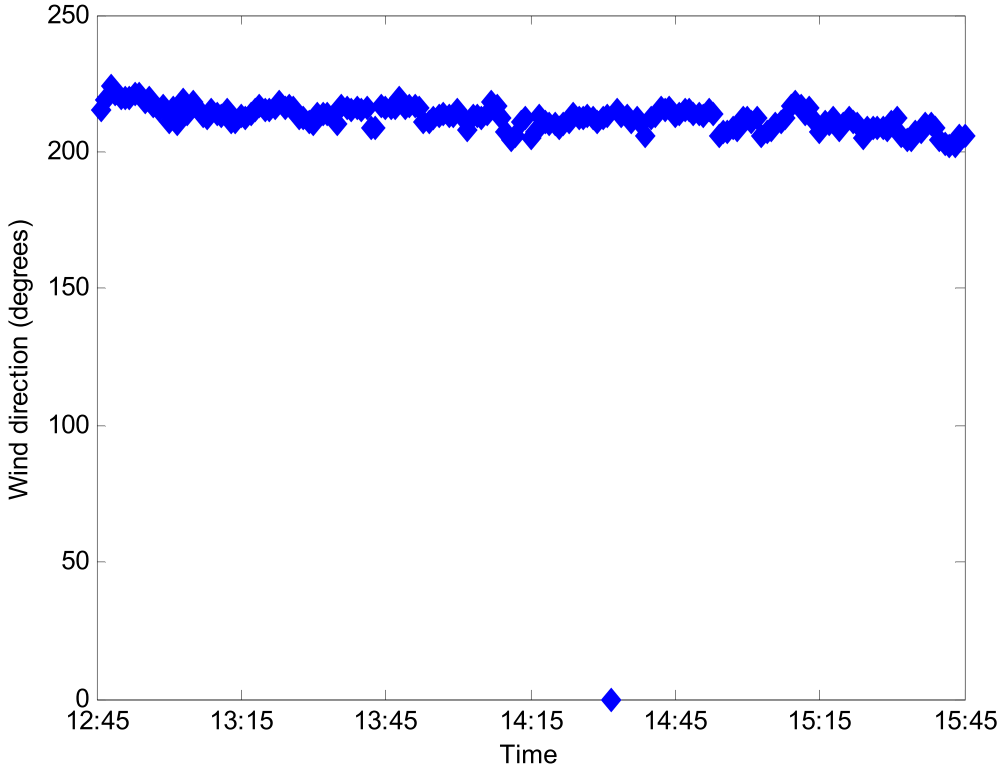

Figure 98: Measured wind direction at Melville Water during wind wave trials at Quarry Point on 12th Feb 2010

The observed wind conditions were ideal for testing the wind wave predictions, with a strong onshore wind producing wind waves towards the upper end of those likely to be encountered at Quarry Point. A photo of the wind waves is shown below.

Figure 99: Wind waves at Quarry Point during 20 – 25 knot sea breeze, 12th Feb 2010 at 15:30

Measured individual wave heights are shown below, together with predicted values using the mean wind speed at the time and the USACERC 1977 method outlined in the initial report (AMC – CMST 2009).

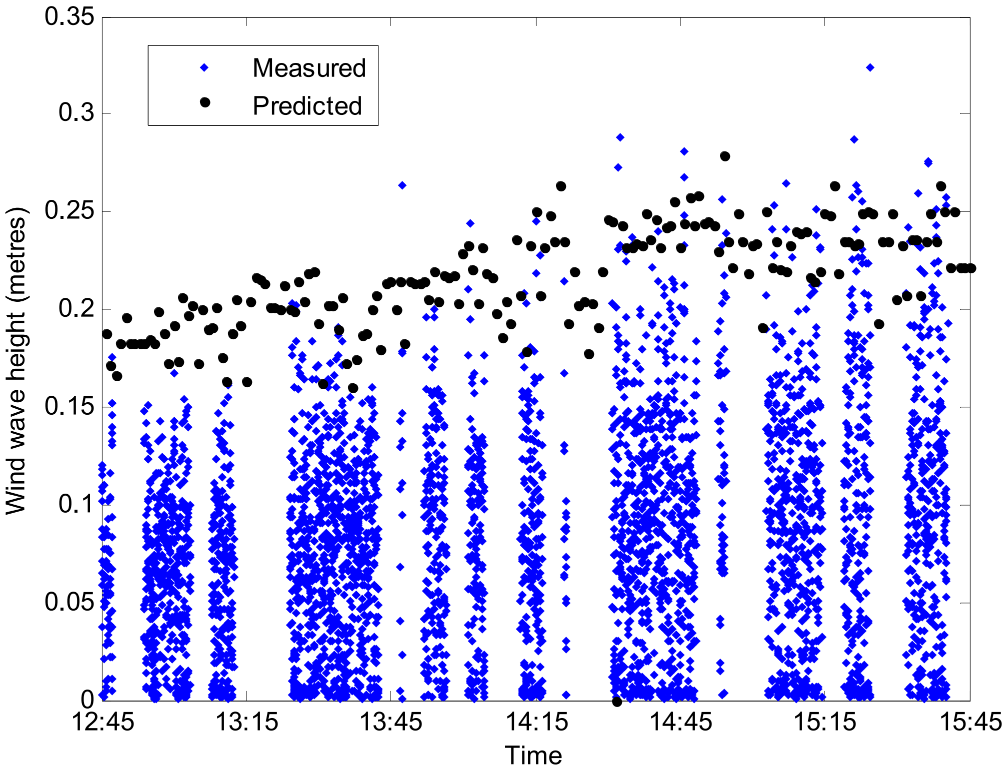

Figure 100: Measured individual wind wave heights, together with wave height predictions, during wind wave trials at Quarry Point on 12th Feb 2010

The increasing wave height during the afternoon, due to increasing wind strength, can be seen.

Measured wind wave heights and periods over 30-minute intervals are shown below.

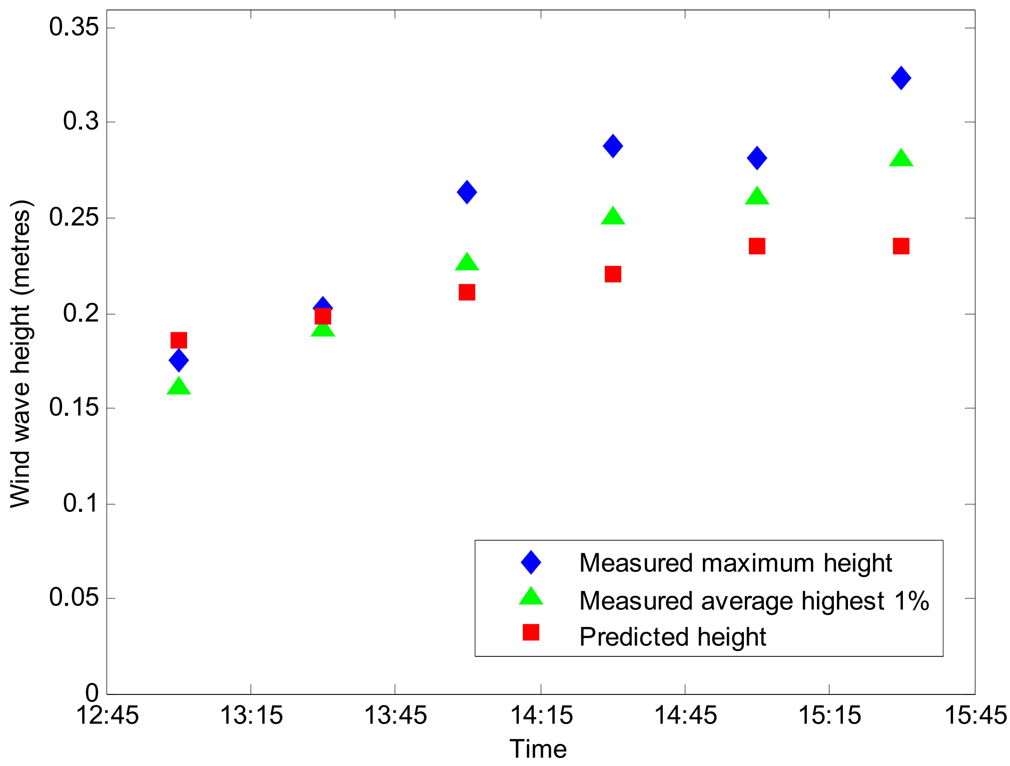

Figure 101: Measured wind wave heights, together with wave height predictions, over 30-minute intervals during wind wave trials at Quarry Point on 12th Feb 2010

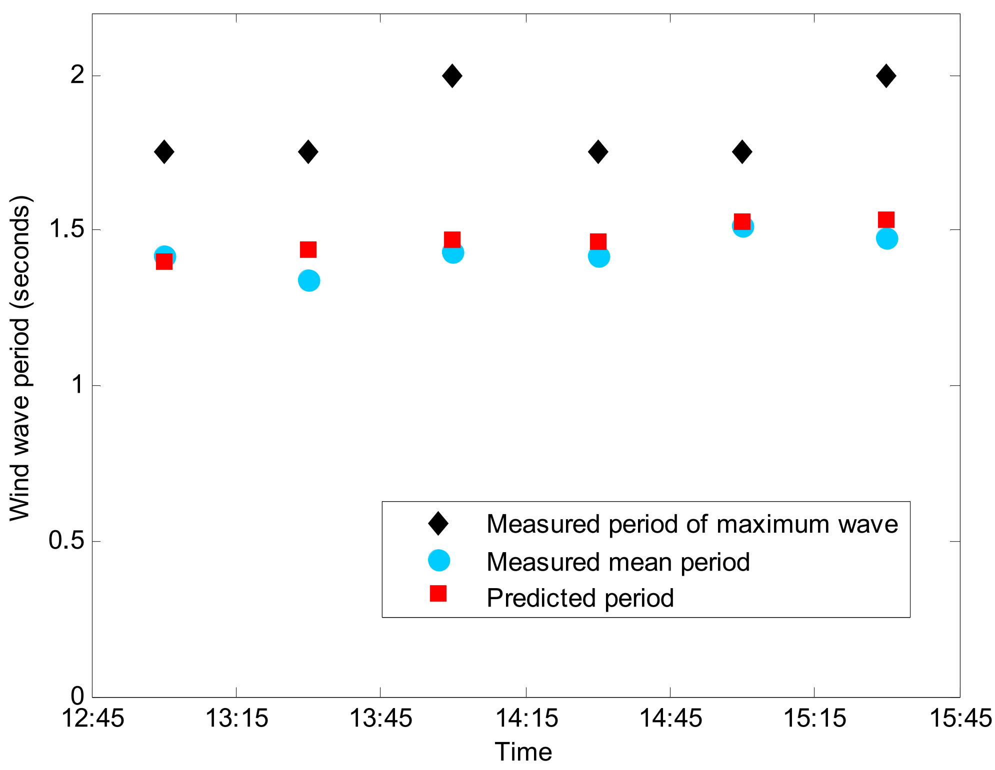

Figure 102: Measured wind wave periods, together with wave period predictions, over 30-minute intervals during wind wave trials at Quarry Point on 12th Feb 2010

We see that the predicted wave heights correspond quite well with the average 1% highest waves, but the maximum measured wave heights are an average of 18% higher than those predicted.

The predicted wave periods correspond very closely with the mean wave period, but the period of the maximum wave is an average of 25% higher than those predicted.

Therefore the USACERC1977 formula gives a very accurate estimate of the “average” wave quantities, but we are most interested in the extreme values, that is the height and period of the maximum wave, as this is what is being compared between the boat waves and wind waves. Therefore the wind wave height predictions used for maximum wave comparisons should be increased by 18%, and the wave period predictions increased by 25%, in order to draw a fair comparison between maximum wind waves and boat waves in this report. This has been done in all of the Quarry Point comparisons shown in this report.

When the height and period of the maximum wave are used to calculate wave power, the results are shown below.

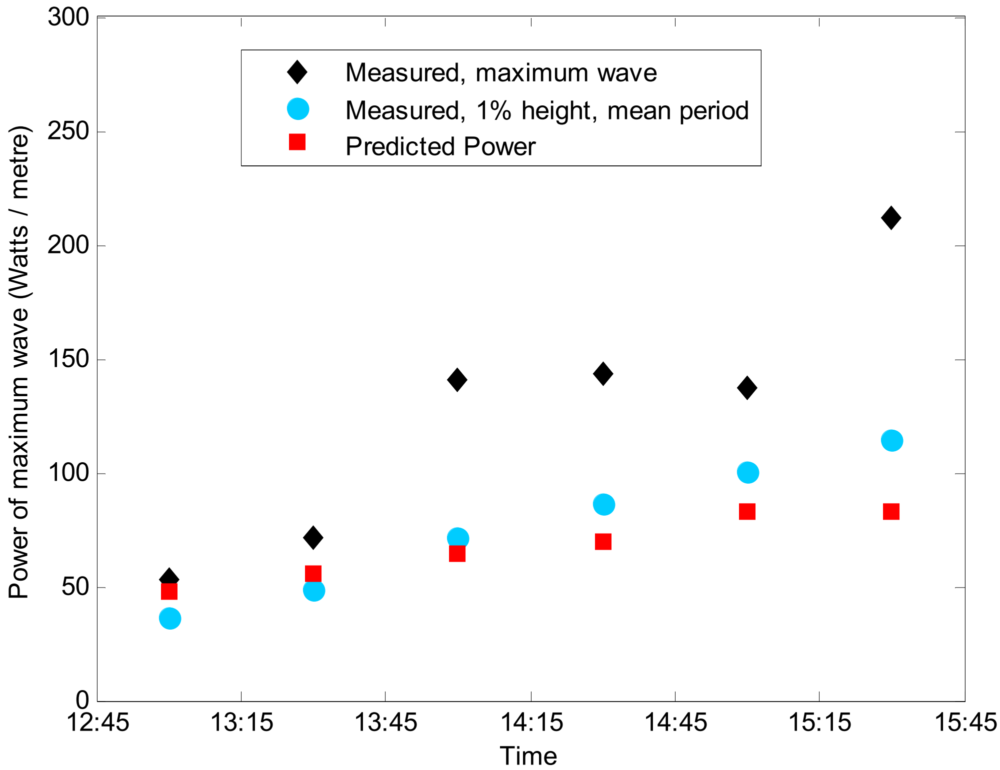

Figure 103: Measured energy of maximum wind waves, together with predictions, over 30-minute intervals during wind wave trials at Quarry Point on 12th Feb 2010

Again, the USACERC 1977 method gives a good estimate of representative wave power (in this case based on the average highest 1% of wave heights, and mean wave period). However the power of the maximum wave is an average of 80% higher than the predicted value. Therefore the Quarry Point wind wave energy predictions used in this report have been increased by 80% over the USACERC formulae, in order to draw a fair comparison between maximum wind waves and boat waves.

When the height and period of the maximum wave are used to calculate energy per wavelength, the results are shown below.

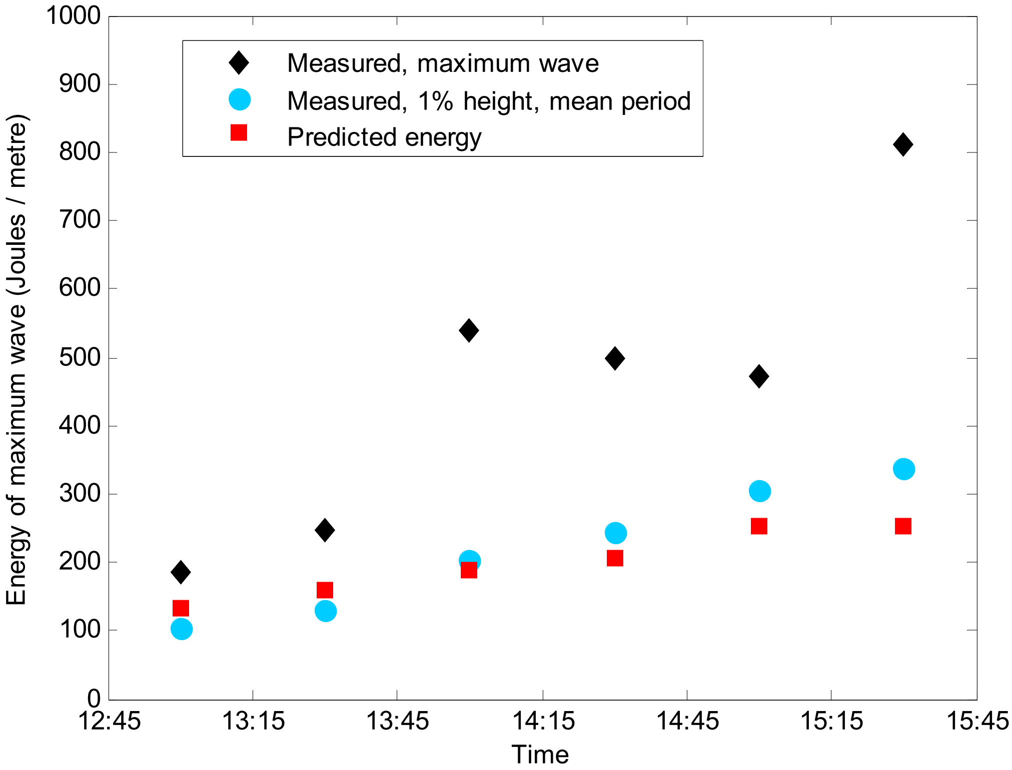

Figure 104: Measured energy of maximum wind waves, together with predictions, over 30-minute intervals during wind wave trials at Quarry Point on 12th Feb 2010

The USACERC 1977 method gives a good estimate of representative wave energy (in this case based on the average highest 1% of wave heights, and mean wave period). However the energy of the maximum wave is an average of 120% higher than the predicted value. Therefore the Quarry Point wind wave energy predictions used in this report have been increased by 120% over the USACERC formulae, in order to draw a fair comparison between maximum wind waves and boat waves.

7.5 Cumulative wind wave energy for all trials

The method for determining cumulative (total) wave energy is described in Appendix A. Total wave energies are divided by the total measuring time to give the total wave energy per hour. For wind wave measurements, only the time with no passing boats is included, as described in Sections 7.1 – 7.4.

The cumulative wave energy for all wind wave trials is shown below, and compared to the cumulative wave energy for boat wake trials described in Section 6.2.

Trial and date	Measured cumulative (total) wave energy per hour, per metre of wave front
Wind waves, Ashfield Parade 2nd Feb	0.05 kJ/m
Wind waves, Ashfield Parade 3rd Feb	0.02 kJ/m
Wind waves, Quarry Point 11th Feb	3.0 kJ/m
Wind waves, Quarry Point 12th Feb	35 kJ/m
Boat wakes, Quarry Point 31st Jan	57 kJ/m
Boat wakes, Chidley Point 13th Feb	70 kJ/m
Boat wakes, Goodwood Parade 14th Feb	29 kJ/m

Table 17: Cumulative wave energy for all wind wave trials. Cumulative boat wake energy (from Section 6.2) also shown for comparison

The table above gives a comparison between measured cumulative wind wave energy and boat wake energy at various locations. For example, we see that the total wave energy produced at Quarry Point by the 20 – 25 knot sea breeze on 12th February was much less than the total wave energy produced by normal vessel traffic (with very light wind) on 31st January. However, when considering shoreline erosion there is likely to be a threshold value of “energy per wave” (depending on the properties of the shoreline) above which erosion accelerates. Therefore for any area with regular boat traffic, maximum energy per wave is seen as a better measure of erosion likelihood, as discussed in the initial report (AMC – CMST 2009). Maximum energy per wave has been compared between wind waves and boat waves in Sections 3 & 4.

8 EFFECT OF WATER DEPTH ON RESULTS

The boat wake predictions made in the initial report (AMC-CMST 2009) were based on model test data from deep water, as deep-water model test data are more readily available and cover a wide range of hull shapes. In addition, shallow water data are usually for constant depth, so are difficult to apply to real waterways with complicated bathymetry.

In some cases, water depth can have an important effect on the boat wakes generated, so these cases will now be discussed.

8.1 Waves produced in shallow water

Waves produced in moderately shallow water (even of constant depth) will be slightly different to those produced in deep water at low speeds. However, there is a certain speed in shallow water (called the “critical speed”) at which the wave pattern will be very different to what it would it would be in deep water. The critical speed is discussed in the initial report (AMC-CMST 2009).

For non-uniform depth, the relevant depth and hence the critical speed are more difficult to define. However using a representative depth of 2 – 2.5m for Ashfield Parade gives a critical speed of 8.5 – 9.5 knots. Therefore the measured waves for boats travelling at close to this speed will be larger than in deep water. The effect is especially important for larger vessels.

For Quarry Point, with a representative water depth of around 4 – 5m, the critical speed is around 12 – 14 knots. Therefore the measured waves for boats travelling in this speed range will be larger than in deep water. Again, the effect is most important for larger vessels.

At supercritical (higher than critical) speeds in shallow water, the wave pattern will be moderately different to what it would be in deep water, as discussed in the initial report (AMC-CMST 2009).

8.2 Waves moving into shallower water

As individual wave components move into shallower water, their period remains constant. The measured periods of wave trains produced by boats should also not change appreciably.

The wave power produced by each wave component also remains constant as the wave moves into shallower water, neglecting friction with the seabed. Wave power depends on the wave height and group velocity (see Appendix A). As the group velocity changes, so will the wave height.

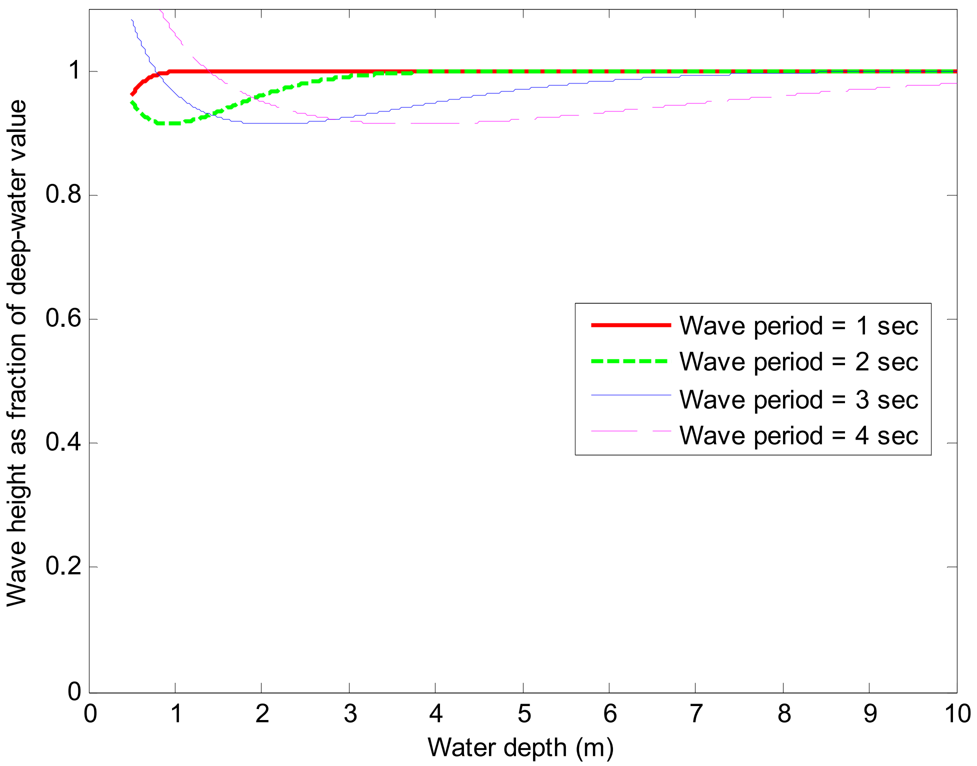

Figure 105: Changing wave height as a linear wave moves into shallower water

An example calculation of the changing height of a linear wave as it moves into shallow water is shown above, as compared to its value in deep water (USACERC 1977 p2-28). When the wave reaches a water depth of around twice its height, nonlinear effects take over and the wave height generally increases before wave breaking occurs. For the dedicated trials and wind wave measurements described here, the water depth at Ashfield Parade was around 2 – 2.5m on the sailing line, down to 1.7 – 1.9m at the waverecorder. At Quarry Point it was around 4 – 5m on the sailing line, down to 2.5 – 2.7m at the waverecorder. We see from the Figure above that for waves moving between these depths, the expected change in wave height due to shoaling water is in the order of a few percent for the wave periods encountered at each site.

8.3 Relationship of wave power and energy to wave height and period

The initial report (AMC-CMST 2009) used deep-water equations to relate wave power and energy to wave height and period. In this report, we have used shallow-water equations for wave power and energy. As described above, wave height, period and power should be comparable between deep and shallow water at low speeds. Note however that wavelengths change appreciably between deep and shallow water for longer-period waves, so the energy per wavelength will not be comparable for longer-period waves (e.g. greater than 4 seconds).

An example plot showing the effect of water depth on energy per wavelength is shown below.

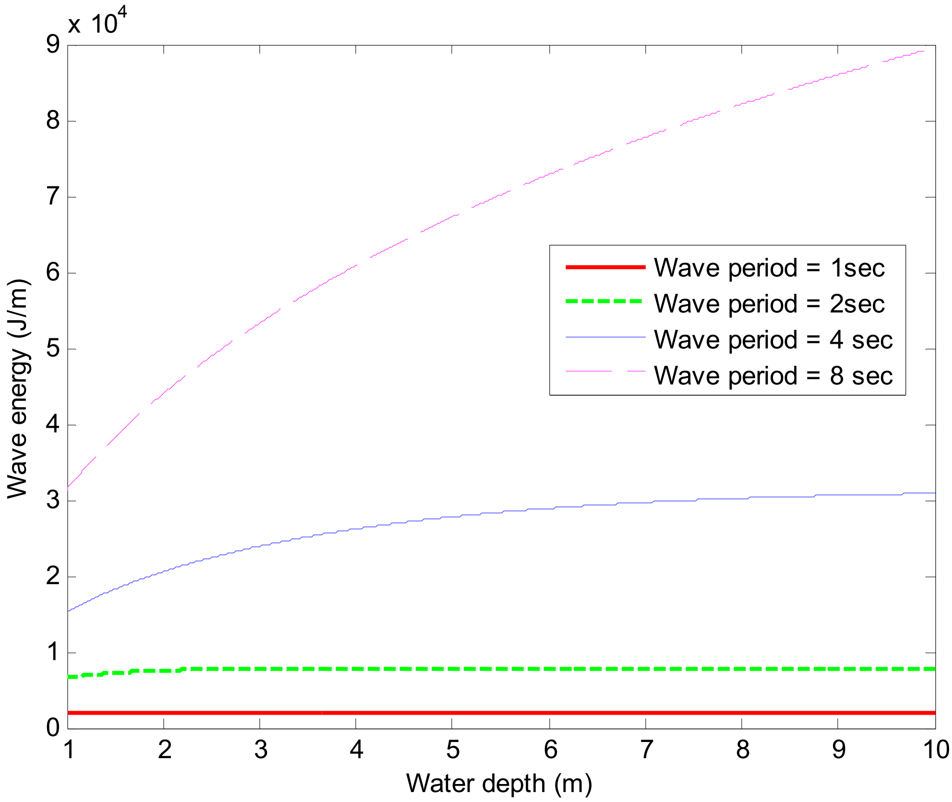

Figure 106: Effect of water depth on energy per wavelength, for different wave periods. Based on linear wave height = 1.0m.

9 CONCLUSIONS

9.1 Dedicated trials at Ashfield Parade

- All vessels tested produced similar wave heights to the extreme wind waves, but longer wave periods than the extreme wind waves
- The Quintrex 470 and 570 produced their highest-energy wake at 7 – 8 knots
- The Haines Hunter Patriot 680 and Bayliner 275 produced their highest-energy wake at 8 – 9 knots
- The “hump speed” at which each boat produces its highest-energy wake, increased with the hull length
- The maximum wave energy produced increased with the hull displacement. The largest waves produced by the Bayliner 275 at close approach had almost 20 times the energy of the extreme wind waves.
- Peak wave energy produced at hump speed was generally 30 – 40% lower at distant approach than at close approach
- At 12 knots, wave energy was similar for close approach and distant approach, as the wave pattern is mainly diverging waves which attenuate slowly
- The recreational vessels tested, as well as the River Lady, produced much higher wave energy than the predicted extreme wind waves at the current speed limit of 8 knots, at close approach and distant approach
- At 12 knots, the Haines Hunter Patriot 680 and Bayliner 275 produced higher-energy waves than the extreme wind waves, while the Quintrex 470 and 570 produced higher-energy waves than the 1% exceedence wind waves
- At 5 knots, all vessels produced much lower-energy waves than the extreme wind waves, and generally less than the 1% exceedence wind waves
- Measured wave heights and periods corresponded well with deep-water predictions (AMC – CMST 2009) for the Haines Hunter Patriot 680
- Measured wave heights corresponded well with deep-water predictions (AMC – CMST 2009) for the River Lady, but measured periods were slightly longer than predicted. Having a large waterline length, the River Lady is more affected by shallow water.

9.2 Dedicated trials at Quarry Point

- The LeisureCat Mako 9000 and Haines Hunter Patriot 680 produced wave heights that were comparable to the 1% exceedence wind waves, and periods that were comparable to the extreme wind waves
- The Riviera Offshore Express 48 and Star Flyte Express produced wave heights that were comparable to the extreme wind waves, and much longer wave periods than the extreme wind waves

- The Haines Hunter Patriot 680 produced its peak wave energy at 8 knots, as at Ashfield Parade. The LeisureCat Mako 9000 produced its peak wave energy at 10 – 12 knots. The larger hump speed is due to the larger waterline length.
- At 15 – 20 knots, the Haines Hunter Patriot 680 and LeisureCat Mako 9000 both produced similar wave energy, despite the LeisureCat having a larger displacement. This highlights the generally lower wave-making of catamarans as compared to monohulls.
- At close approach, the Riviera Offshore Express 48 produced the highest wave energy of all vessels tested, which was around 6 times the predicted extreme wind wave energy at a speed of 10 knots
- At distant approach, the Star Flyte Express produced the highest wave energy of all vessels tested, which was around 10 times the predicted extreme wind wave energy at a speed of 12 knots. This was a special shallow-water effect, with the vessel travelling at the critical speed.
- The Haines Hunter Patriot 680 measured results agreed well with the deep-water predictions from (AMC – CMST 2009)
- The Star Flyte Express had quite different results to the deep-water predictions, with shallow-water effects being crucial due to her large (shiplength / depth) ratio. This effect was most noticeable at the critical speed of 12 – 14 knots

9.3 Dedicated trials at Ellam St

- The SRT Noel Robins produced her highest-energy wake at around 8 knots
- The SRT Noel Robins produced slightly smaller peak wave energy than the Haines Hunter Patriot 680 and LeisureCat Mako 9000 at similar transverse distances

9.4 Total wave wake measurements during normal traffic

- At Quarry Point and Chidley Point, the boats producing the largest wave energy were high-displacement recreational vessels
- Chidley Point had the largest wave energy produced by an individual vessel, and the largest cumulative boat wake energy despite having the smallest number of passing boats. This was due to the generally large size and high speed of passing recreational vessels at Chidley Point.
- Goodwood Parade waterski area, despite having over 400 passing boats during the 4-hour period, had around half the cumulative boat wake energy of Quarry Point and Chidley Point

9.5 Wind wave measurements

- At Ashfield Parade, all wind wave measurements were tiny, being less than 0.020m
- Ashfield Parade is very protected; the first day of measurements saw winds of 25 – 35 knots measured at Melville Water, but quite calm conditions at Ashfield Parade

- Winds were generally offshore at the measurement site, making wave heights small and comparison with predictions difficult. During the time the wind was onshore (which produces the largest waves), measured wind waves were smaller and shorter period than those predicted. This is most likely due to the wind being much lighter and more erratic than at Melville Water
- There was not enough data to recommend changes to the prediction method at Ashfield Parade, but it seems likely that the prediction method used overestimates the wind wave heights and periods at Ashfield Parade, due to using Melville Water wind data
- Quarry Point is a much more exposed location, and a 20 – 25 knot sea breeze on one of the measurement days offered ideal conditions for validating the wind wave prediction method used in (AMC – CMST 2009)
- The wind wave prediction method was seen to give a good estimate of the average of the highest 1% of wave heights, and the mean wave period
- The height and period of the maximum wave were generally larger than the wind wave predictions. Since we wished to compare maximum boat waves with maximum wind waves, the prediction method for Quarry Point needed to be adjusted to more accurately predict maximum waves. This was done, and the resulting method used for all the (boat wave / wind wave) comparisons previously described.
- Although maximum energy per wave is seen as a better measure of shoreline erosion potential (AMC – CMST 2009), cumulative wind wave energy was also compared with cumulative boat wake energy. It was seen for example that the total wave energy produced at Quarry Point by the 20 – 25 knot sea breeze on 12th February was much less than the total wave energy produced by normal vessel traffic (with very light wind) on 31st January.

10 REFERENCES

Australian Maritime College and Centre for Marine Science and Technology 2009 Investigation into the effect of wash of boats and wind waves on the Swan River. AMC report 09/G/17.

Guo, J. 2002 Simple and explicit solution of wave dispersion equation. Coastal Engineering 45, 71–74.

U.S. Army Coastal Engineering Research Centre 1977 Shore Protection Manual.

APPENDIX A: CONVERTING MEASURED PRESSURE TO WAVE ELEVATIONS

For the wave types encountered during these experiments (wave height $H = 0.1 - 0.8\mathrm{m}$, wave period $T = 1.5 - 6.0\mathrm{s}$, water depth $h = 2.0 - 4.0\mathrm{m}$), the most applicable wave theory (following the Méhauté chart, USACERC 1977 p2-35) is linear Airy theory. Therefore the pressure is related to the wave elevation (USACERC 1977 p2-22) through

$$\frac{p}{\rho g} = h_w + z\left[\frac{\cosh\left(k(h-h_w)\right)}{\cosh(kh)}\right] \tag{1}$$

The waverecorder submergence h_w (which changes with the changing tide height) is found from the moving average of $p/\rho g$. Oscillations on top of this are essentially the wave elevation *z*, since the quantity in square brackets is close to 1 when the waverecorder submergence is small. However the exact value is calculated by first finding the wave number *k* from the measured period *T* of each wave, through the dispersion relation (Guo 2002)

$$\begin{aligned} \sigma &= \frac{2\pi}{T} \\ k &= \frac{\sigma^2}{g}\left(1 - e^{-\left(\sigma\sqrt{h/g}\right)^{5/2}}\right)^{-2/5} \end{aligned} \tag{2}$$

This also allows us to find the wavelength *λ* of each passing wave, through

$$\lambda = \frac{2\pi}{k} \tag{3}$$

The wave elevation *z* is then found by rearranging equation (1) to give

$$z = \frac{\frac{p}{\rho g} - h_w}{\left[\frac{\cosh\left(k(h-h_w)\right)}{\cosh(kh)}\right]} \tag{4}$$

In this report and the previous report (AMC-CMST 2009), wave heights *H* are defined as the elevation difference between each adjacent peak and trough, while wave periods *T* are defined as twice the time difference between each adjacent peak and trough.

Wave energy density (per square metre of water surface) is calculated using the following formula (USACERC 1977 p2-27)

$$\overline{E} = \frac{\rho g H^2}{8} \tag{5}$$

The wave energy density can be multiplied by the wavelength λ to obtain the energy E in each wavelength (per unit width of wave crest)

$$E = \frac{\rho g H^2 \lambda}{8} \tag{6}$$

Wave power is the rate at which wave energy is transmitted in the direction of wave propagation. The average wave power per unit width of wave crest is (USACERC 1977 p2-28)

$$\overline{P} = \overline{E} c_g \tag{7}$$

c_g is the group velocity, which is given (USACERC 1977 p2-25) by

$$c_g = \frac{\lambda}{2T}\left[1 + \frac{2kd}{\sinh 2kd}\right] \tag{8}$$

Note that the total wave power is used in this report, to avoid errors in defining the direction of wave propagation. This differs from the method used for wind waves in the initial report (AMC – CMST 2009), which used the wave power component perpendicular to the shoreline.

The cumulative energy received at a certain site (per unit width of wave crest) is the integral of the wave power with time, i.e.

$$E_c = \int \overline{P}\, dt \tag{9}$$

APPENDIX B: ERROR ANALYSIS

Wave elevations

Expected RMS error for the measured wave elevations is shown below.

Quantity	Value	Source
Pressure changes maximum likely error	0.3%	Unispan PT2X product specification; checked by pressure sensor calibration performed on 30-11-2009
Pressure resolution	7Pa	Unispan PT2X product specification; checked by output analysis
Resolution error in wave elevations	0.7mm	Pressure resolution / (ρg)
River water density	1025 ± 5 kg/m^3	Estimate
Error in wave elevations due to density uncertainty	0.5% of wave elevation	Based on 0.5% density uncertainty
Error in water depth at sensor (using mean water depth for calculations)	0.2m	Maximum likely
Error in wave elevations due to error in water depth	2.0% of wave elevation	Checked using sensitivity analysis of equation (4)
Error in sensor submergence due to density uncertainty	3.5mm	Based on typical submergence 0.7m, 0.5% density uncertainty
Error in wave elevations due to sensor submergence uncertainty	1.0% of wave elevation	Checked using sensitivity analysis of equation (4)
Error in specifying wave period for pressure dilution in equation (4)	0.25s	Maximum likely
Error in wave elevations due to error in specifying wave period	1% for 5s wave 2% for 4s wave 4% for 3s wave 14% for 2s wave	Checked using sensitivity analysis of equation (4)
Error in wave elevations due to nonlinearity in wave pressure	Estimate up to 1% of wave elevation for longer-period boat waves ≥3s Estimate up to 2% of wave elevation for shorter-period wind waves ≤2s	Negligible for longer period waves as pressure tends to hydrostatic; pressure dilution included for short period waves (see Appendix A) but allow some error for nonlinearity.
Total RMS (root mean square) error in wave elevations	0.7mm + A% of wave elevation A = 2.7% for 5s wave A = 3.2% for 4s wave A = 5.0% for 3s wave A = 14.3% for 2s wave	RMS of the above errors

Table 18: RMS error for wave elevations

Wave period, power and energy

The wave periods quoted in this report are consistent with those used in the initial report (AMC – CMST 2009) and give the period of the maximum wave. With a time resolution of 0.125s and smooth wave elevation traces, this period can be determined to within 0.125s.

In some cases, there are a number of waves that are close to the maximum, all with varying periods. In this case, a small change in the wave elevation profile can cause a different wave to become the maximum wave, and the quoted period to jump to higher or lower values. This effect then transfers to the quoted wave power (approximately proportional to the wave period) and energy per wavelength (approximately proportional to the period squared).

GPS position and speed

The standard GPS type used has a typical position error of around 10 – 15m (www.kowoma.de/en/gps/errors.htm). This error is normally slowly-varying however, so that relative positions measured over a short time have much better accuracy. Speed error is in the order of 0.1 knot.

APPENDIX C: DEPTH PROFILES

The following depth profiles were generated from raw soundings data provided by the WA Department of Transport.

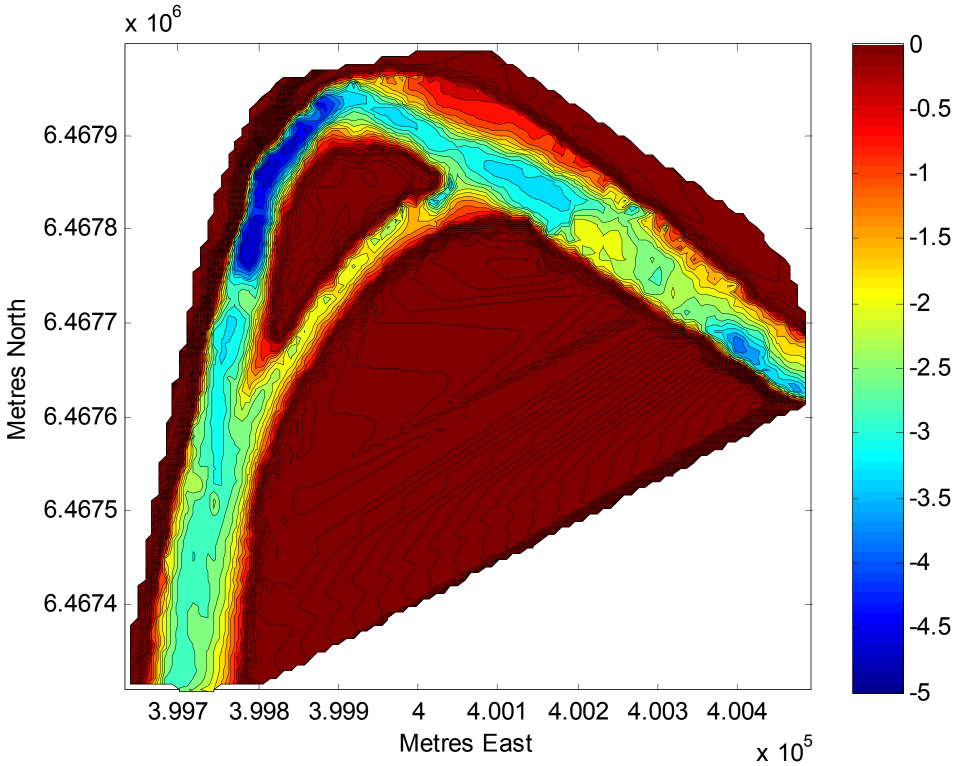

Figure 107: Raw soundings data from 1990, 1998 near Ron Courtney Island. Horizontal datum = GDA94, vertical datum = chart datum Fremantle, 0.76m below AHD.

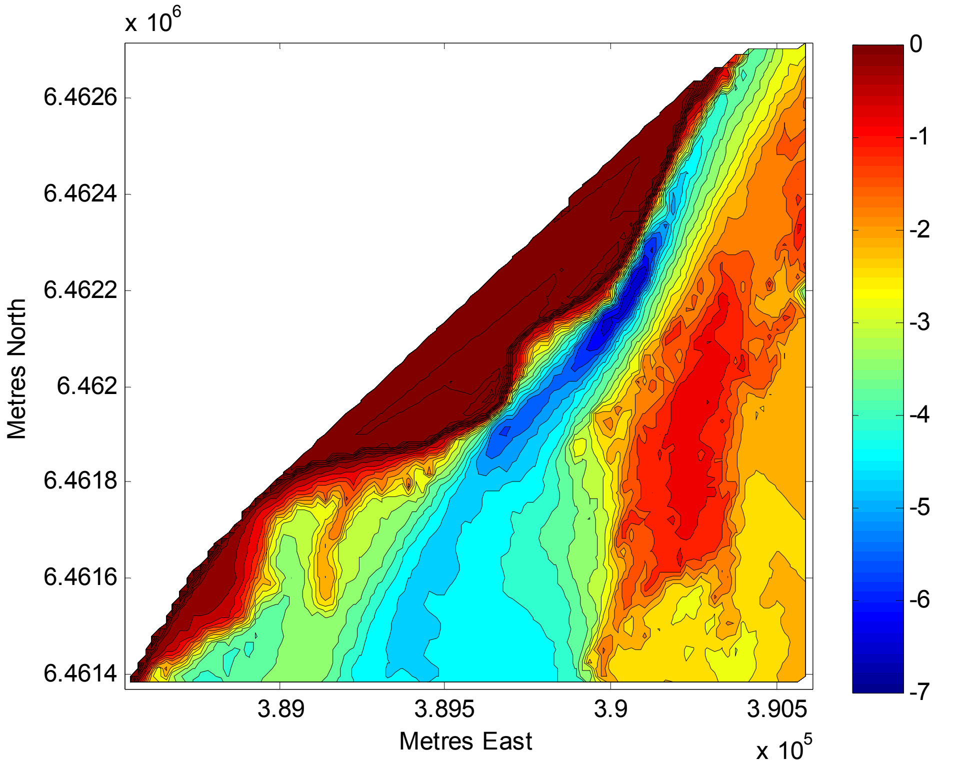

Figure 108: Raw soundings data from 1970 near Quarry Point. Horizontal datum = GDA94, vertical datum = chart datum Fremantle, 0.76m below AHD.