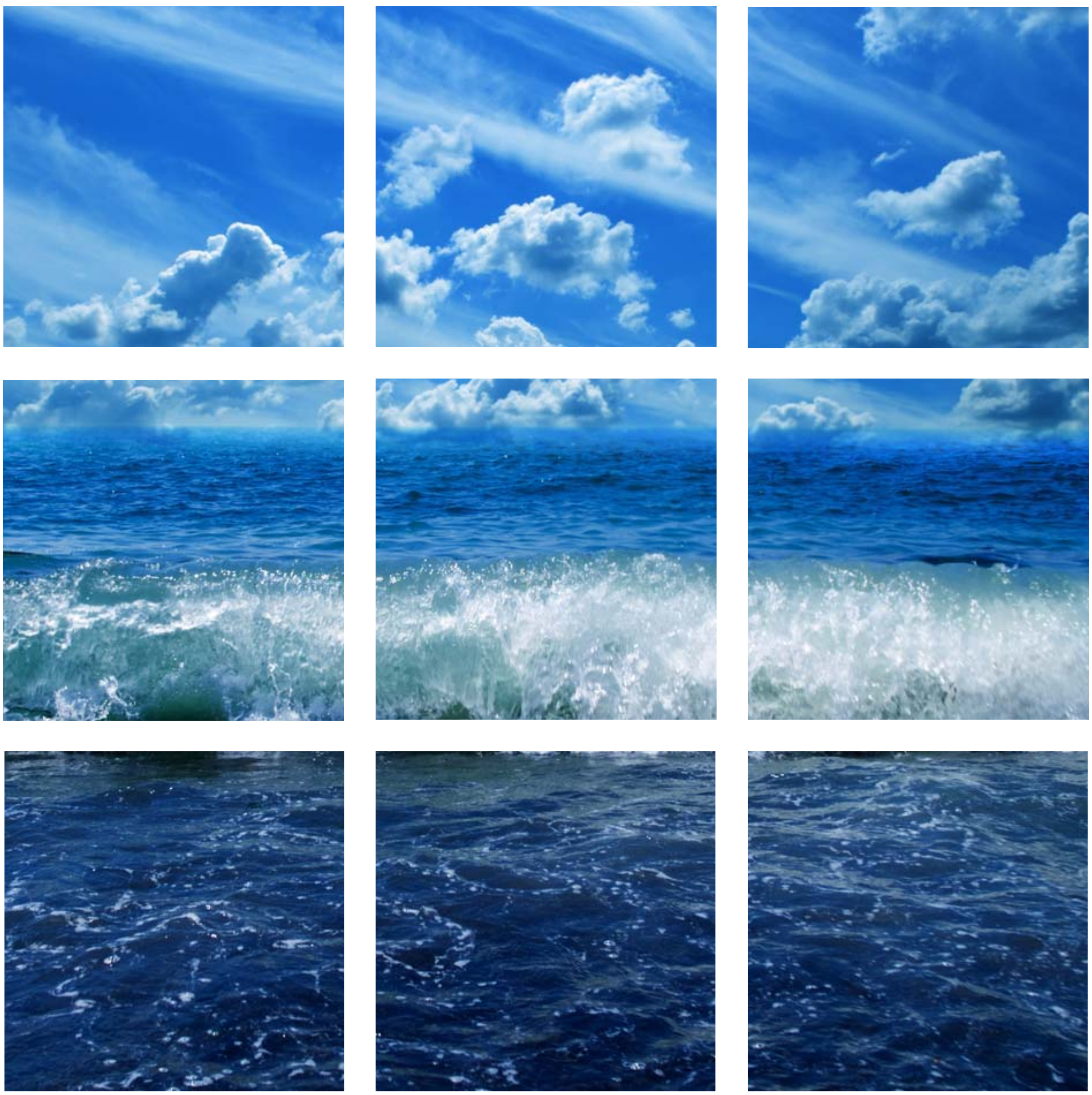
Irish Coastal Protection Strategy Study
Phase 3 - North East Coast

Work Packages 2, 3 & 4A - Technical Report Appendices 1-6, 9

IBE0071/June 2010



Appendices

Appendix 1: Storm Track Figures

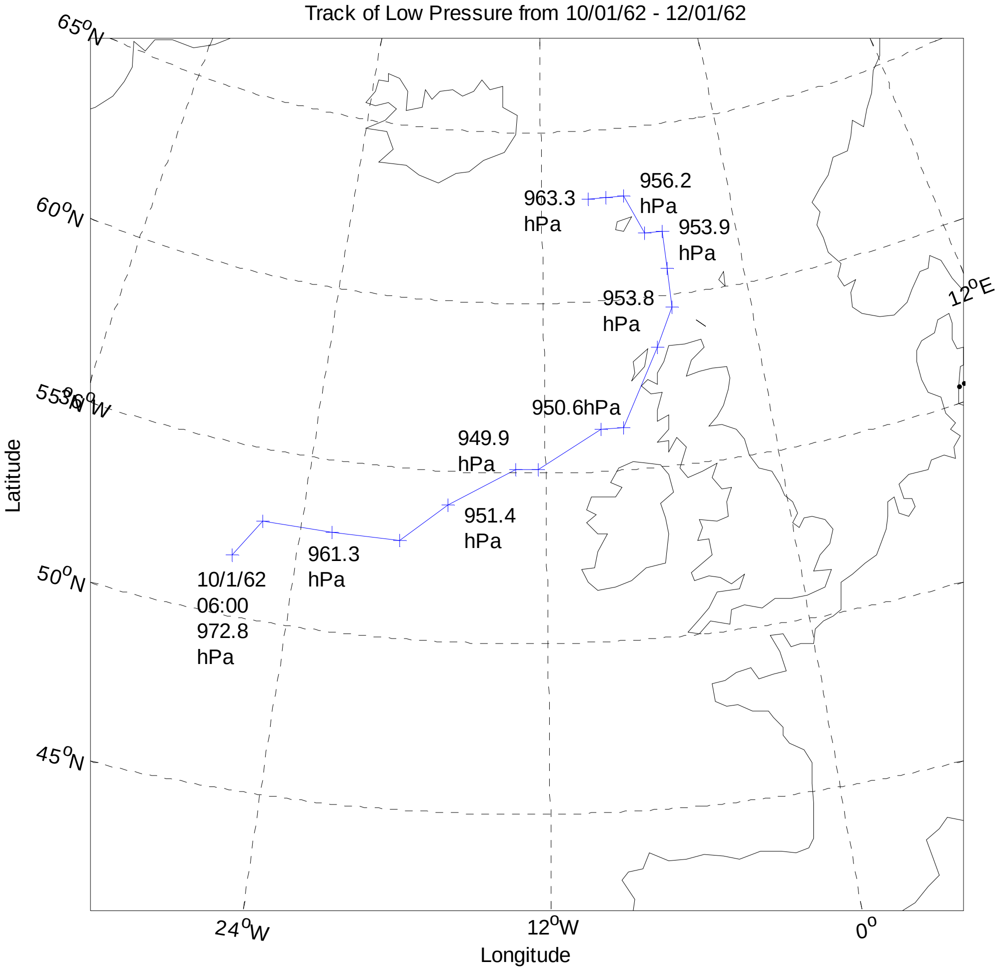


Figure 1: Centre of storm from 10/01/62 - 12/01/62 plotted at 3 hourly intervals, resulting in maximum surge level of 0.764m. in Dublin Bay.

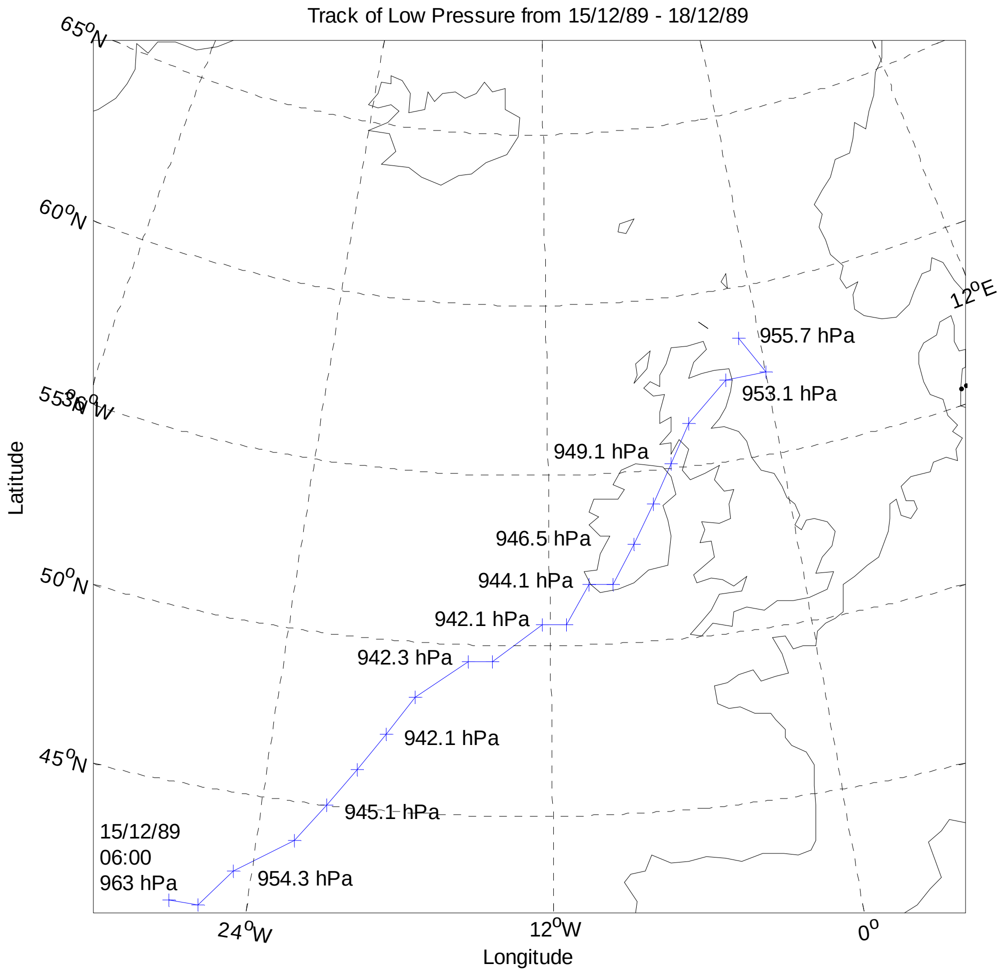


Figure 2: Centre of storm from 15/12/89 - 18/12/89 plotted at 3 hourly intervals, resulting in maximum surge level of 0.937m. in Dublin Bay.

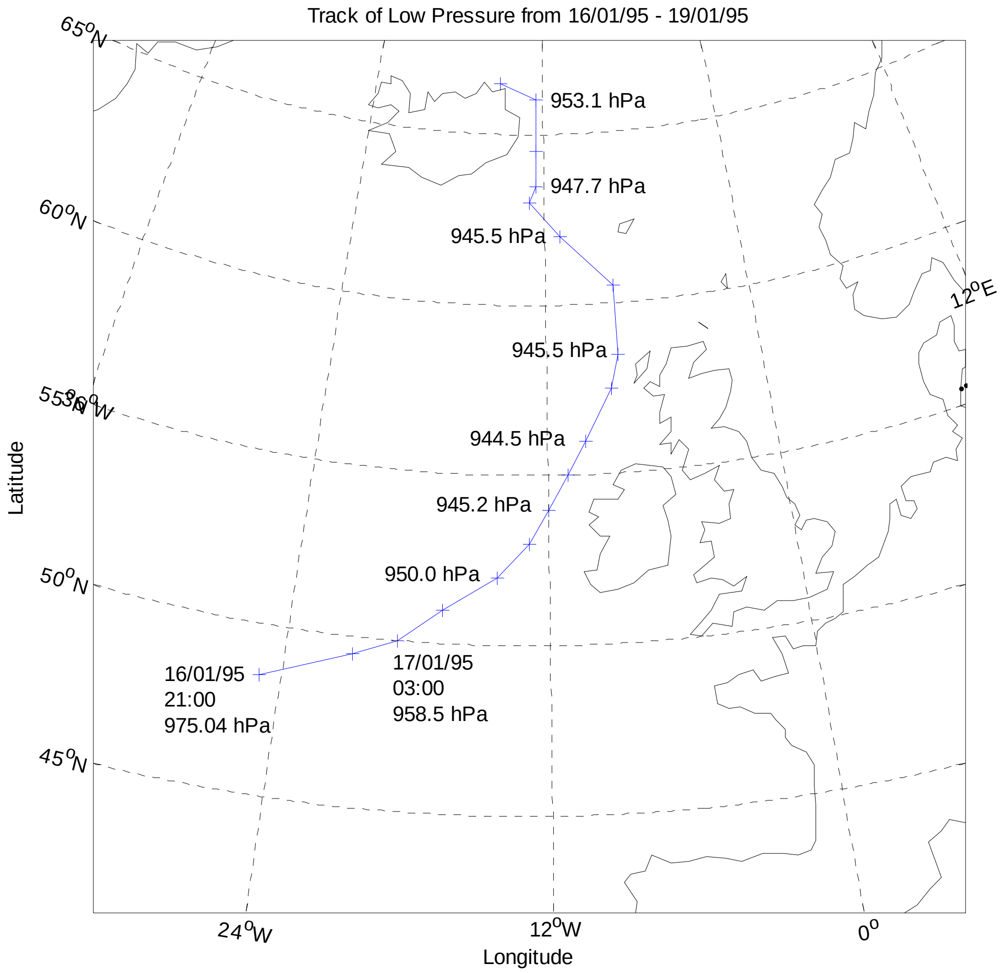


Figure 3: Centre of storm from 16/01/95 - 19/01/95 plotted at 3 hourly intervals, resulting in maximum surge level of 0.752m. in Dublin Bay.

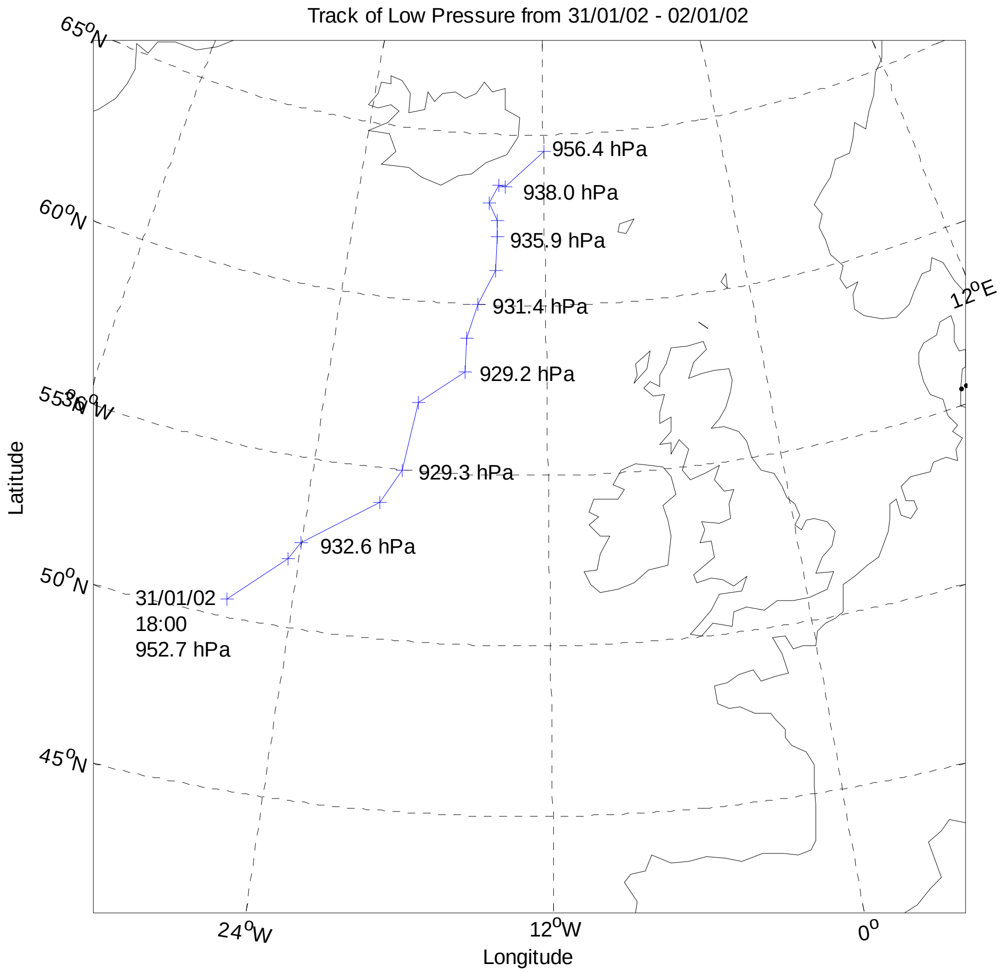
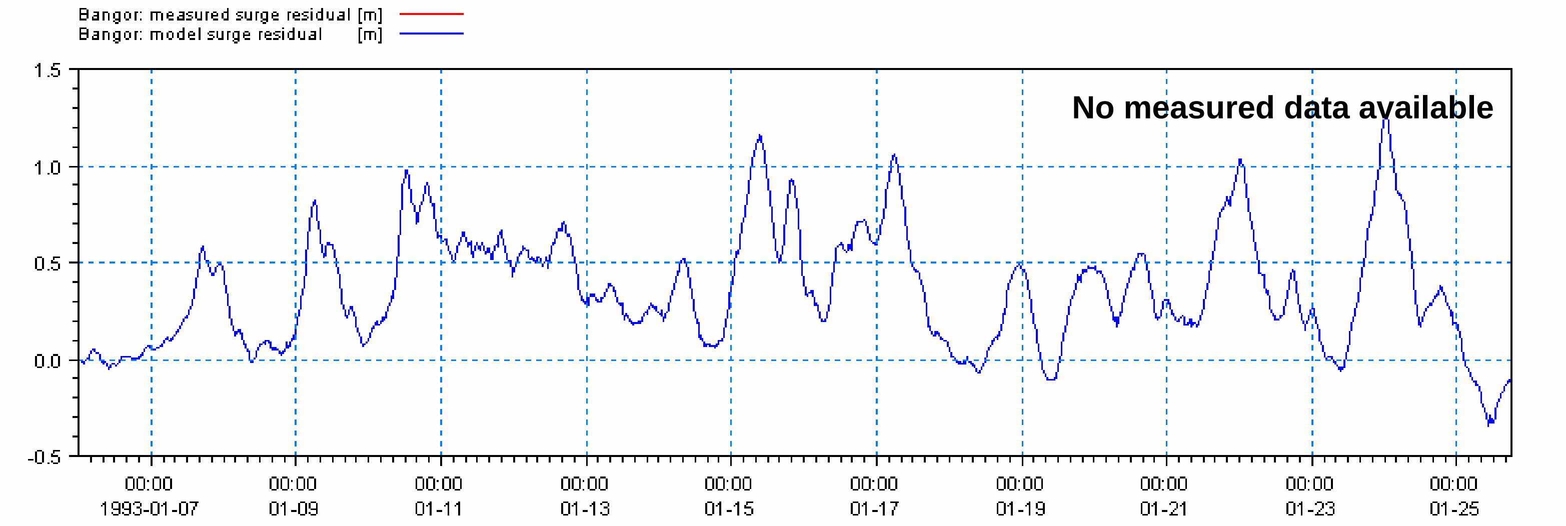
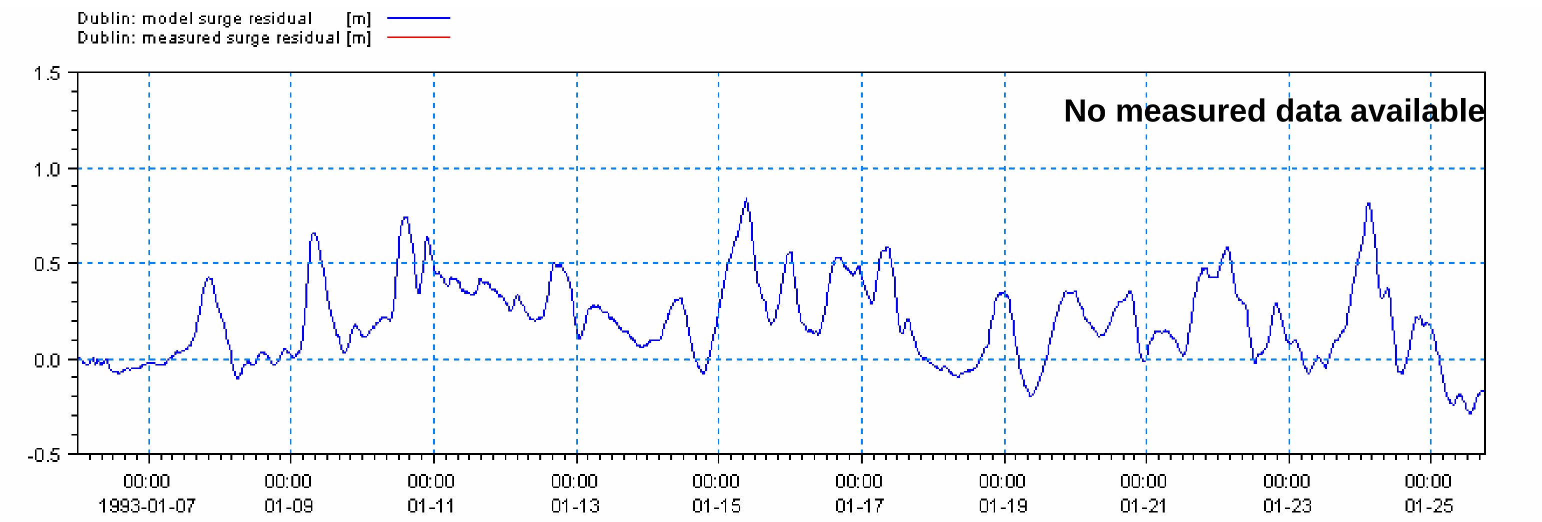


Figure 4 : Centre of storm from 31/01/02 - 02/02/02 plotted at 3 hourly intervals, resulting in maximum surge level of 0.912m. in Dublin Bay.

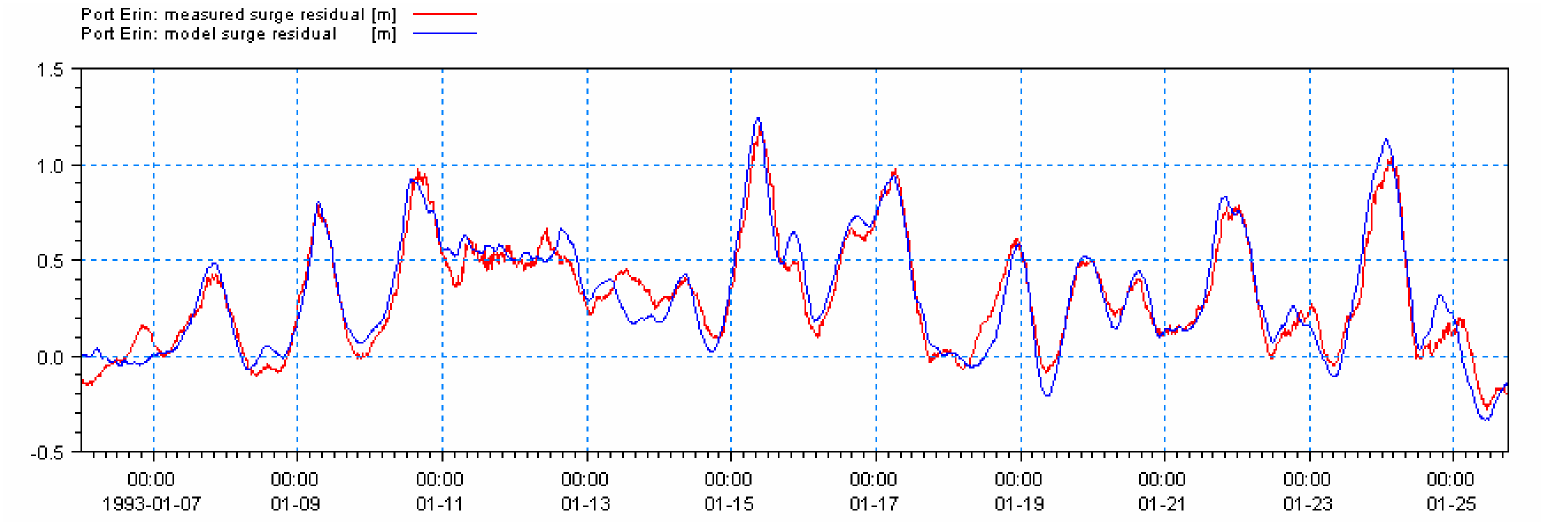
Appendix 2: Validation Figures of Storm Surge Simulation

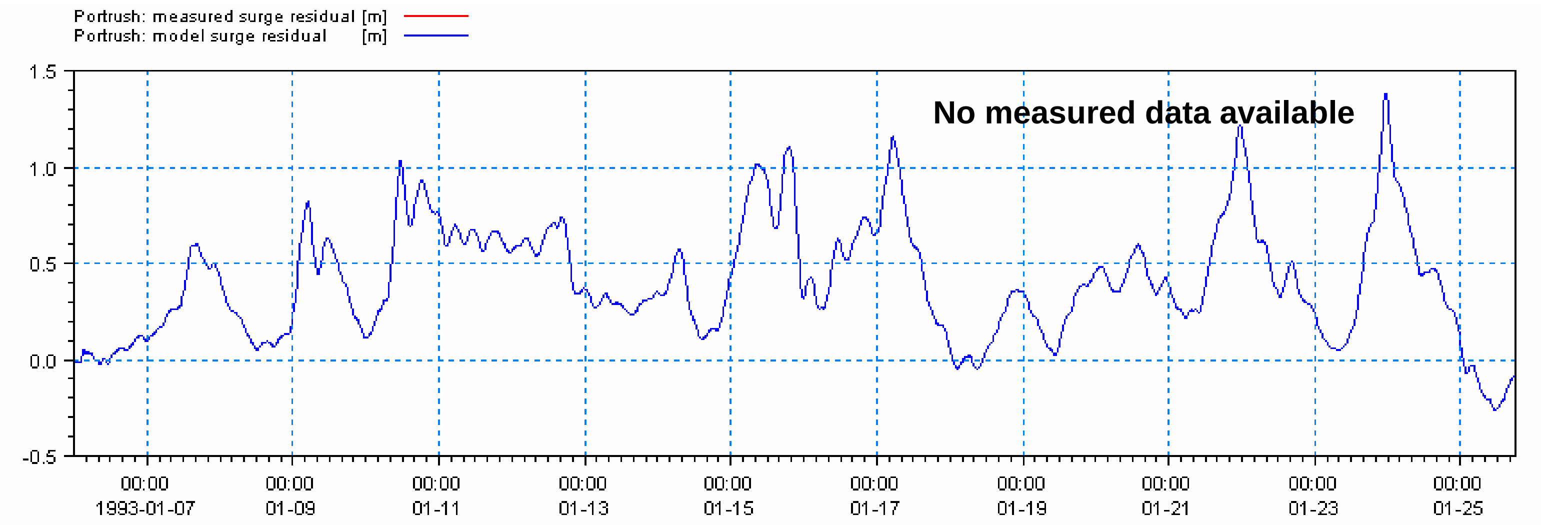
Validation Figures of Storm Surge Simulation: January 1993



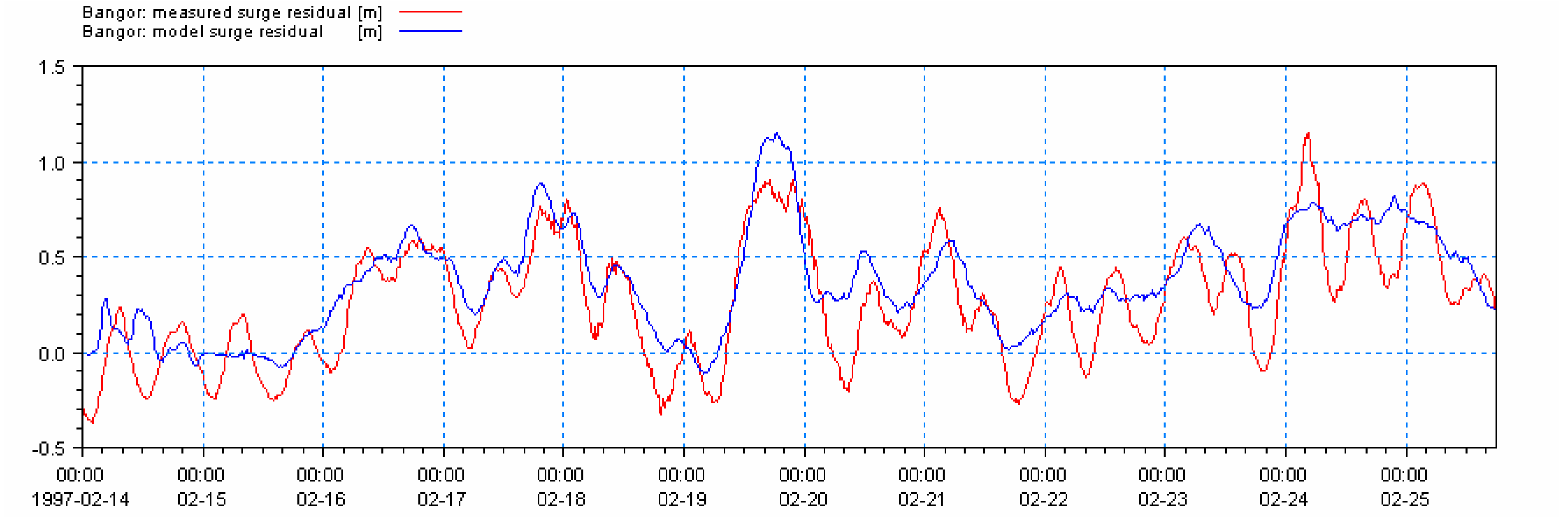


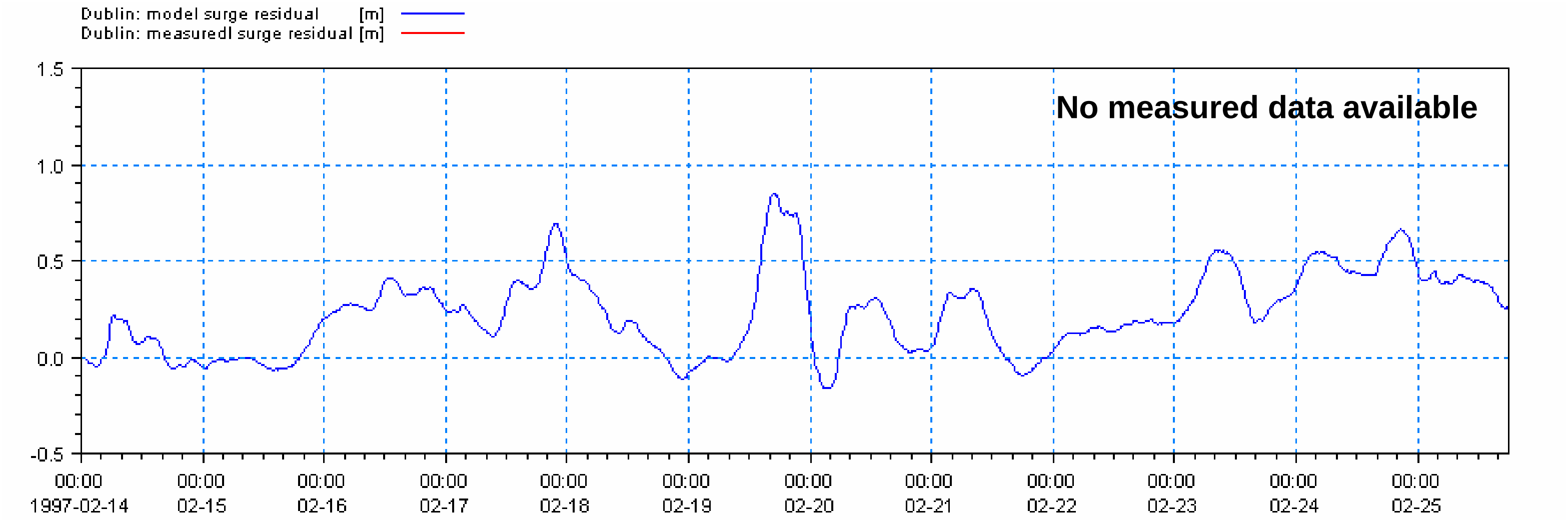
Validation Figures of Storm Surge Simulation: January 1993



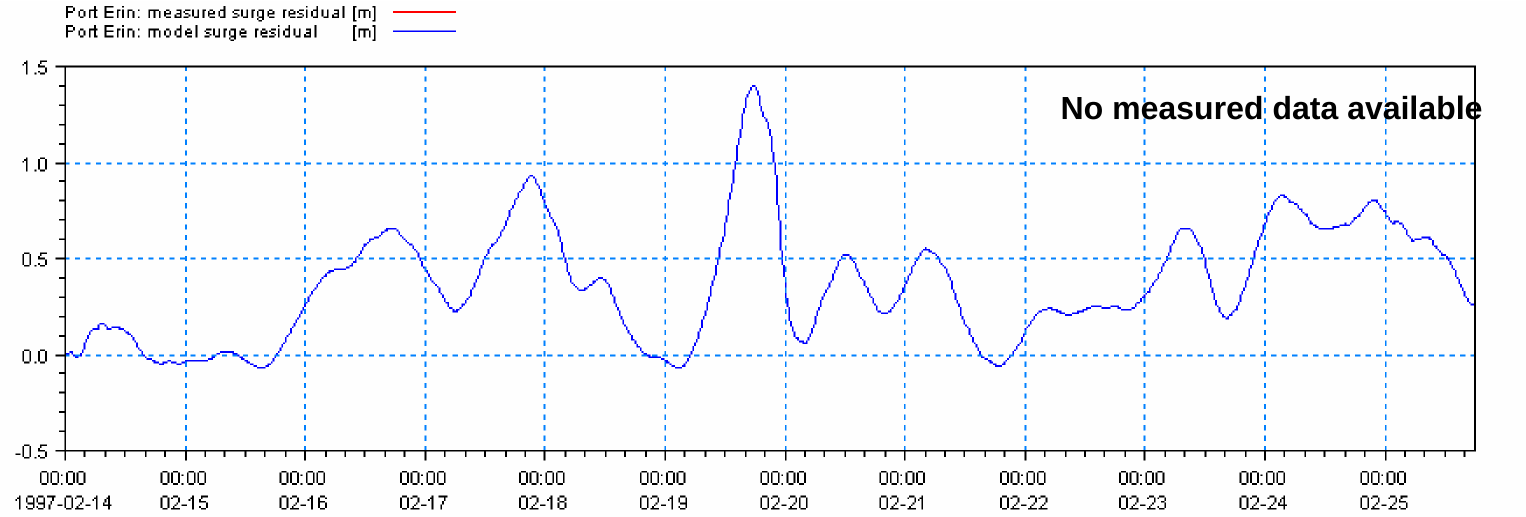


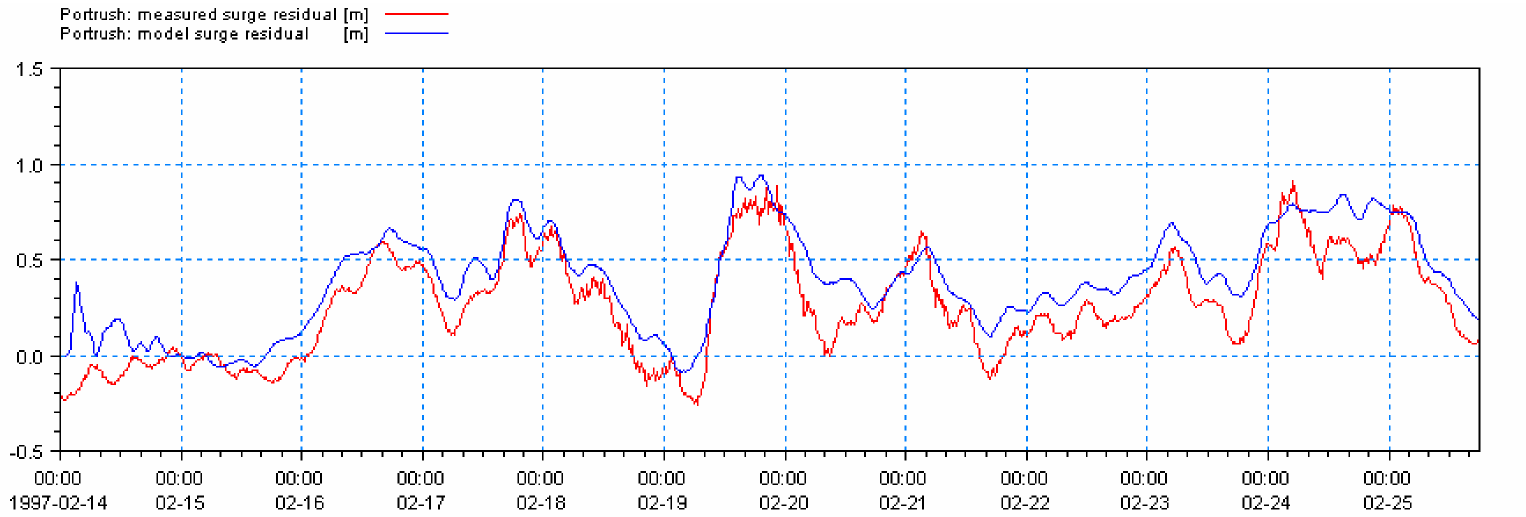
Validation Figures of Storm Surge Simulation: February 1997



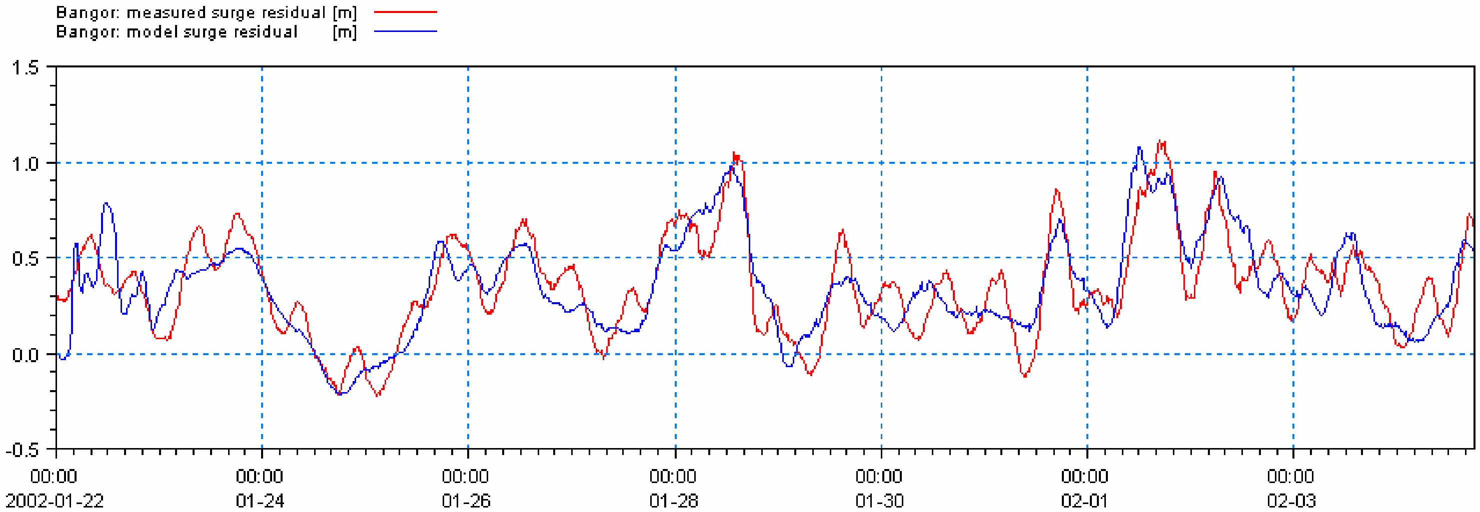


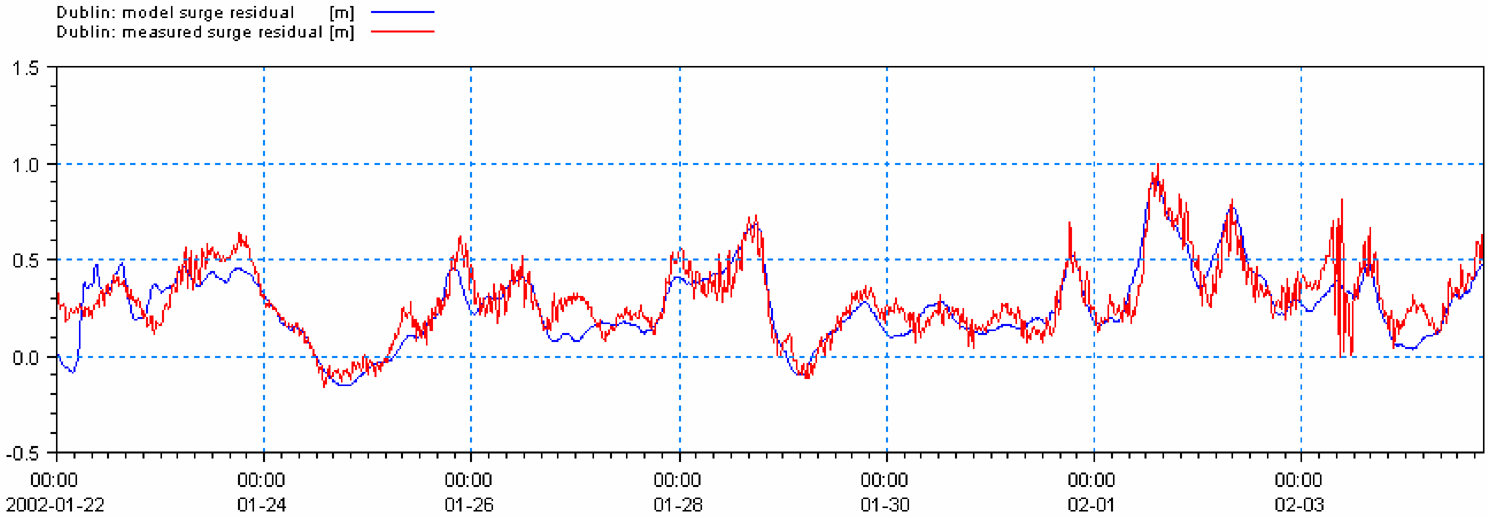
Validation Figures of Storm Surge Simulation: February 1997



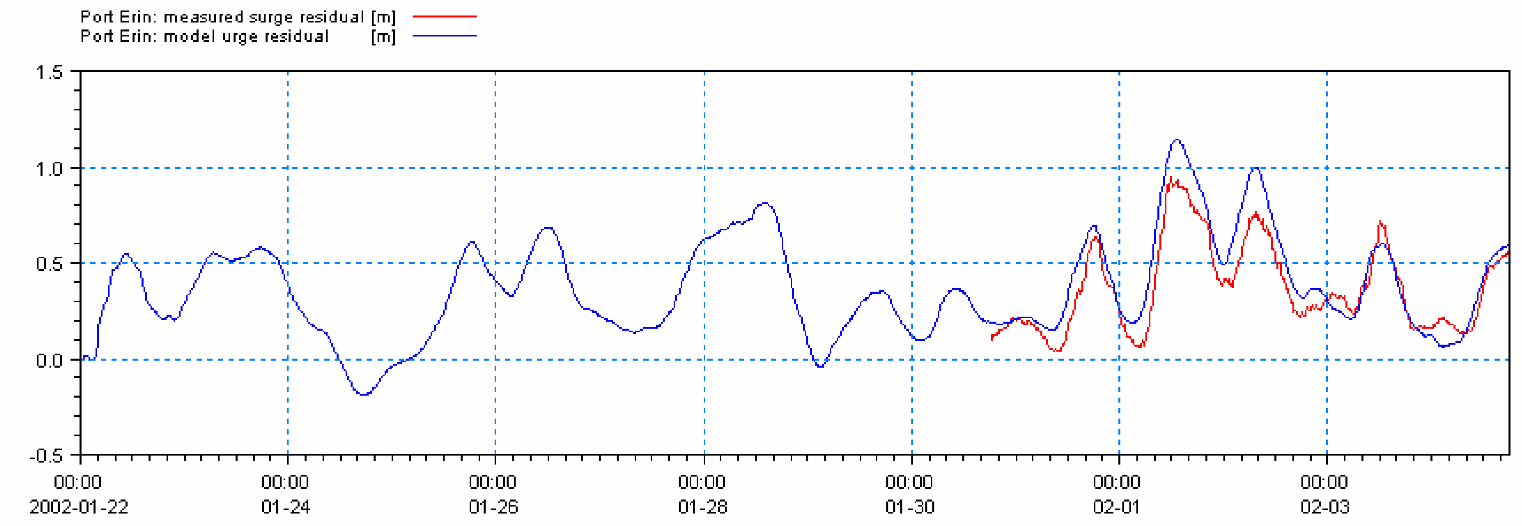


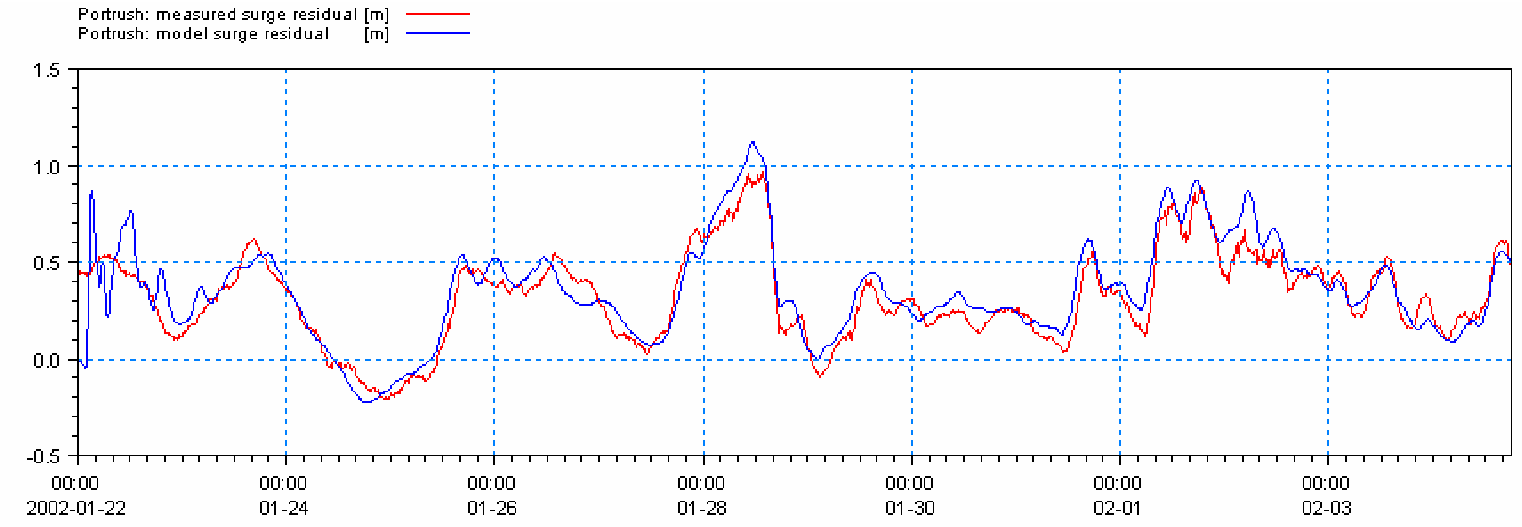
Validation Figures of Storm Surge Simulation: January 2002





Validation Figures of Storm Surge Simulation: January 2002

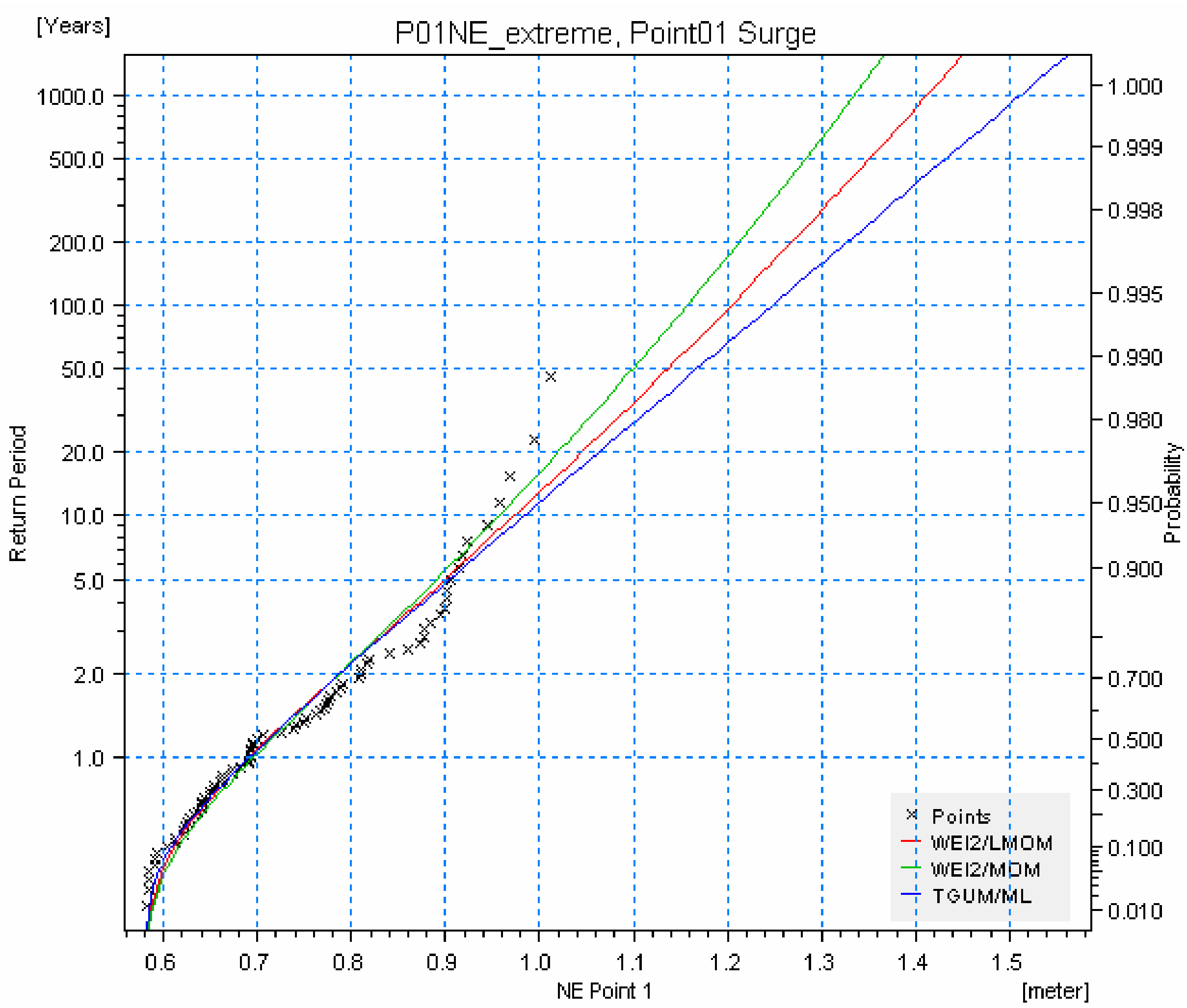




Appendix 3: Extreme Value Analysis of surge residual:
Points 1 – 3, 7-16, 18-26

ICPSS III Surge								
Point 01								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.885	0.89	0.877	0.889	0.872	0.883	0.9
	10	0.968	0.981	0.952	0.978	0.951	0.972	1.008
	25	1.067	1.091	1.039	1.087	1.047	1.081	1.142
	50	1.137	1.169	1.099	1.168	1.116	1.16	1.24
	100	1.203	1.245	1.157	1.248	1.184	1.238	1.338
	200	1.268	1.319	1.212	1.327	1.251	1.315	1.435
	1000	1.412	1.485	1.334	1.51	1.403	1.492	1.658
Average quantile	5	0.885	0.891	0.878	0.891	0.873	0.883	0.902
	10	0.968	0.983	0.952	0.98	0.951	0.971	1.011
	25	1.066	1.093	1.039	1.09	1.047	1.08	1.147
	50	1.134	1.172	1.1	1.171	1.117	1.159	1.247
	100	1.2	1.247	1.157	1.251	1.184	1.236	1.346
	200	1.264	1.321	1.212	1.331	1.251	1.313	1.444
	1000	1.405	1.486	1.333	1.515	1.404	1.488	1.671
Standard deviation	5	0.02	0.022	0.019	0.023	0.019	0.02	0.024
	10	0.024	0.03	0.022	0.029	0.022	0.025	0.034
	25	0.032	0.045	0.027	0.038	0.027	0.032	0.049
	50	0.039	0.058	0.032	0.045	0.032	0.038	0.062
	100	0.047	0.072	0.037	0.052	0.037	0.045	0.074
	200	0.056	0.087	0.042	0.06	0.041	0.052	0.087
	1000	0.077	0.123	0.056	0.077	0.054	0.068	0.118
Goodness-of-fit statistics	CHISQ	5.43	11.506	8.468	6.443	11	8.722	11
	KS	0.075	0.083	0.084	0.071	0.089	0.084	0.091
	SLSC	0.046	0.05	0.043	0.044	0.047	0.047	0.057
	PPCC1	0.98	0.975	0.984	0.976	0.977	0.973	0.964
	PPCC2	0.973	0.969	0.977	0.976	0.977	0.973	0.964
	LLM	67.497	67.755	66.565	68.812	60.837	64.608	66.676

RPS Consulting Engineers		Client: OPW	
		Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers	Client: OPW Project: ICPSS, Phase 3	MIKE Zero
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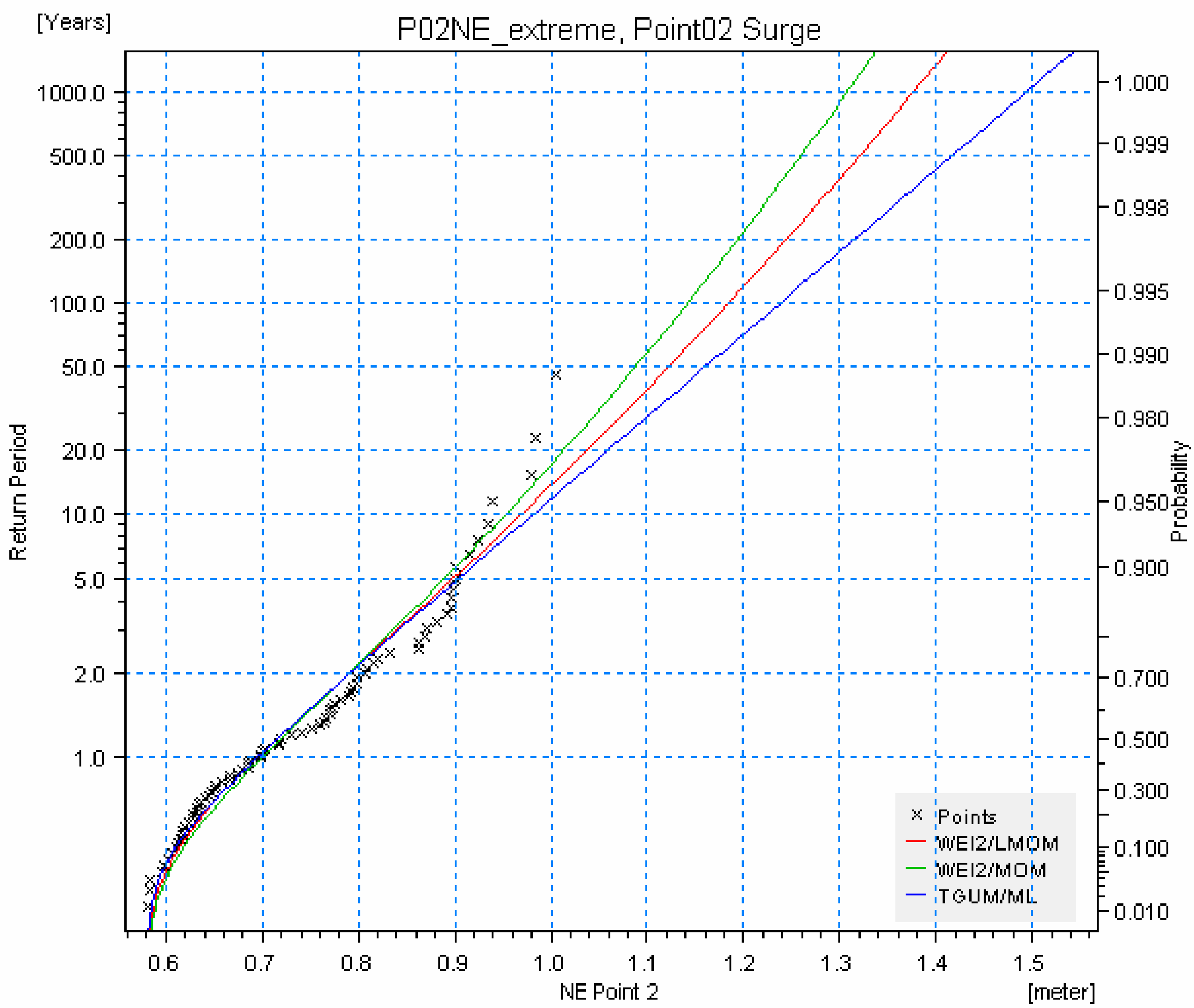
Init: C.Robinson		

ICPSS III Surge								
Point 02								
		D/E Combination						
	Return Period [years]	WEI2/LMOM	WEI2/ML	WEI2/MOM	TGUM/ML	GAM/MOM	GAM/LMOM	GAM/ML
Estimated quantile	5	0.885	0.886	0.877	0.89	0.872	0.883	0.897
	10	0.964	0.969	0.949	0.976	0.948	0.968	0.996
	25	1.057	1.067	1.031	1.082	1.04	1.073	1.12
	50	1.122	1.136	1.088	1.16	1.107	1.149	1.21
	100	1.184	1.202	1.142	1.238	1.172	1.223	1.299
	200	1.244	1.266	1.194	1.315	1.236	1.297	1.388
	1000	1.376	1.408	1.307	1.493	1.381	1.465	1.591
Average quantile	5	0.885	0.888	0.878	0.891	0.872	0.883	0.899
	10	0.964	0.972	0.949	0.978	0.948	0.968	1.001
	25	1.056	1.071	1.031	1.085	1.041	1.072	1.127
	50	1.12	1.141	1.088	1.163	1.107	1.147	1.219
	100	1.181	1.207	1.142	1.241	1.172	1.221	1.31
	200	1.24	1.272	1.194	1.318	1.236	1.295	1.4
	1000	1.37	1.415	1.306	1.497	1.381	1.462	1.608
Standard deviation	5	0.019	0.02	0.018	0.022	0.018	0.019	0.023
	10	0.023	0.027	0.021	0.027	0.021	0.023	0.033
	25	0.03	0.039	0.026	0.035	0.026	0.03	0.047
	50	0.036	0.049	0.03	0.042	0.03	0.035	0.058
	100	0.044	0.06	0.035	0.048	0.035	0.042	0.069
	200	0.051	0.072	0.04	0.055	0.039	0.048	0.081
	1000	0.071	0.099	0.054	0.07	0.051	0.064	0.109
Goodness-of-fit statistics	CHISQ	7.709	7.962	9.481	9.734	12.772	7.203	9.987
	KS	0.097	0.103	0.091	0.094	0.106	0.109	0.115
	SLSC	0.046	0.049	0.043	0.045	0.048	0.048	0.055
	PPCC1	0.98	0.978	0.984	0.976	0.976	0.972	0.965
	PPCC2	0.973	0.971	0.977	0.976	0.976	0.972	0.965
	LLM	67.935	68.005	67.335	68.379	62.211	65.254	66.557

RPS Consulting Engineers	Client: OPW Project: ICPSS, Phase 3		MIKE Zero
Date: 02/05/08	Probability table	Drawing no. CR0071	
Init: C.Robinson			



RPS Consulting Engineers		Client: OPW	MIKE Zero
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ICPSS III Surge								
Point 03								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.901	0.901	0.896	0.909	0.891	0.898	0.914
	10	0.968	0.97	0.959	0.989	0.961	0.975	1.005
	25	1.045	1.049	1.031	1.088	1.045	1.067	1.115
	50	1.097	1.102	1.079	1.161	1.105	1.133	1.195
	100	1.146	1.153	1.124	1.233	1.163	1.198	1.273
	200	1.192	1.201	1.167	1.304	1.22	1.261	1.35
	1000	1.292	1.304	1.258	1.47	1.349	1.404	1.526
Average quantile	5	0.901	0.902	0.896	0.91	0.891	0.898	0.916
	10	0.968	0.972	0.96	0.991	0.961	0.975	1.008
	25	1.044	1.051	1.031	1.09	1.045	1.066	1.12
	50	1.095	1.106	1.08	1.163	1.105	1.132	1.201
	100	1.143	1.157	1.125	1.235	1.163	1.196	1.281
	200	1.189	1.205	1.167	1.307	1.22	1.259	1.359
	1000	1.287	1.309	1.258	1.473	1.349	1.401	1.538
Standard deviation	5	0.019	0.019	0.018	0.02	0.018	0.019	0.021
	10	0.024	0.024	0.022	0.026	0.022	0.024	0.028
	25	0.032	0.034	0.028	0.033	0.028	0.032	0.04
	50	0.039	0.042	0.033	0.039	0.033	0.039	0.049
	100	0.046	0.05	0.038	0.045	0.038	0.046	0.058
	200	0.054	0.058	0.043	0.051	0.043	0.053	0.068
	1000	0.071	0.077	0.056	0.066	0.056	0.07	0.091
Goodness-of-fit statistics	CHISQ	8.722	6.696	7.962	7.962	8.468	6.696	8.975
	KS	0.079	0.088	0.072	0.083	0.088	0.089	0.123
	SLSC	0.028	0.03	0.026	0.035	0.036	0.036	0.046
	PPCC1	0.992	0.992	0.994	0.987	0.987	0.985	0.979
	PPCC2	0.99	0.99	0.992	0.987	0.987	0.985	0.979
	LLM	65.28	65.367	64.946	66.066	57.164	59.922	62.308

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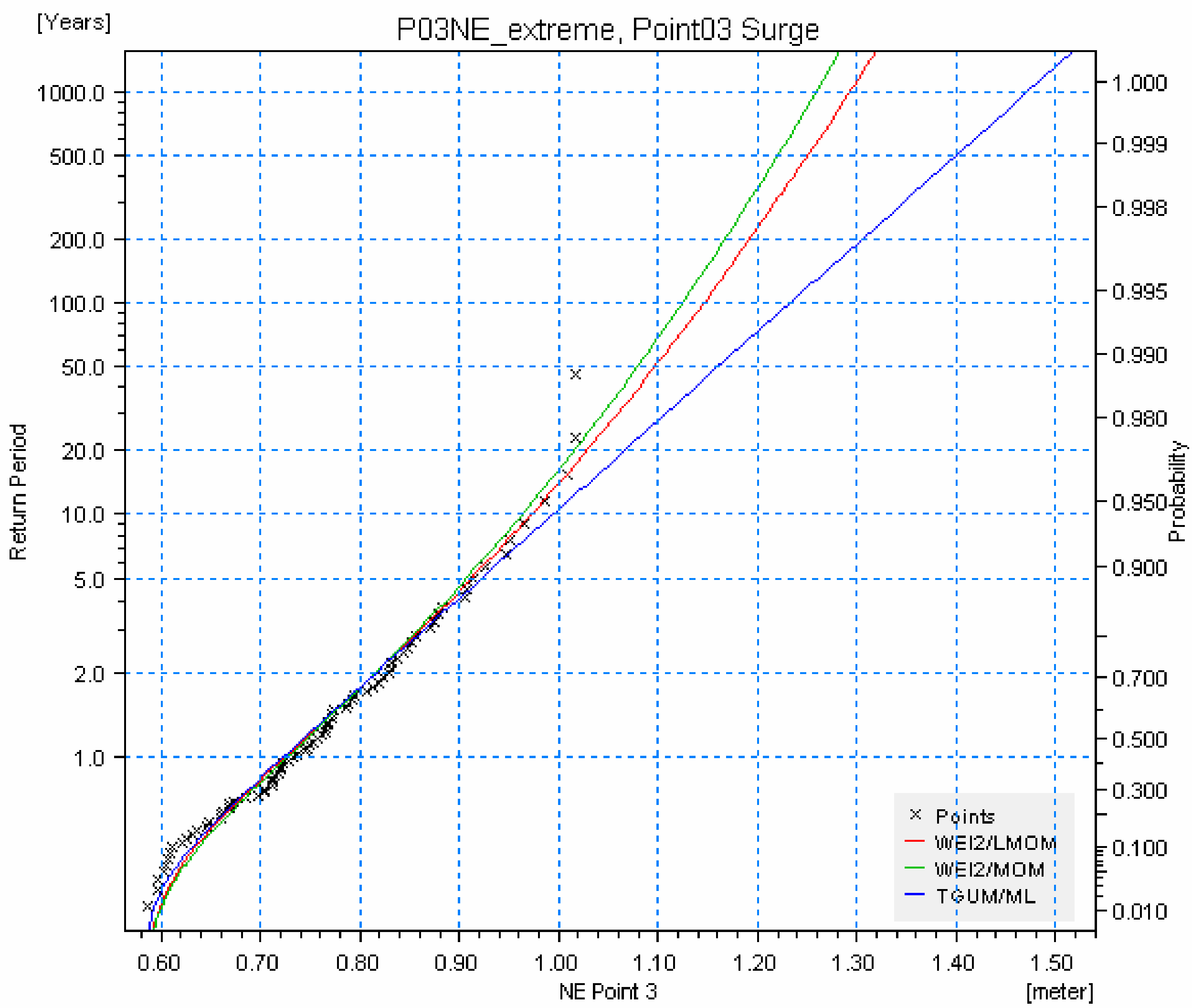

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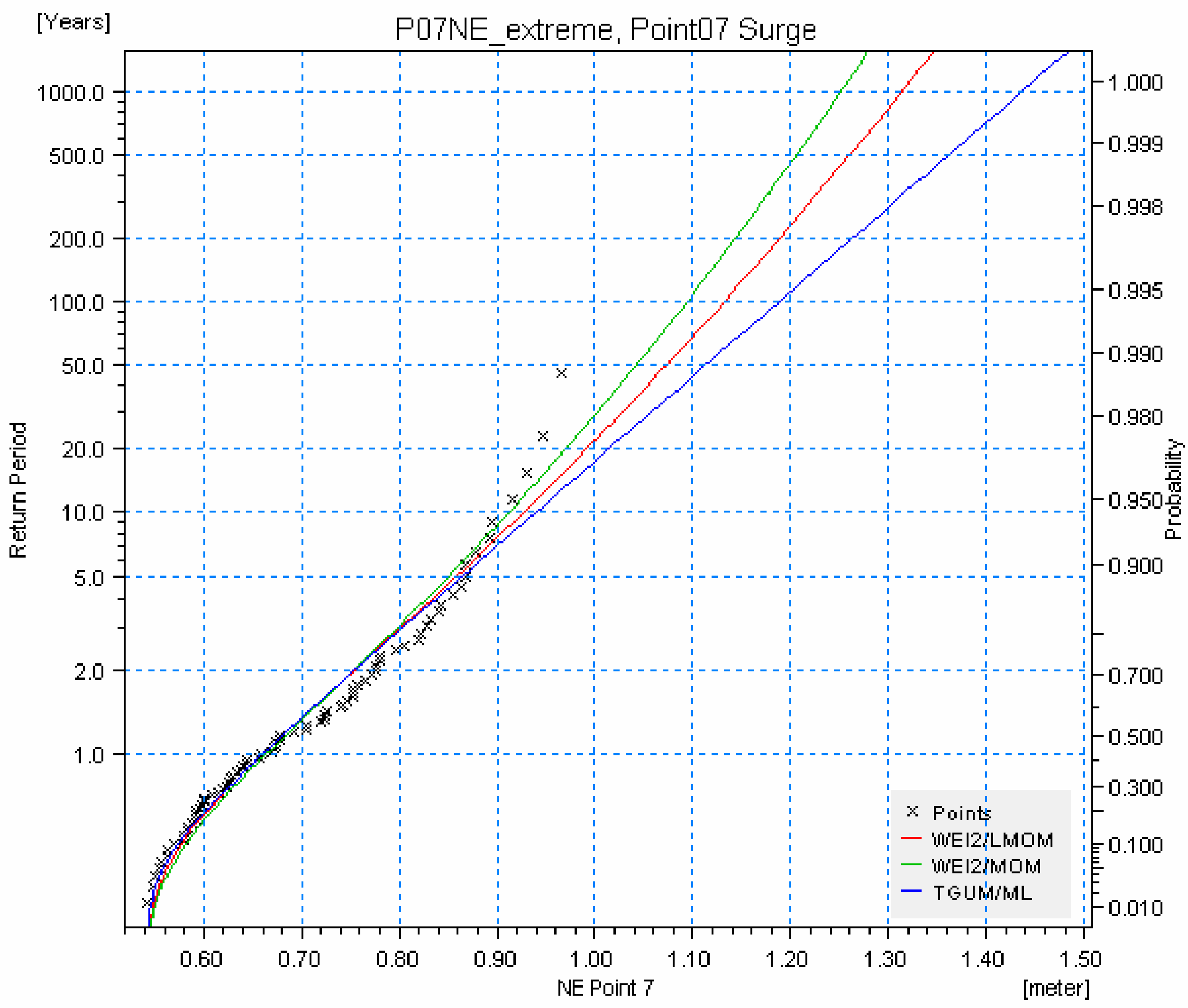
	Init: C.Robinson		

ICPSS III Surge								
Point 07								
		D/E Combination						
	Return Period [years]	WEI2/LMOM	WEI2/ML	WEI2/MOM	TGUM/ML	GAM/MOM	GAM/LMOM	GAM/ML
Estimated quantile	5	0.846	0.844	0.838	0.85	0.833	0.843	0.853
	10	0.922	0.921	0.908	0.934	0.908	0.927	0.946
	25	1.011	1.01	0.987	1.037	0.997	1.028	1.059
	50	1.073	1.071	1.042	1.113	1.062	1.101	1.142
	100	1.132	1.13	1.094	1.188	1.125	1.173	1.224
	200	1.188	1.187	1.143	1.263	1.187	1.244	1.304
	1000	1.313	1.311	1.25	1.435	1.328	1.406	1.489
Average quantile	5	0.846	0.846	0.839	0.851	0.834	0.843	0.855
	10	0.922	0.923	0.908	0.935	0.908	0.926	0.949
	25	1.01	1.013	0.988	1.039	0.998	1.027	1.065
	50	1.071	1.076	1.042	1.116	1.062	1.1	1.149
	100	1.129	1.136	1.094	1.191	1.125	1.172	1.232
	200	1.185	1.193	1.143	1.266	1.187	1.242	1.314
	1000	1.307	1.319	1.25	1.439	1.328	1.403	1.503
Standard deviation	5	0.019	0.019	0.018	0.021	0.018	0.019	0.022
	10	0.023	0.025	0.021	0.027	0.021	0.023	0.029
	25	0.03	0.034	0.026	0.035	0.026	0.03	0.04
	50	0.036	0.042	0.03	0.041	0.03	0.035	0.049
	100	0.043	0.05	0.035	0.047	0.035	0.041	0.058
	200	0.05	0.058	0.04	0.054	0.039	0.048	0.067
	1000	0.069	0.079	0.053	0.069	0.051	0.063	0.089
Goodness-of-fit statistics	CHISQ	8.975	10.241	6.696	8.975	12.266	8.975	8.722
	KS	0.085	0.088	0.084	0.084	0.104	0.098	0.099
	SLSC	0.042	0.042	0.038	0.041	0.044	0.044	0.049
	PPCC1	0.984	0.984	0.987	0.98	0.98	0.976	0.972
	PPCC2	0.978	0.978	0.982	0.98	0.98	0.976	0.972
	LLM	68.352	68.36	67.916	68.454	63.015	65.682	66.683

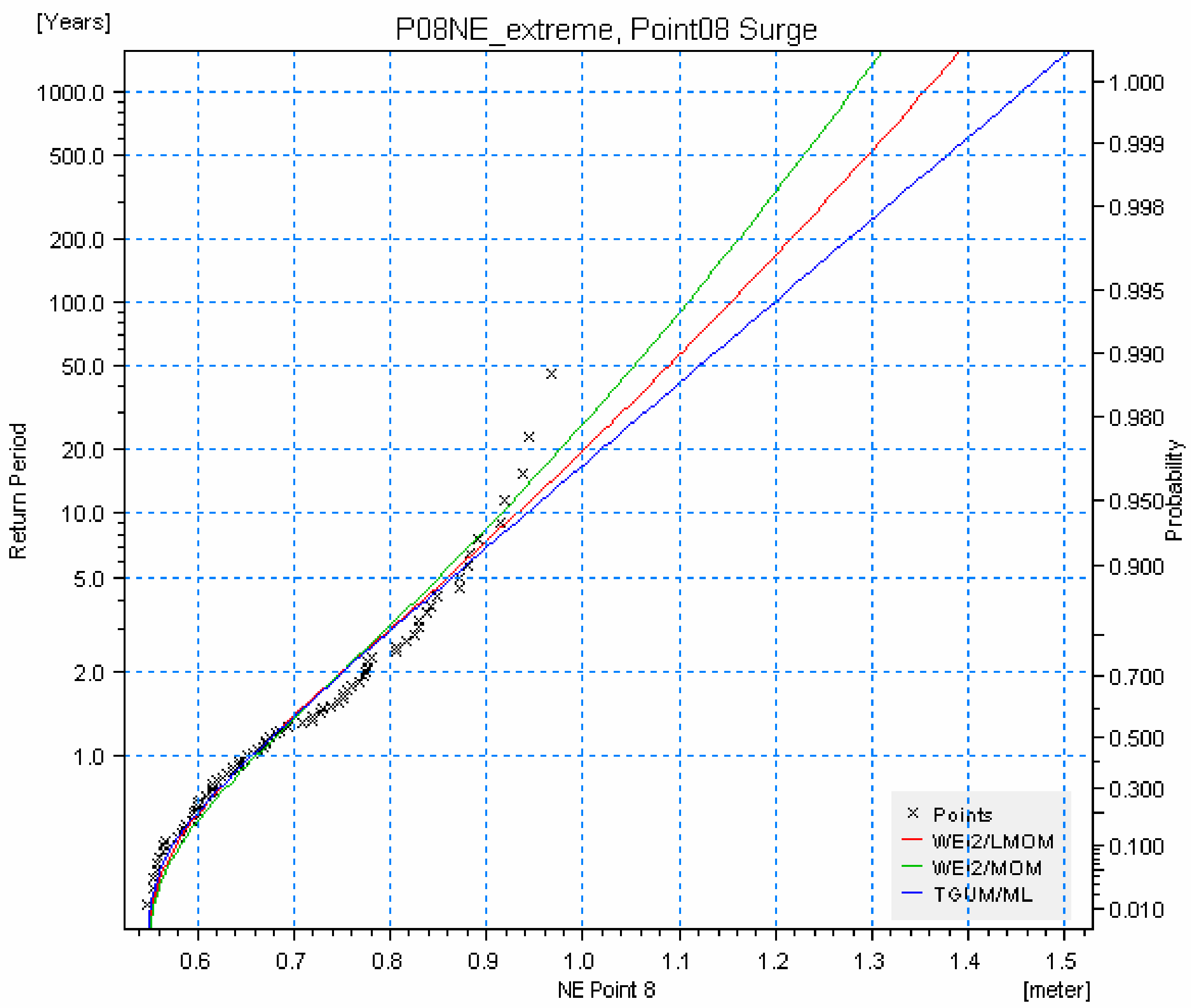
RPS Consulting Engineers		Client: OPW	MIKE Zero
		Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3		MIKE Zero
	Date: 02/05/08	Probability plot	Drawing no. CR0071	
	Init: C.Robinson			

ICPSS III Surge								
Point 08								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.846	0.846	0.838	0.85	0.833	0.844	0.853
	10	0.926	0.928	0.91	0.936	0.91	0.93	0.949
	25	1.022	1.025	0.994	1.043	1.002	1.036	1.069
	50	1.089	1.093	1.053	1.121	1.07	1.113	1.156
	100	1.153	1.159	1.108	1.198	1.135	1.188	1.242
	200	1.215	1.223	1.161	1.275	1.2	1.263	1.327
	1000	1.353	1.364	1.278	1.454	1.348	1.434	1.523
Average quantile	5	0.846	0.847	0.838	0.851	0.833	0.844	0.855
	10	0.926	0.93	0.911	0.938	0.91	0.929	0.952
	25	1.02	1.028	0.995	1.045	1.003	1.035	1.073
	50	1.087	1.097	1.053	1.124	1.07	1.111	1.161
	100	1.15	1.164	1.108	1.202	1.136	1.187	1.249
	200	1.211	1.228	1.161	1.279	1.2	1.261	1.335
	1000	1.346	1.37	1.277	1.458	1.348	1.431	1.534
Standard deviation	5	0.02	0.02	0.019	0.022	0.018	0.019	0.023
	10	0.024	0.026	0.022	0.028	0.022	0.024	0.031
	25	0.031	0.037	0.026	0.036	0.027	0.031	0.042
	50	0.038	0.046	0.031	0.043	0.031	0.037	0.051
	100	0.045	0.055	0.036	0.05	0.036	0.043	0.06
	200	0.053	0.065	0.041	0.056	0.04	0.05	0.07
	1000	0.074	0.09	0.055	0.073	0.052	0.066	0.093
Goodness-of-fit statistics	CHISQ	6.949	5.684	6.696	6.443	8.722	5.684	8.215
	KS	0.084	0.087	0.083	0.081	0.096	0.094	0.096
	SLSC	0.044	0.045	0.041	0.043	0.046	0.046	0.051
	PPCC1	0.981	0.981	0.985	0.978	0.979	0.975	0.97
	PPCC2	0.975	0.975	0.98	0.978	0.979	0.975	0.97
	LLM	69.754	69.796	69.132	70.169	64.644	67.551	68.584

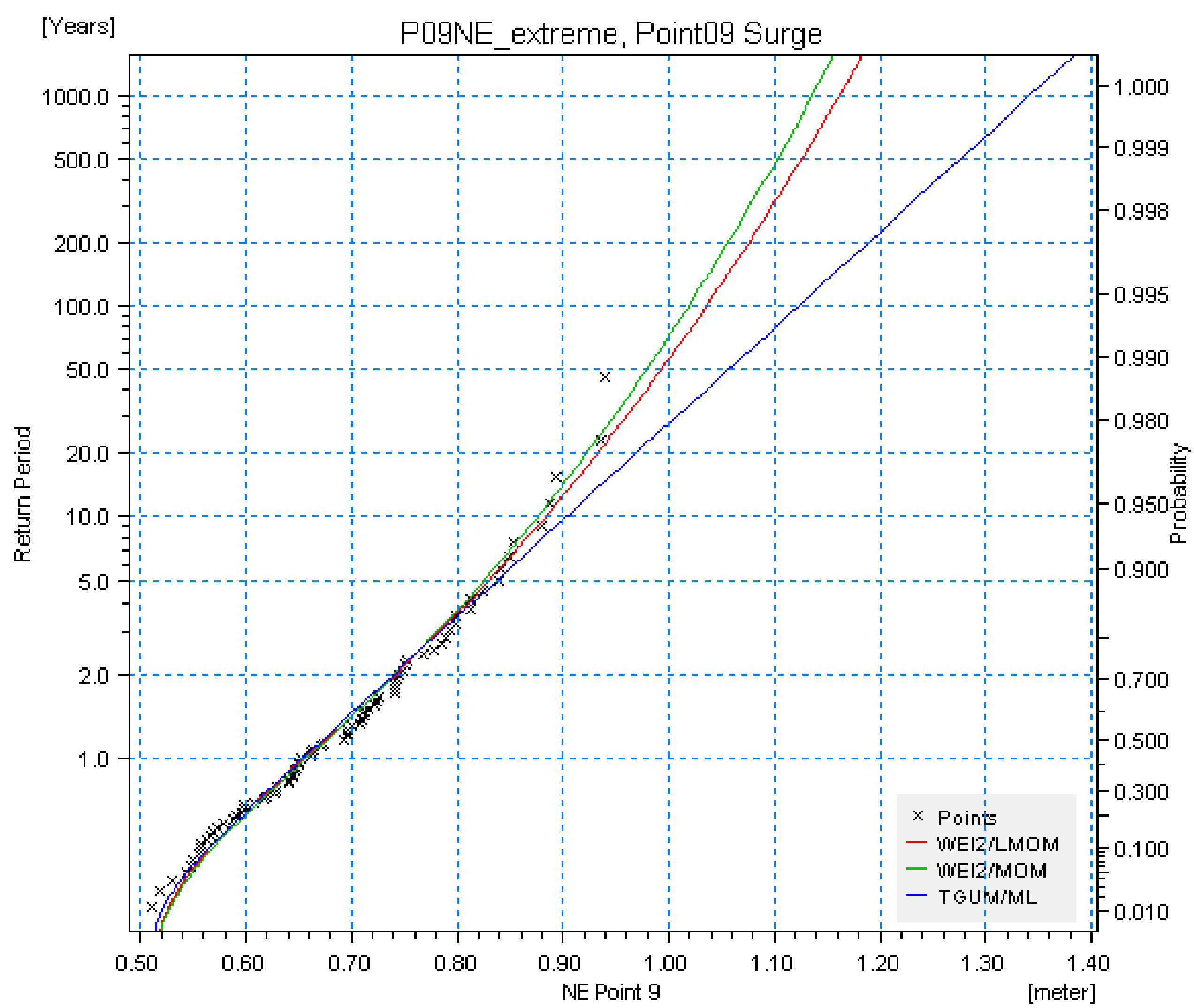
RPS Consulting Engineers		Client: OPW	
		Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers	Client: OPW	
	Project: ICPSS, Phase 3	
Date: 02/05/08	Probability plot	Drawing no. CR0071
Init: C.Robinson		

ICPSS III Surge								
Point 09								
		D/E Combination						
	Return Period [years]	WEI2/LMOM	WEI2/ML	WEI2/MOM	TGUM/ML	GAM/MOM	GAM/LMOM	GAM/ML
Estimated quantile	5	0.819	0.817	0.815	0.825	0.81	0.817	0.83
	10	0.88	0.878	0.873	0.899	0.875	0.887	0.911
	25	0.948	0.946	0.936	0.99	0.952	0.971	1.009
	50	0.993	0.991	0.979	1.057	1.006	1.031	1.079
	100	1.036	1.033	1.019	1.123	1.059	1.089	1.148
	200	1.075	1.073	1.056	1.189	1.111	1.146	1.215
	1000	1.161	1.158	1.135	1.341	1.228	1.275	1.368
Average quantile	5	0.819	0.819	0.816	0.826	0.811	0.817	0.835
	10	0.88	0.882	0.873	0.901	0.875	0.887	0.92
	25	0.947	0.951	0.937	0.992	0.953	0.971	1.023
	50	0.992	0.998	0.98	1.059	1.007	1.031	1.097
	100	1.034	1.042	1.02	1.126	1.06	1.089	1.169
	200	1.074	1.083	1.057	1.192	1.112	1.146	1.24
	1000	1.158	1.171	1.136	1.344	1.229	1.274	1.401
Standard deviation	5	0.017	0.017	0.017	0.019	0.016	0.017	0.02
	10	0.022	0.022	0.02	0.024	0.02	0.022	0.03
	25	0.028	0.03	0.025	0.031	0.025	0.029	0.043
	50	0.034	0.037	0.03	0.036	0.03	0.034	0.054
	100	0.04	0.044	0.034	0.042	0.034	0.04	0.064
	200	0.045	0.05	0.039	0.047	0.039	0.046	0.075
	1000	0.059	0.066	0.049	0.06	0.05	0.061	0.101
Goodness-of-fit statistics	CHISQ	3.405	2.392	5.43	4.418	8.722	6.19	13.785
	KS	0.071	0.075	0.067	0.08	0.089	0.093	0.102
	SLSC	0.024	0.024	0.022	0.032	0.034	0.033	0.042
	PPCC1	0.995	0.995	0.996	0.988	0.989	0.987	0.982
	PPCC2	0.993	0.993	0.994	0.988	0.989	0.987	0.982
	LLM	68.77	68.782	68.568	69.278	60.679	63.042	65.023

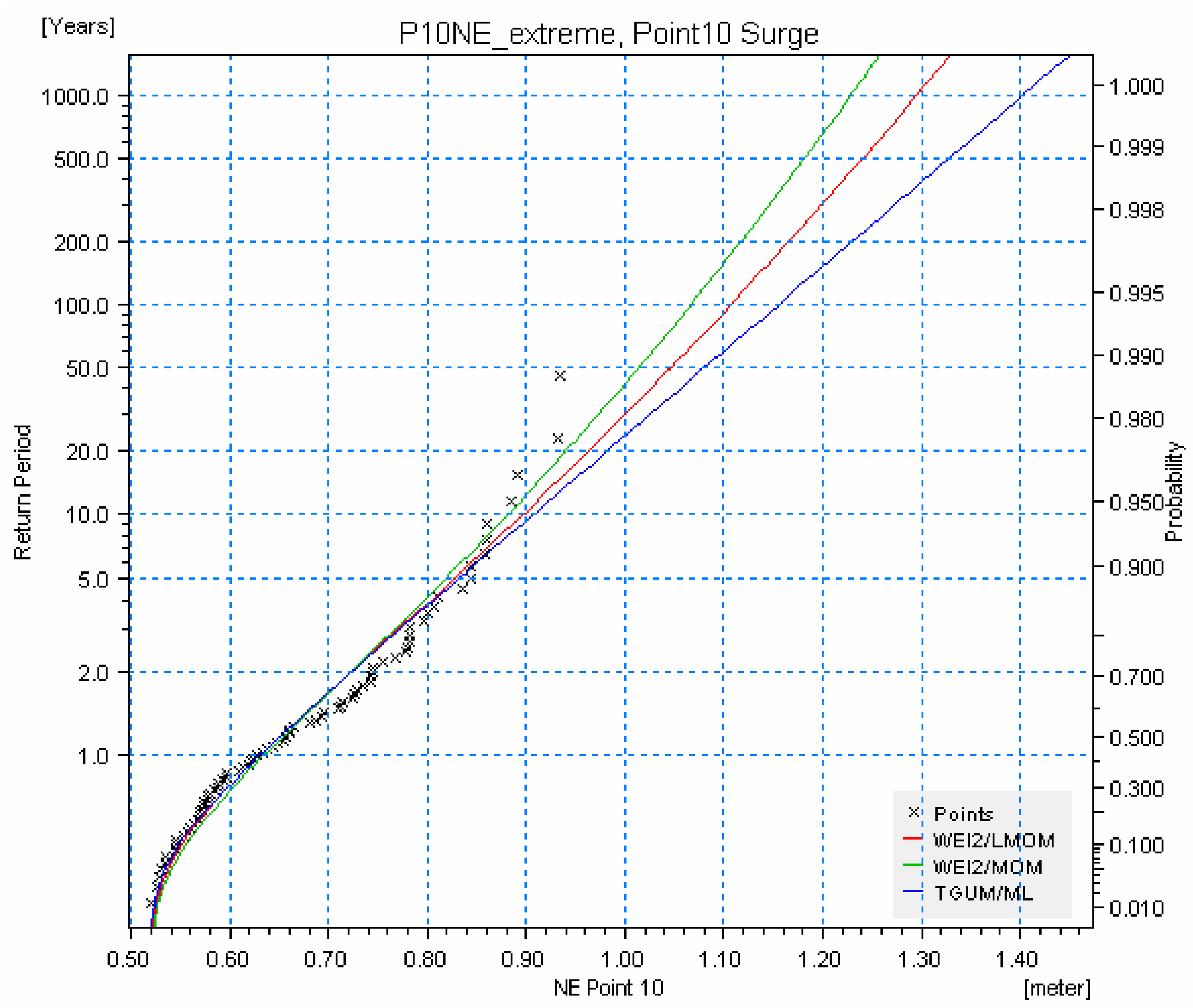
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKEZero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKEZero
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 10								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.815	0.814	0.807	0.818	0.802	0.812	0.821
	10	0.892	0.891	0.877	0.902	0.877	0.896	0.913
	25	0.983	0.982	0.958	1.005	0.966	0.998	1.027
	50	1.046	1.046	1.013	1.08	1.031	1.072	1.11
	100	1.107	1.107	1.066	1.155	1.095	1.144	1.191
	200	1.165	1.166	1.117	1.229	1.157	1.216	1.272
	1000	1.295	1.296	1.228	1.401	1.299	1.38	1.458
Average quantile	5	0.815	0.815	0.808	0.82	0.803	0.812	0.823
	10	0.892	0.894	0.878	0.903	0.877	0.895	0.917
	25	0.981	0.986	0.958	1.007	0.967	0.997	1.032
	50	1.044	1.051	1.014	1.083	1.032	1.07	1.117
	100	1.104	1.113	1.067	1.158	1.095	1.143	1.2
	200	1.162	1.172	1.117	1.233	1.158	1.214	1.282
	1000	1.289	1.304	1.227	1.406	1.3	1.377	1.471
Standard deviation	5	0.019	0.02	0.018	0.021	0.018	0.019	0.022
	10	0.023	0.025	0.021	0.027	0.021	0.023	0.03
	25	0.03	0.035	0.026	0.035	0.026	0.03	0.041
	50	0.036	0.043	0.03	0.041	0.03	0.036	0.049
	100	0.044	0.051	0.035	0.048	0.035	0.042	0.058
	200	0.051	0.06	0.041	0.054	0.04	0.048	0.067
	1000	0.07	0.082	0.054	0.069	0.051	0.064	0.089
Goodness-of-fit statistics	CHISQ	5.684	5.937	7.709	8.215	9.987	6.696	7.709
	KS	0.089	0.092	0.087	0.087	0.102	0.1	0.101
	SLSC	0.042	0.043	0.039	0.042	0.045	0.044	0.049
	PPCC1	0.983	0.983	0.987	0.979	0.98	0.976	0.972
	PPCC2	0.978	0.977	0.982	0.979	0.98	0.976	0.972
	LLM	71.08	71.086	70.691	70.916	66.821	69.137	69.804

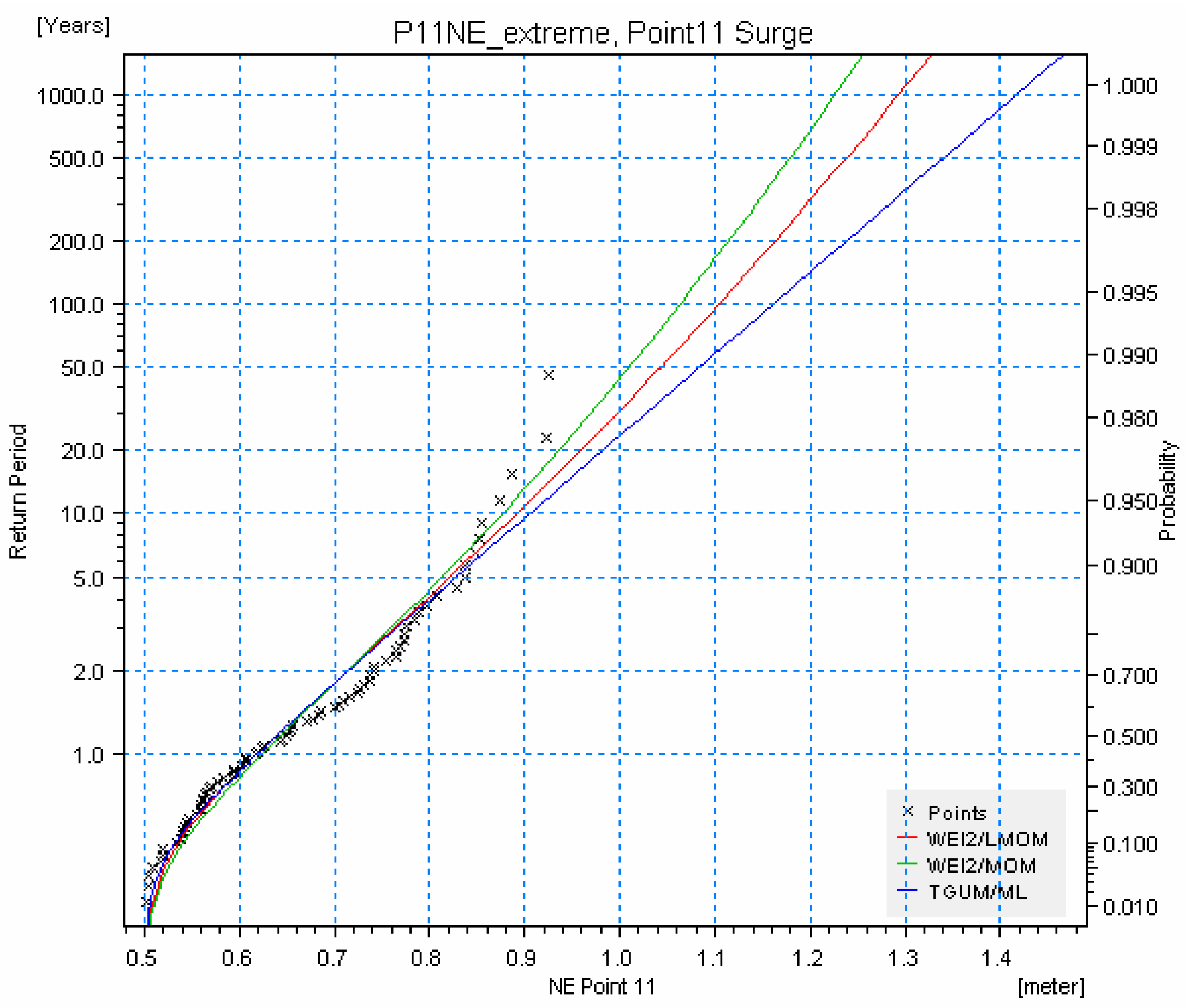
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW	
		Project: ICPSS, Phase 3	MIKEZero
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 11								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.808	0.81	0.801	0.814	0.796	0.806	0.822
	10	0.887	0.893	0.872	0.9	0.871	0.891	0.922
	25	0.979	0.991	0.953	1.006	0.963	0.995	1.047
	50	1.043	1.059	1.01	1.084	1.029	1.071	1.138
	100	1.104	1.125	1.063	1.162	1.094	1.145	1.228
	200	1.163	1.189	1.114	1.238	1.157	1.218	1.317
	1000	1.293	1.329	1.225	1.416	1.302	1.385	1.522
Average quantile	5	0.808	0.812	0.801	0.815	0.796	0.806	0.824
	10	0.887	0.895	0.872	0.902	0.872	0.891	0.926
	25	0.978	0.994	0.954	1.008	0.964	0.994	1.053
	50	1.041	1.063	1.01	1.087	1.03	1.07	1.145
	100	1.101	1.129	1.063	1.165	1.094	1.143	1.237
	200	1.159	1.193	1.114	1.242	1.158	1.216	1.327
	1000	1.286	1.334	1.225	1.421	1.302	1.381	1.536
Standard deviation	5	0.019	0.02	0.018	0.022	0.018	0.019	0.023
	10	0.023	0.027	0.021	0.027	0.021	0.023	0.032
	25	0.03	0.039	0.026	0.035	0.026	0.03	0.046
	50	0.036	0.049	0.03	0.042	0.03	0.035	0.057
	100	0.044	0.06	0.035	0.048	0.035	0.042	0.068
	200	0.051	0.072	0.04	0.055	0.04	0.048	0.08
	1000	0.07	0.099	0.054	0.07	0.051	0.064	0.108
Goodness-of-fit statistics	CHISQ	5.684	6.19	8.975	7.456	14.544	8.215	14.797
	KS	0.093	0.096	0.095	0.09	0.109	0.104	0.103
	SLSC	0.045	0.048	0.041	0.044	0.047	0.047	0.056
	PPCC1	0.981	0.979	0.985	0.977	0.977	0.973	0.965
	PPCC2	0.975	0.973	0.98	0.977	0.977	0.973	0.965
	LLM	66.933	67.043	66.277	67.651	60.459	63.781	65.446

RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKEZero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW	MIKE Zero
		Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 12								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.811	0.812	0.804	0.815	0.799	0.809	0.821
	10	0.891	0.894	0.875	0.9	0.875	0.894	0.918
	25	0.984	0.99	0.958	1.005	0.966	0.999	1.038
	50	1.05	1.059	1.015	1.082	1.033	1.075	1.126
	100	1.113	1.124	1.07	1.159	1.098	1.149	1.212
	200	1.173	1.187	1.122	1.234	1.162	1.223	1.298
	1000	1.307	1.328	1.237	1.41	1.307	1.391	1.496
Average quantile	5	0.811	0.814	0.804	0.816	0.799	0.809	0.823
	10	0.89	0.897	0.876	0.902	0.875	0.894	0.922
	25	0.983	0.995	0.958	1.008	0.967	0.998	1.044
	50	1.048	1.064	1.016	1.085	1.033	1.073	1.134
	100	1.11	1.13	1.07	1.162	1.098	1.147	1.223
	200	1.17	1.194	1.122	1.238	1.162	1.22	1.311
	1000	1.301	1.337	1.236	1.415	1.308	1.388	1.513
Standard deviation	5	0.019	0.02	0.019	0.022	0.018	0.019	0.023
	10	0.023	0.027	0.021	0.028	0.021	0.023	0.032
	25	0.03	0.038	0.026	0.036	0.026	0.03	0.045
	50	0.037	0.048	0.03	0.042	0.03	0.036	0.055
	100	0.044	0.058	0.035	0.049	0.035	0.042	0.066
	200	0.052	0.069	0.04	0.056	0.04	0.049	0.077
	1000	0.071	0.095	0.054	0.072	0.051	0.064	0.103
Goodness-of-fit statistics	CHISQ	4.418	7.709	6.19	4.418	11.253	8.215	8.215
	KS	0.093	0.096	0.095	0.09	0.107	0.103	0.1
	SLSC	0.046	0.047	0.043	0.044	0.047	0.047	0.053
	PPCC1	0.98	0.979	0.984	0.977	0.977	0.973	0.967
	PPCC2	0.974	0.972	0.977	0.977	0.977	0.973	0.967
	LLM	70.015	70.049	69.499	70.235	65.22	67.874	68.794

RPS Consulting Engineers

Client: OPW

Project: ICPSS, Phase 3

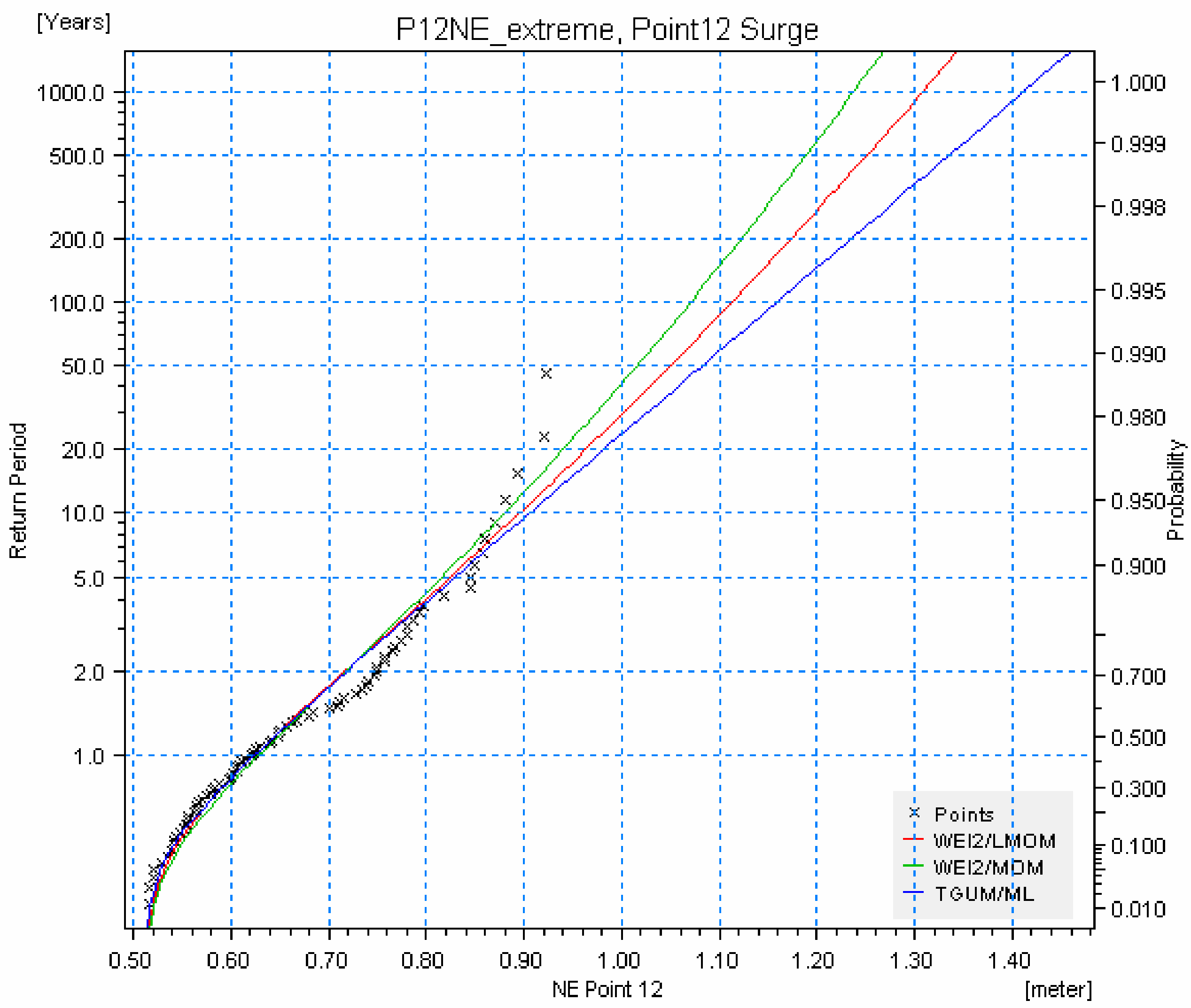
MIKE Zero

Date: 02/05/08

Init: C.Robinson

Probability table

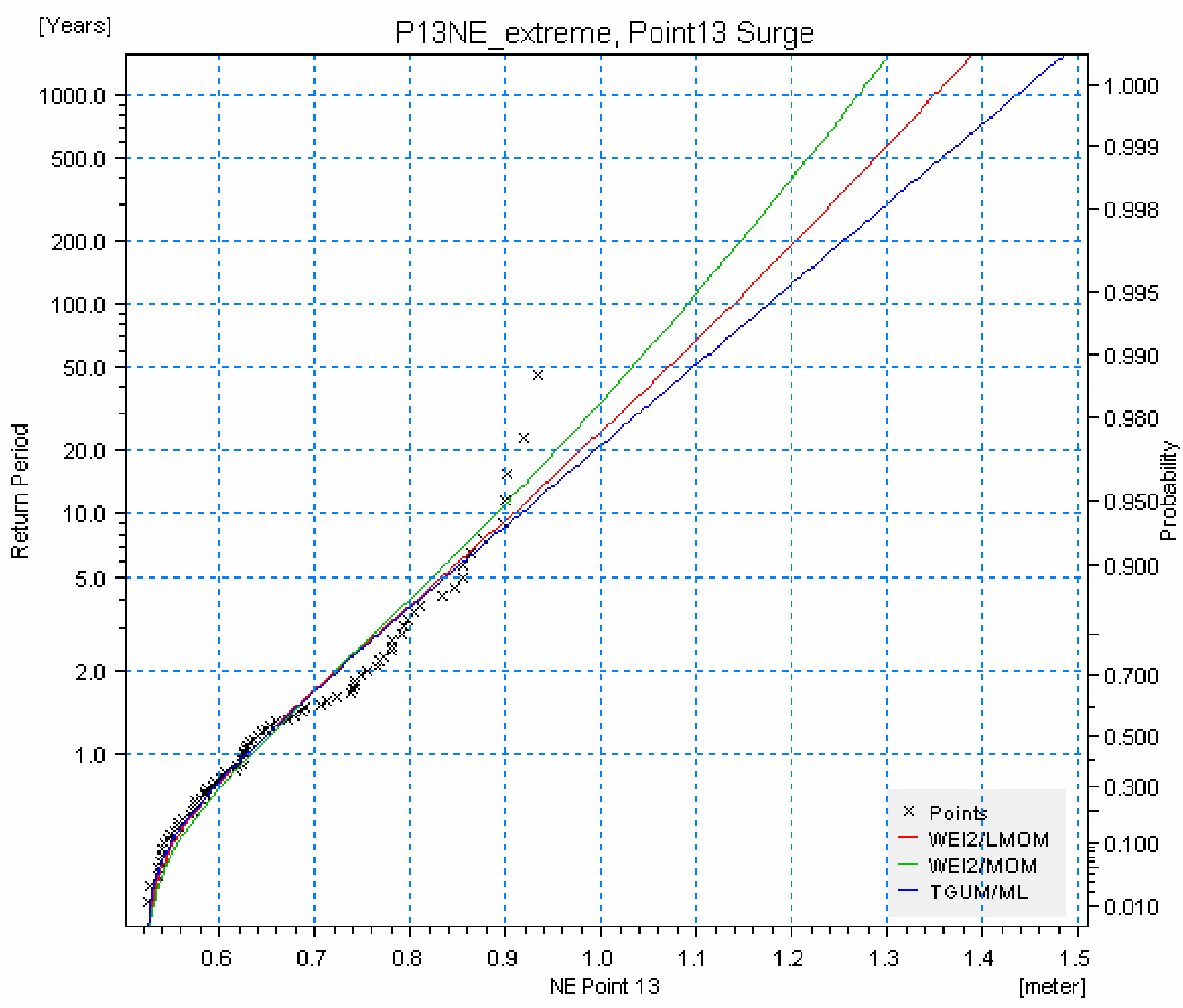
Drawing no. CR0071



RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 13								
		D/E Combination						
	Return Period [years]	WEI2/LMOM	WEI2/ML	WEI2/MOM	TGUM/ML	GAM/MOM	GAM/LMOM	GAM/ML
Estimated quantile	5	0.819	0.82	0.811	0.822	0.807	0.817	0.827
	10	0.902	0.905	0.885	0.91	0.884	0.905	0.924
	25	1.001	1.006	0.972	1.018	0.979	1.013	1.046
	50	1.071	1.079	1.033	1.097	1.048	1.092	1.136
	100	1.138	1.149	1.091	1.176	1.115	1.169	1.224
	200	1.204	1.217	1.146	1.254	1.182	1.246	1.312
	1000	1.349	1.369	1.269	1.435	1.333	1.422	1.513
Average quantile	5	0.819	0.822	0.812	0.824	0.807	0.817	0.831
	10	0.902	0.91	0.886	0.912	0.885	0.905	0.933
	25	1	1.016	0.973	1.02	0.98	1.012	1.061
	50	1.069	1.092	1.033	1.1	1.049	1.091	1.155
	100	1.136	1.164	1.091	1.179	1.116	1.168	1.247
	200	1.201	1.235	1.147	1.258	1.183	1.245	1.339
	1000	1.344	1.393	1.269	1.44	1.334	1.42	1.552
Standard deviation	5	0.02	0.021	0.019	0.022	0.019	0.02	0.024
	10	0.024	0.029	0.022	0.029	0.022	0.024	0.034
	25	0.032	0.041	0.027	0.037	0.027	0.032	0.048
	50	0.039	0.052	0.031	0.044	0.031	0.038	0.059
	100	0.046	0.063	0.036	0.051	0.036	0.044	0.071
	200	0.055	0.076	0.041	0.058	0.041	0.051	0.083
	1000	0.076	0.106	0.055	0.075	0.052	0.067	0.112
Goodness-of-fit statistics	CHISQ	9.228	10.747	9.228	9.734	12.772	10.494	11
	KS	0.103	0.105	0.105	0.1	0.116	0.111	0.108
	SLSC	0.048	0.049	0.046	0.045	0.048	0.048	0.053
	PPCC1	0.978	0.976	0.982	0.975	0.976	0.972	0.967
	PPCC2	0.971	0.97	0.975	0.975	0.976	0.972	0.967
	LLM	71.145	71.182	70.551	71.411	66.898	69.493	70.266

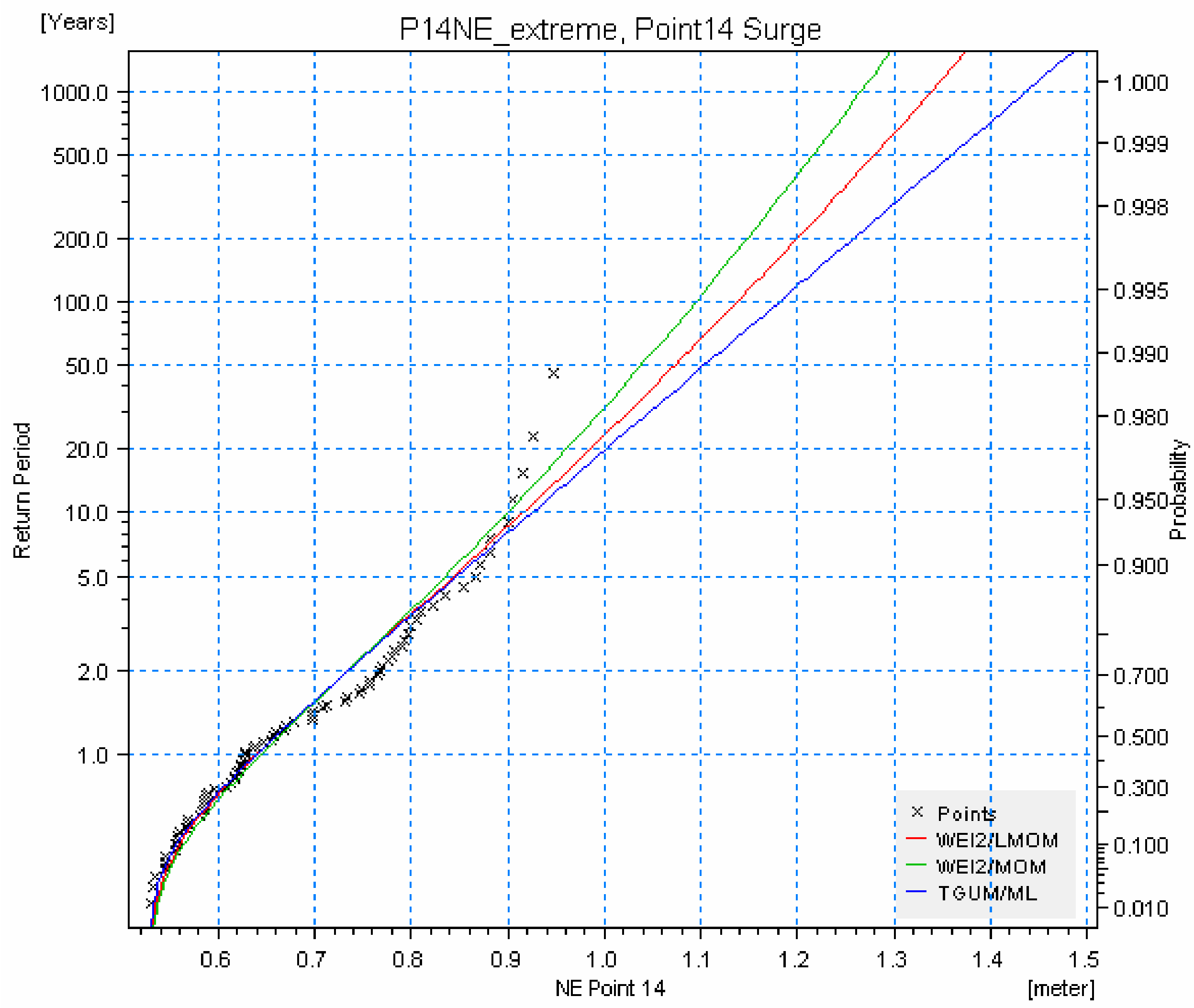
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW		
		Project: ICPSS, Phase 3		MIKE Zero
	Date: 02/05/08	Probability plot	Drawing no. CR0071	
	Init: C.Robinson			

ICPSS III Surge								
Point 14								
		D/E Combination						
	Return Period [years]	WEI2/LMOM	WEI2/ML	WEI2/MOM	TGUM/ML	GAM/MOM	GAM/LMOM	GAM/ML
Estimated quantile	5	0.83	0.831	0.822	0.833	0.817	0.828	0.84
	10	0.911	0.915	0.895	0.919	0.894	0.914	0.938
	25	1.006	1.014	0.98	1.026	0.988	1.02	1.061
	50	1.073	1.084	1.038	1.104	1.056	1.098	1.151
	100	1.138	1.152	1.094	1.181	1.122	1.173	1.24
	200	1.2	1.217	1.148	1.258	1.187	1.248	1.328
	1000	1.338	1.363	1.265	1.436	1.335	1.42	1.53
Average quantile	5	0.83	0.833	0.823	0.834	0.818	0.828	0.843
	10	0.91	0.918	0.896	0.921	0.895	0.914	0.945
	25	1.005	1.02	0.98	1.028	0.988	1.02	1.071
	50	1.072	1.092	1.039	1.107	1.056	1.096	1.164
	100	1.135	1.161	1.095	1.184	1.122	1.172	1.256
	200	1.196	1.228	1.148	1.262	1.187	1.246	1.347
	1000	1.332	1.377	1.265	1.441	1.336	1.417	1.556
Standard deviation	5	0.02	0.021	0.019	0.022	0.019	0.02	0.024
	10	0.024	0.028	0.022	0.028	0.022	0.024	0.034
	25	0.031	0.041	0.026	0.037	0.027	0.031	0.048
	50	0.038	0.051	0.031	0.044	0.031	0.037	0.06
	100	0.045	0.062	0.036	0.051	0.035	0.043	0.072
	200	0.053	0.074	0.041	0.057	0.04	0.05	0.084
	1000	0.073	0.103	0.054	0.074	0.052	0.065	0.114
Goodness-of-fit statistics	CHISQ	11.253	9.734	12.013	8.722	16.823	11.759	6.443
	KS	0.094	0.097	0.096	0.091	0.108	0.103	0.1
	SLSC	0.046	0.048	0.044	0.044	0.047	0.047	0.053
	PPCC1	0.98	0.978	0.984	0.976	0.977	0.973	0.967
	PPCC2	0.973	0.972	0.977	0.976	0.977	0.973	0.967
	LLM	69.331	69.376	68.782	69.681	64.52	67.205	68.178

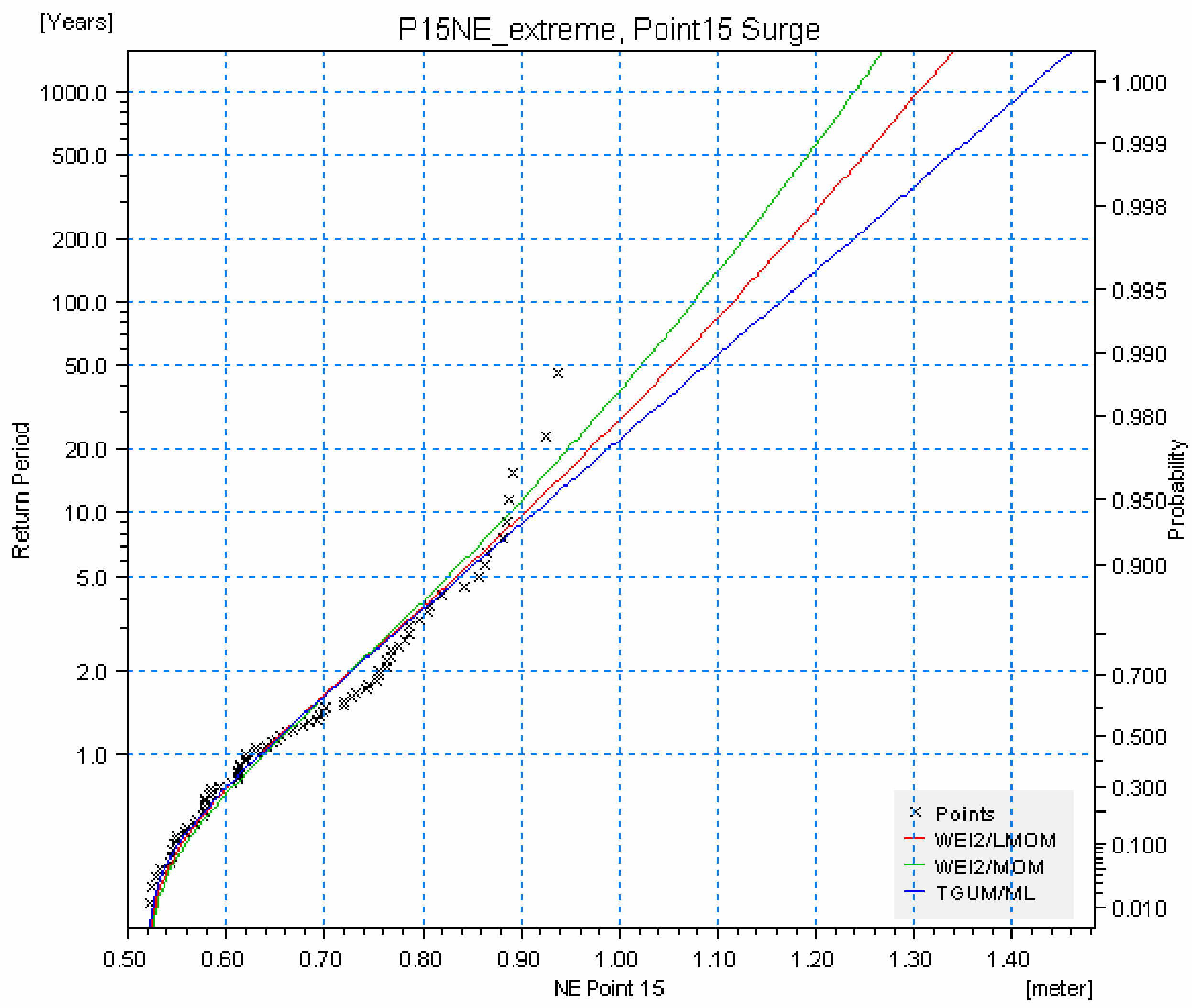
RPS Consulting Engineers	Client: OPW Project: ICPSS, Phase 3		MIKEZero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW	
		Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 15								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.83	0.831	0.822	0.833	0.817	0.828	0.84
	10	0.911	0.915	0.895	0.919	0.894	0.914	0.938
	25	1.006	1.014	0.98	1.026	0.988	1.02	1.061
	50	1.073	1.084	1.038	1.104	1.056	1.098	1.151
	100	1.138	1.152	1.094	1.181	1.122	1.173	1.24
	200	1.2	1.217	1.148	1.258	1.187	1.248	1.328
	1000	1.338	1.363	1.265	1.436	1.335	1.42	1.53
Average quantile	5	0.83	0.833	0.823	0.834	0.818	0.828	0.843
	10	0.91	0.918	0.896	0.921	0.895	0.914	0.945
	25	1.005	1.02	0.98	1.028	0.988	1.02	1.071
	50	1.072	1.092	1.039	1.107	1.056	1.096	1.164
	100	1.135	1.161	1.095	1.184	1.122	1.172	1.256
	200	1.196	1.228	1.148	1.262	1.187	1.246	1.347
	1000	1.332	1.377	1.265	1.441	1.336	1.417	1.556
Standard deviation	5	0.02	0.021	0.019	0.022	0.019	0.02	0.024
	10	0.024	0.028	0.022	0.028	0.022	0.024	0.034
	25	0.031	0.041	0.026	0.037	0.027	0.031	0.048
	50	0.038	0.051	0.031	0.044	0.031	0.037	0.06
	100	0.045	0.062	0.036	0.051	0.035	0.043	0.072
	200	0.053	0.074	0.041	0.057	0.04	0.05	0.084
	1000	0.073	0.103	0.054	0.074	0.052	0.065	0.114
Goodness-of-fit statistics	CHISQ	11.253	9.734	12.013	8.722	16.823	11.759	6.443
	KS	0.094	0.097	0.096	0.091	0.108	0.103	0.1
	SLSC	0.046	0.048	0.044	0.044	0.047	0.047	0.053
	PPCC1	0.98	0.978	0.984	0.976	0.977	0.973	0.967
	PPCC2	0.973	0.972	0.977	0.976	0.977	0.973	0.967
	LLM	69.331	69.376	68.782	69.681	64.52	67.205	68.178

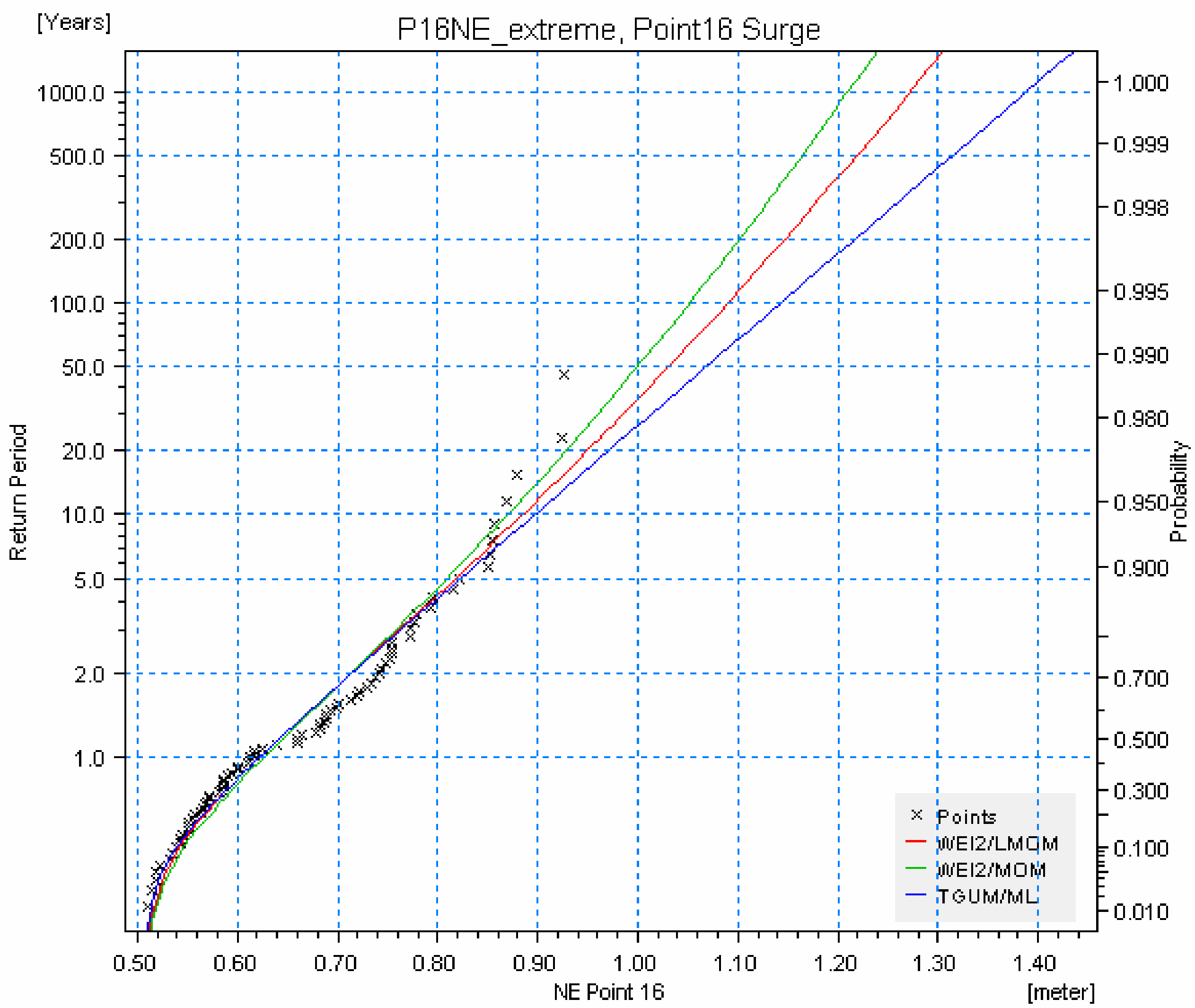
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 16								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.805	0.805	0.798	0.809	0.793	0.802	0.813
	10	0.88	0.882	0.866	0.892	0.866	0.884	0.906
	25	0.969	0.972	0.945	0.994	0.955	0.984	1.021
	50	1.031	1.036	1	1.069	1.019	1.057	1.104
	100	1.09	1.096	1.052	1.143	1.081	1.128	1.187
	200	1.146	1.154	1.101	1.217	1.143	1.199	1.268
	1000	1.271	1.283	1.209	1.387	1.282	1.359	1.455
Average quantile	5	0.805	0.806	0.798	0.81	0.793	0.802	0.816
	10	0.88	0.885	0.867	0.893	0.866	0.884	0.911
	25	0.968	0.977	0.946	0.996	0.955	0.984	1.029
	50	1.029	1.042	1.001	1.071	1.019	1.056	1.115
	100	1.087	1.104	1.052	1.146	1.082	1.127	1.2
	200	1.143	1.163	1.101	1.22	1.143	1.197	1.283
	1000	1.265	1.295	1.209	1.391	1.283	1.356	1.476
Standard deviation	5	0.019	0.019	0.018	0.021	0.018	0.018	0.022
	10	0.023	0.025	0.021	0.026	0.021	0.023	0.03
	25	0.03	0.036	0.026	0.034	0.026	0.03	0.042
	50	0.037	0.044	0.031	0.04	0.03	0.036	0.052
	100	0.044	0.054	0.036	0.046	0.035	0.042	0.062
	200	0.051	0.063	0.041	0.053	0.04	0.048	0.072
	1000	0.07	0.087	0.054	0.067	0.052	0.064	0.096
Goodness-of-fit statistics	CHISQ	9.228	7.709	11.506	9.228	14.797	8.722	7.456
	KS	0.101	0.106	0.095	0.099	0.109	0.114	0.12
	SLSC	0.042	0.043	0.038	0.042	0.045	0.045	0.051
	PPCC1	0.983	0.982	0.986	0.979	0.979	0.976	0.97
	PPCC2	0.978	0.977	0.982	0.979	0.979	0.976	0.97
	LLM	70.814	70.837	70.394	70.793	66.011	68.488	69.399

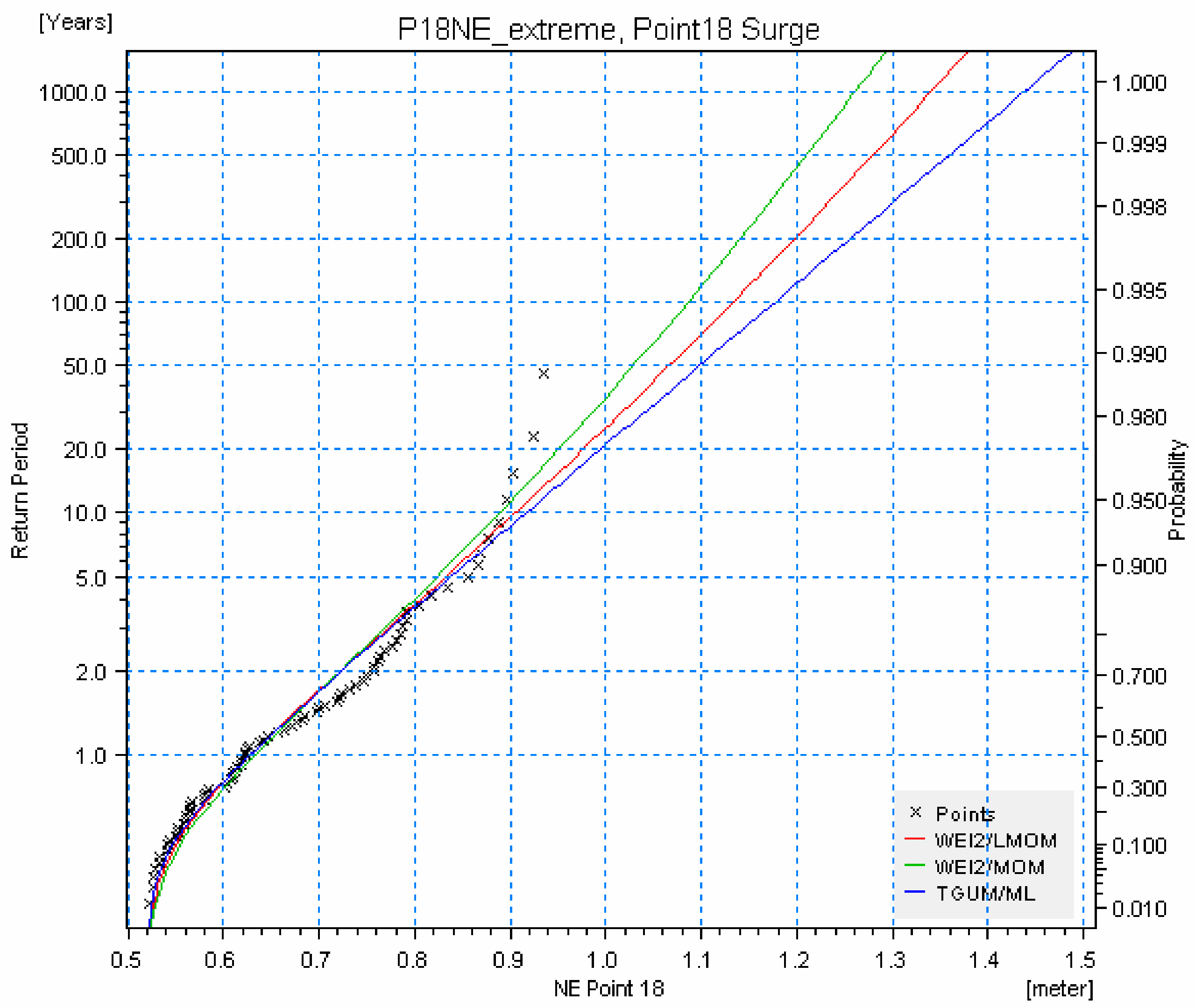
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 18								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.819	0.82	0.811	0.823	0.806	0.816	0.829
	10	0.901	0.906	0.884	0.91	0.883	0.904	0.929
	25	0.998	1.009	0.969	1.019	0.977	1.011	1.053
	50	1.067	1.082	1.029	1.098	1.045	1.089	1.145
	100	1.133	1.152	1.086	1.177	1.112	1.166	1.235
	200	1.197	1.221	1.14	1.255	1.178	1.242	1.325
	1000	1.34	1.374	1.26	1.437	1.327	1.417	1.531
Average quantile	5	0.819	0.822	0.811	0.824	0.806	0.816	0.831
	10	0.9	0.909	0.885	0.912	0.884	0.903	0.933
	25	0.997	1.013	0.97	1.021	0.978	1.01	1.06
	50	1.065	1.087	1.03	1.101	1.046	1.088	1.153
	100	1.13	1.159	1.086	1.18	1.112	1.165	1.245
	200	1.193	1.228	1.14	1.259	1.178	1.24	1.337
	1000	1.333	1.383	1.26	1.441	1.328	1.413	1.548
Standard deviation	5	0.02	0.021	0.019	0.022	0.019	0.02	0.023
	10	0.024	0.028	0.022	0.028	0.022	0.024	0.032
	25	0.032	0.04	0.027	0.036	0.027	0.032	0.045
	50	0.039	0.051	0.032	0.043	0.032	0.038	0.055
	100	0.047	0.062	0.037	0.05	0.036	0.044	0.065
	200	0.056	0.074	0.042	0.057	0.041	0.051	0.076
	1000	0.078	0.103	0.057	0.074	0.054	0.068	0.102
Goodness-of-fit statistics	CHISQ	8.215	6.949	12.013	8.215	16.57	7.203	6.443
	KS	0.089	0.093	0.091	0.085	0.111	0.098	0.098
	SLSC	0.045	0.047	0.042	0.044	0.046	0.046	0.053
	PPCC1	0.98	0.978	0.985	0.977	0.978	0.974	0.967
	PPCC2	0.975	0.972	0.979	0.977	0.978	0.974	0.967
	LLM	70.113	70.182	69.441	70.542	65.16	68.101	69.15

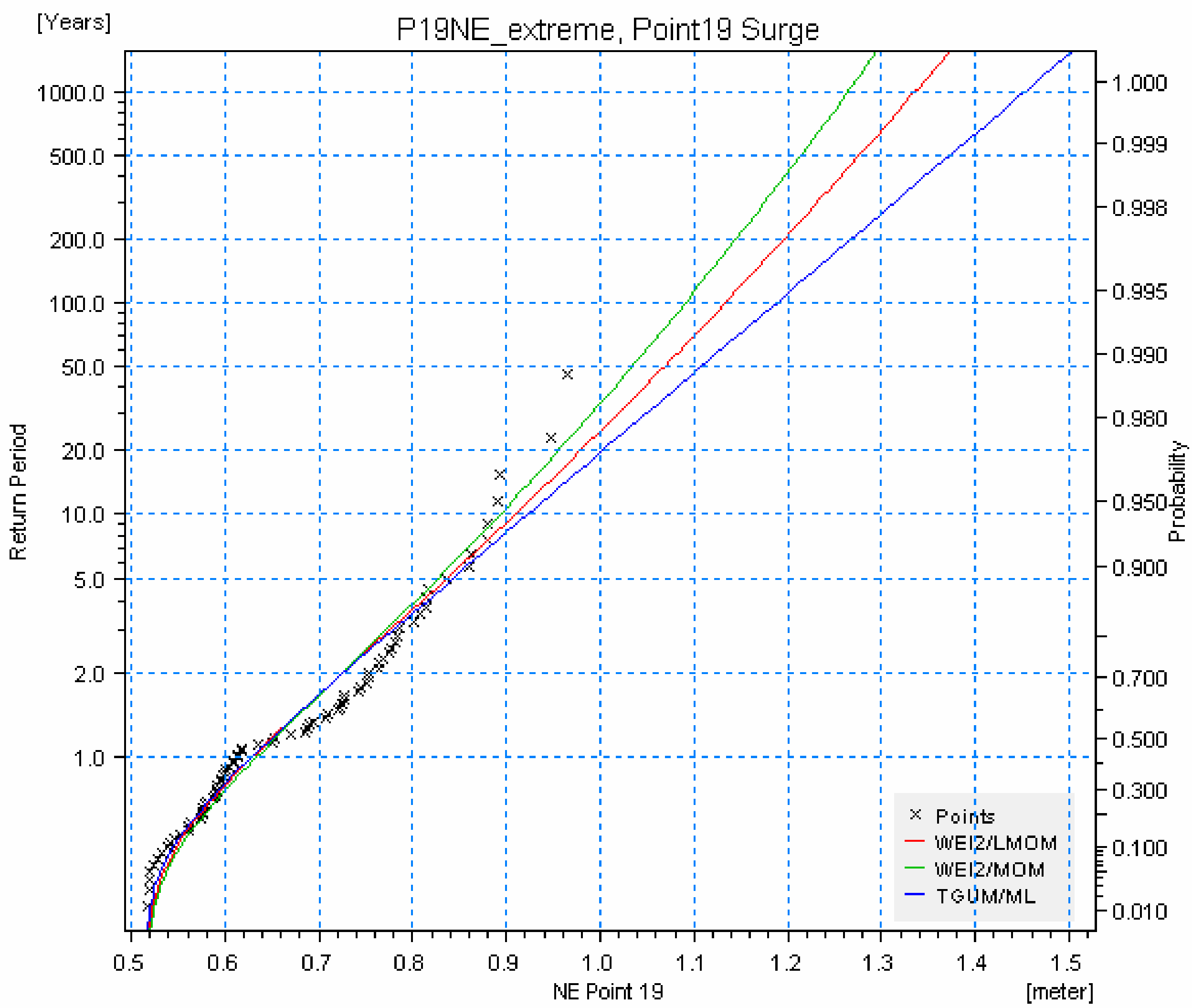
RPS Consulting Engineers	Client: OPW		MIKEZero
	Project: ICPSS, Phase 3		
Date: 02/05/08	Probability table	Drawing no. CR0071	
Init: C.Robinson			



RPS Consulting Engineers	Client: OPW Project: ICPSS, Phase 3	MIKEZero
Date: 02/05/08 Init: C.Robinson	Probability plot	Drawing no. CR0071

ICPSS III Surge								
Point 19								
		D/E Combination						
	Return Period [years]	WEI2/LMOM	WEI2/ML	WEI2/MOM	TGUM/ML	GAM/MOM	GAM/LMOM	GAM/ML
Estimated quantile	5	0.822	0.828	0.815	0.828	0.81	0.82	0.84
	10	0.904	0.919	0.888	0.917	0.888	0.908	0.948
	25	1	1.028	0.974	1.027	0.983	1.015	1.083
	50	1.068	1.106	1.034	1.108	1.051	1.093	1.183
	100	1.133	1.182	1.09	1.188	1.118	1.17	1.281
	200	1.196	1.255	1.144	1.267	1.185	1.246	1.379
	1000	1.335	1.42	1.263	1.451	1.335	1.42	1.605
Average quantile	5	0.822	0.829	0.815	0.829	0.81	0.82	0.842
	10	0.904	0.921	0.889	0.919	0.888	0.907	0.951
	25	0.999	1.031	0.975	1.03	0.983	1.014	1.088
	50	1.066	1.109	1.034	1.111	1.052	1.092	1.189
	100	1.13	1.184	1.09	1.191	1.119	1.168	1.289
	200	1.191	1.258	1.144	1.271	1.185	1.243	1.389
	1000	1.327	1.421	1.262	1.456	1.335	1.416	1.617
Standard deviation	5	0.02	0.021	0.019	0.022	0.019	0.02	0.024
	10	0.024	0.03	0.022	0.028	0.022	0.024	0.034
	25	0.032	0.045	0.028	0.036	0.028	0.032	0.049
	50	0.039	0.059	0.033	0.043	0.032	0.038	0.062
	100	0.048	0.073	0.038	0.05	0.037	0.045	0.074
	200	0.056	0.088	0.044	0.057	0.043	0.052	0.087
	1000	0.078	0.124	0.059	0.074	0.056	0.069	0.119
Goodness-of-fit statistics	CHISQ	19.861	15.557	17.329	18.595	15.304	17.835	13.785
	KS	0.11	0.116	0.109	0.106	0.122	0.12	0.12
	SLSC	0.043	0.05	0.039	0.044	0.047	0.046	0.058
	PPCC1	0.98	0.975	0.984	0.977	0.978	0.974	0.963
	PPCC2	0.977	0.971	0.981	0.977	0.978	0.974	0.963
	LLM	66.428	66.784	65.467	67.95	59.005	62.989	65.586

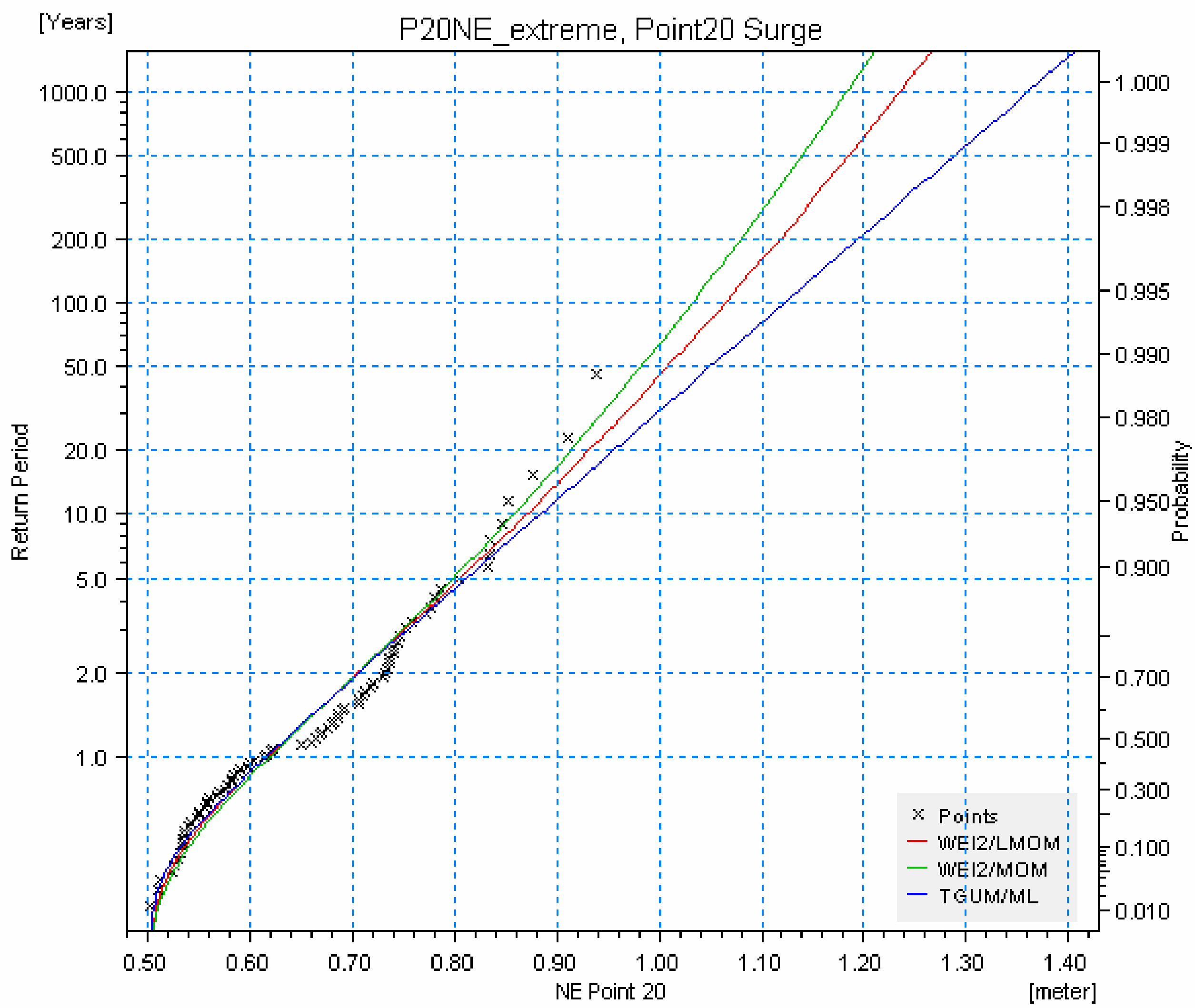
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKEZero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers	Client: OPW Project: ICPSS, Phase 3	MIKE Zero
Date: 02/05/08	Probability plot	Drawing no. CR0071
Init: C.Robinson		

ICPSS III Surge								
Point 20								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.793	0.792	0.787	0.798	0.782	0.791	0.799
	10	0.866	0.864	0.853	0.878	0.853	0.87	0.886
	25	0.95	0.947	0.93	0.978	0.94	0.966	0.992
	50	1.008	1.005	0.983	1.05	1.002	1.036	1.07
	100	1.064	1.06	1.032	1.122	1.062	1.105	1.146
	200	1.117	1.113	1.08	1.194	1.122	1.172	1.221
	1000	1.235	1.229	1.183	1.36	1.258	1.326	1.393
Average quantile	5	0.793	0.793	0.787	0.799	0.782	0.791	0.801
	10	0.865	0.866	0.854	0.88	0.854	0.87	0.889
	25	0.949	0.951	0.93	0.979	0.94	0.966	0.997
	50	1.007	1.01	0.983	1.053	1.002	1.035	1.076
	100	1.061	1.066	1.033	1.125	1.063	1.103	1.154
	200	1.114	1.12	1.08	1.197	1.123	1.17	1.231
	1000	1.229	1.237	1.182	1.364	1.258	1.323	1.406
Standard deviation	5	0.018	0.019	0.018	0.02	0.018	0.018	0.021
	10	0.022	0.024	0.021	0.026	0.021	0.023	0.028
	25	0.03	0.032	0.027	0.033	0.027	0.03	0.038
	50	0.037	0.039	0.032	0.039	0.031	0.036	0.046
	100	0.044	0.047	0.037	0.044	0.036	0.042	0.054
	200	0.051	0.055	0.042	0.05	0.041	0.048	0.062
	1000	0.07	0.073	0.056	0.064	0.054	0.064	0.081
Goodness-of-fit statistics	CHISQ	14.291	14.291	12.772	15.557	17.329	13.785	13.785
	KS	0.107	0.108	0.101	0.106	0.116	0.121	0.126
	SLSC	0.037	0.036	0.033	0.04	0.043	0.043	0.046
	PPCC1	0.985	0.985	0.987	0.981	0.981	0.978	0.975
	PPCC2	0.983	0.984	0.987	0.981	0.981	0.978	0.975
	LLM	71.648	71.644	71.325	71.389	67.02	69.214	70.033

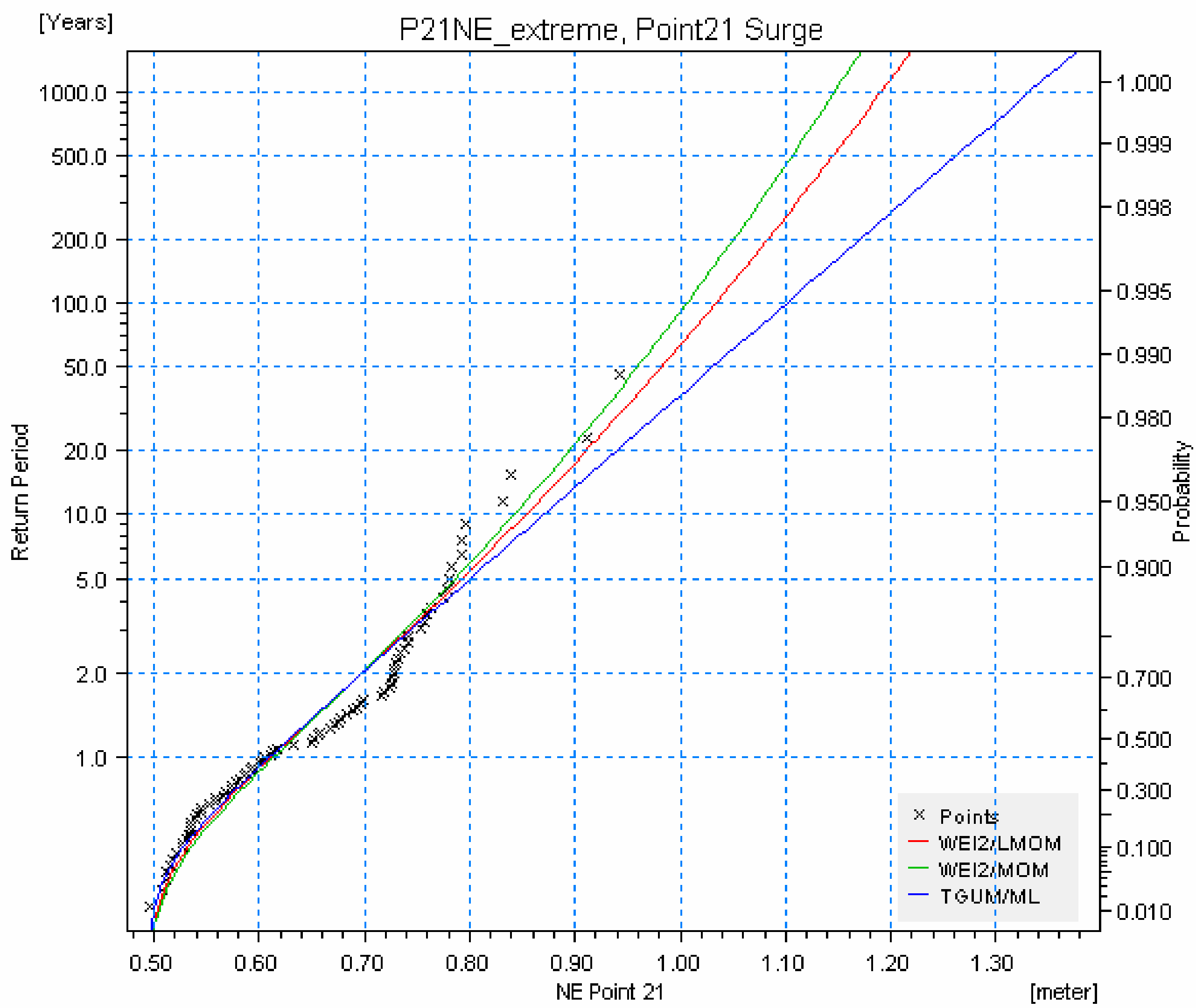
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW
		Project: ICPSS, Phase 3
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 21								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.781	0.779	0.775	0.787	0.77	0.779	0.787
	10	0.849	0.847	0.838	0.865	0.838	0.854	0.87
	25	0.928	0.926	0.91	0.961	0.92	0.945	0.972
	50	0.982	0.98	0.96	1.032	0.979	1.011	1.046
	100	1.034	1.031	1.006	1.101	1.037	1.075	1.118
	200	1.083	1.08	1.05	1.17	1.093	1.139	1.19
	1000	1.19	1.187	1.146	1.331	1.221	1.284	1.353
Average quantile	5	0.781	0.781	0.776	0.788	0.771	0.779	0.789
	10	0.849	0.85	0.839	0.867	0.839	0.853	0.873
	25	0.927	0.93	0.911	0.963	0.921	0.944	0.977
	50	0.98	0.985	0.96	1.034	0.98	1.01	1.052
	100	1.031	1.037	1.006	1.104	1.038	1.074	1.126
	200	1.08	1.086	1.05	1.173	1.094	1.137	1.199
	1000	1.185	1.195	1.145	1.334	1.222	1.281	1.366
Standard deviation	5	0.017	0.018	0.017	0.019	0.017	0.017	0.02
	10	0.021	0.022	0.02	0.024	0.02	0.021	0.026
	25	0.028	0.03	0.026	0.031	0.026	0.027	0.034
	50	0.034	0.037	0.031	0.036	0.031	0.033	0.041
	100	0.041	0.044	0.036	0.041	0.036	0.039	0.048
	200	0.048	0.051	0.042	0.046	0.041	0.045	0.055
	1000	0.065	0.068	0.055	0.059	0.053	0.06	0.073
Goodness-of-fit statistics	CHISQ	14.291	14.797	17.835	14.797	30.241	22.899	16.823
	KS	0.116	0.118	0.119	0.112	0.133	0.126	0.121
	SLSC	0.042	0.042	0.039	0.045	0.048	0.048	0.051
	PPCC1	0.98	0.98	0.983	0.976	0.976	0.973	0.969
	PPCC2	0.978	0.978	0.981	0.976	0.976	0.973	0.969
	LLM	73.436	73.434	73.107	73.127	68.133	70.464	71.532

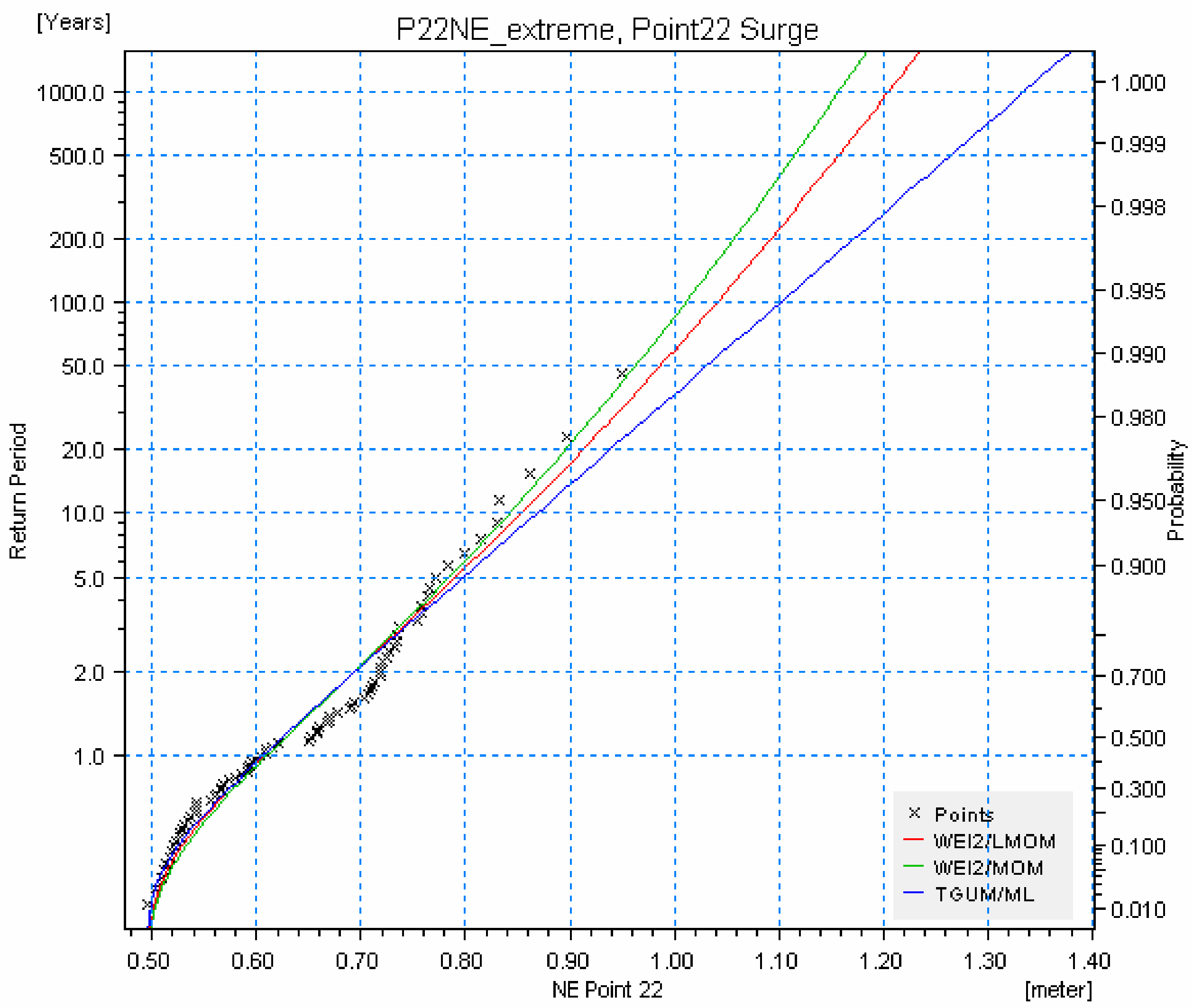
RPS Consulting Engineers
Client: OPW
Project: ICPSS, Phase 3
MIKEZero
Date: 02/05/08
Init: C.Robinson
Probability table
Drawing no. CR0071



RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKEZero
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 22								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.779	0.778	0.773	0.785	0.768	0.777	0.786
	10	0.849	0.849	0.838	0.863	0.838	0.853	0.871
	25	0.93	0.93	0.912	0.96	0.921	0.947	0.976
	50	0.987	0.987	0.963	1.031	0.982	1.014	1.052
	100	1.04	1.041	1.011	1.102	1.041	1.08	1.127
	200	1.092	1.093	1.057	1.172	1.098	1.145	1.201
	1000	1.205	1.206	1.157	1.334	1.23	1.294	1.37
Average quantile	5	0.779	0.78	0.774	0.786	0.769	0.777	0.788
	10	0.849	0.852	0.839	0.865	0.838	0.853	0.875
	25	0.929	0.935	0.913	0.962	0.922	0.946	0.983
	50	0.985	0.994	0.964	1.034	0.983	1.013	1.061
	100	1.038	1.049	1.012	1.104	1.042	1.079	1.138
	200	1.088	1.102	1.057	1.175	1.099	1.144	1.214
	1000	1.199	1.218	1.157	1.337	1.231	1.291	1.388
Standard deviation	5	0.018	0.018	0.018	0.02	0.017	0.018	0.02
	10	0.022	0.024	0.021	0.025	0.021	0.022	0.027
	25	0.03	0.032	0.028	0.032	0.027	0.03	0.037
	50	0.037	0.04	0.033	0.037	0.032	0.036	0.045
	100	0.044	0.048	0.039	0.043	0.038	0.042	0.053
	200	0.052	0.056	0.044	0.048	0.043	0.049	0.061
	1000	0.071	0.076	0.059	0.062	0.056	0.065	0.08
Goodness-of-fit statistics	CHISQ	15.304	15.304	16.063	17.582	20.873	20.114	15.81
	KS	0.109	0.112	0.109	0.109	0.124	0.123	0.131
	SLSC	0.035	0.036	0.032	0.04	0.043	0.042	0.047
	PPCC1	0.985	0.985	0.987	0.982	0.982	0.979	0.975
	PPCC2	0.985	0.984	0.988	0.982	0.982	0.979	0.975
	LLM	73.856	73.867	73.554	73.475	69.321	71.429	72.298

RPS Consulting Engineers		Client: OPW	
		Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW	
		Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 23								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.811	0.822	0.804	0.825	0.799	0.808	0.838
	10	0.881	0.908	0.868	0.909	0.868	0.886	0.945
	25	0.962	1.011	0.941	1.014	0.951	0.979	1.08
	50	1.019	1.084	0.991	1.091	1.011	1.047	1.179
	100	1.072	1.155	1.038	1.166	1.069	1.114	1.276
	200	1.123	1.223	1.083	1.242	1.126	1.179	1.374
	1000	1.235	1.376	1.181	1.417	1.256	1.328	1.598
Average quantile	5	0.811	0.824	0.804	0.826	0.799	0.808	0.841
	10	0.88	0.911	0.868	0.911	0.868	0.885	0.95
	25	0.961	1.015	0.941	1.016	0.952	0.978	1.087
	50	1.016	1.089	0.991	1.093	1.011	1.046	1.188
	100	1.068	1.16	1.038	1.169	1.07	1.111	1.288
	200	1.118	1.228	1.083	1.245	1.127	1.176	1.388
	1000	1.227	1.381	1.179	1.42	1.256	1.324	1.617
Standard deviation	5	0.016	0.018	0.016	0.018	0.016	0.016	0.02
	10	0.02	0.027	0.018	0.022	0.018	0.02	0.028
	25	0.029	0.044	0.024	0.029	0.024	0.028	0.042
	50	0.037	0.059	0.029	0.034	0.028	0.034	0.053
	100	0.045	0.075	0.034	0.04	0.033	0.042	0.065
	200	0.054	0.091	0.04	0.045	0.038	0.049	0.077
	1000	0.076	0.13	0.054	0.059	0.05	0.067	0.106
Goodness-of-fit statistics	CHISQ	23.911	20.873	26.443	18.595	35.304	29.987	23.911
	KS	0.137	0.172	0.125	0.143	0.142	0.15	0.195
	SLSC	0.046	0.061	0.04	0.055	0.053	0.053	0.073
	PPCC1	0.975	0.963	0.979	0.967	0.97	0.965	0.945
	PPCC2	0.975	0.961	0.98	0.967	0.97	0.965	0.945
	LLM	67.83	69.012	66.477	71.028	54.561	60.66	67.415

RPS Consulting Engineers

Client: OPW

Project: ICPSS, Phase 3

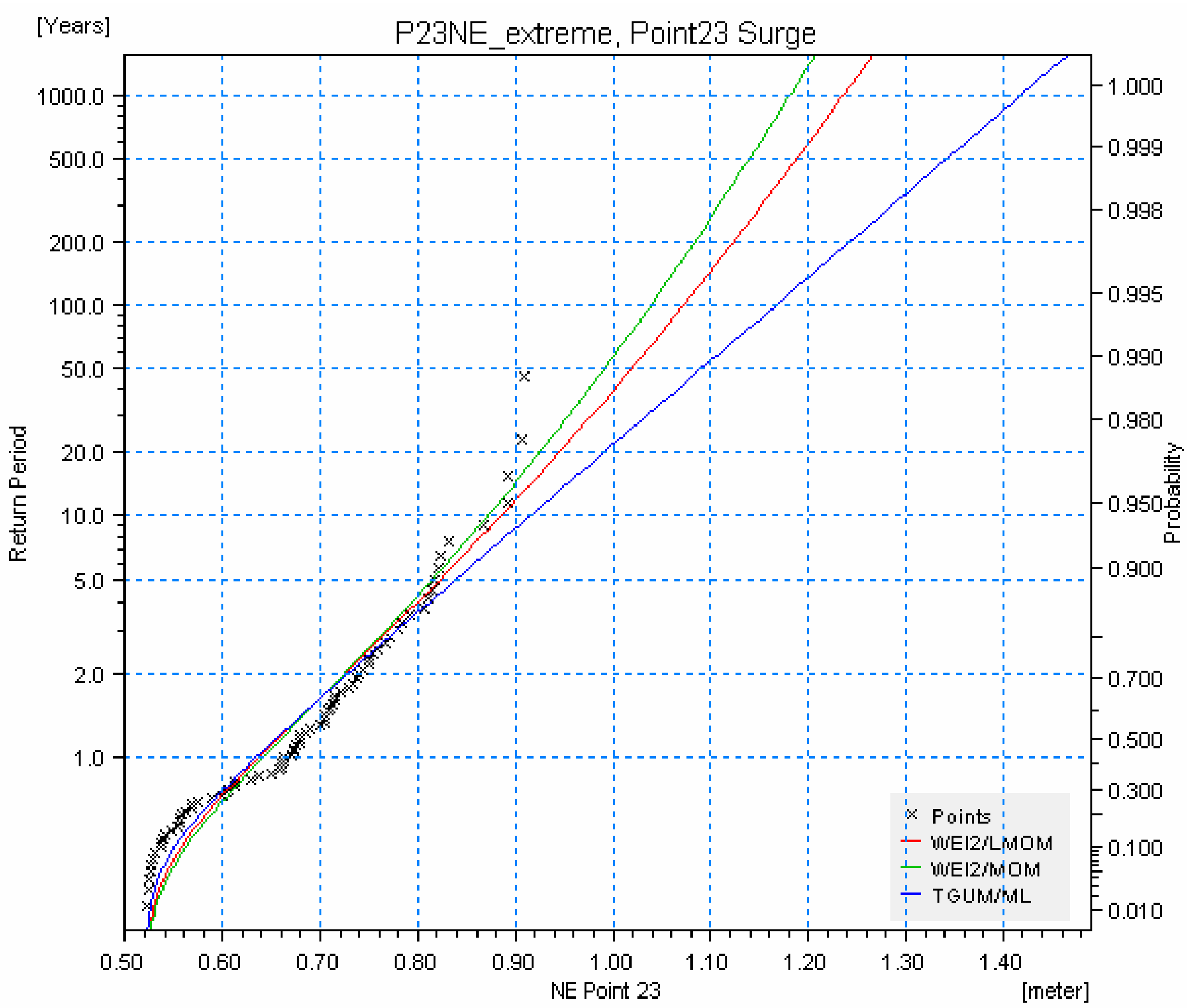
MIKE Zero

Date: 02/05/08

Init: C.Robinson

Probability table

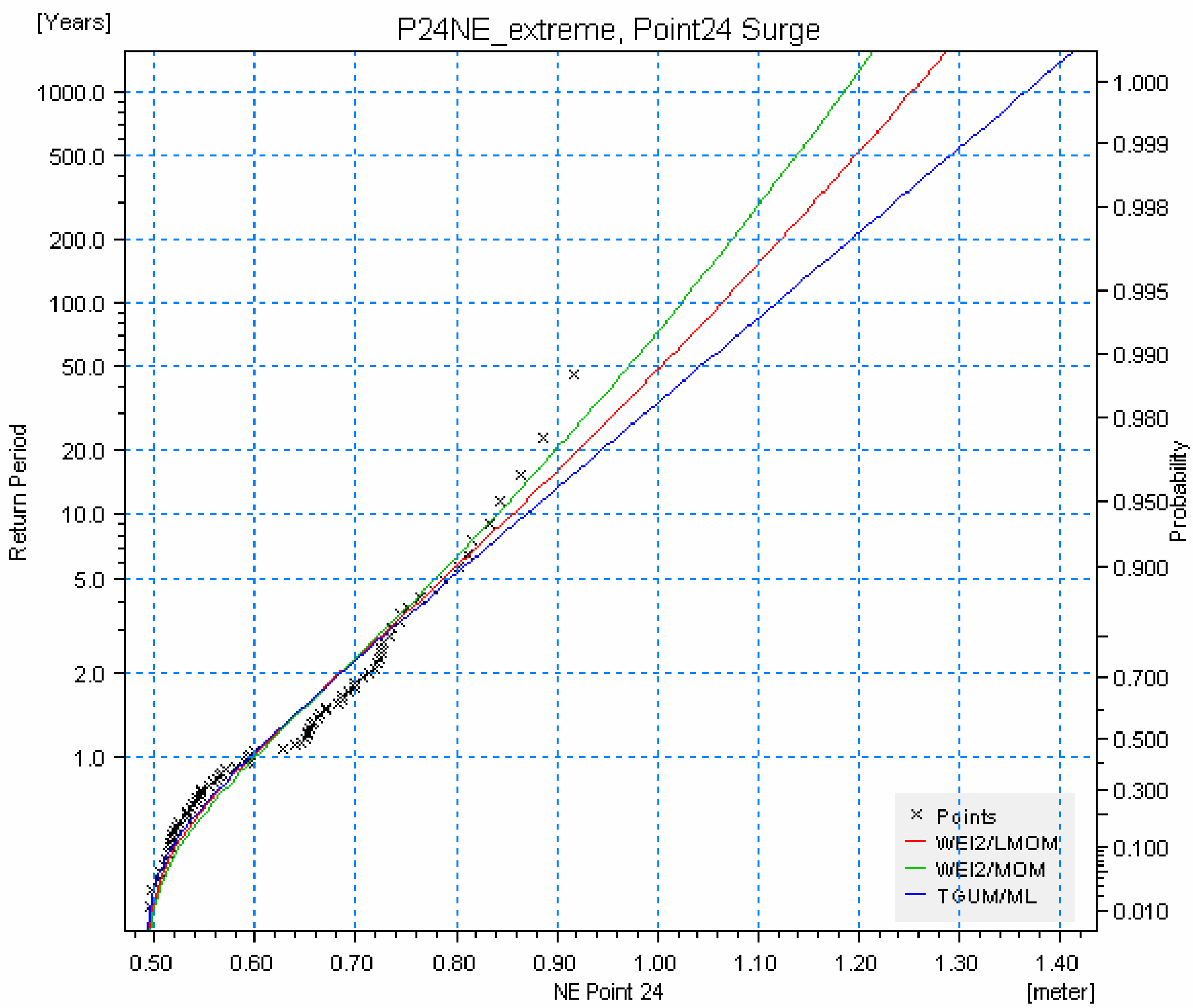
Drawing no. CR0071



RPS Consulting Engineers		Client: OPW
		Project: ICPSS, Phase 3
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

ICPSS III Surge								
Point 24								
		D/E Combination						
	Return Period [years]	**WEI2/LMOM**	**WEI2/ML**	**WEI2/MOM**	**TGUM/ML**	**GAM/MOM**	**GAM/LMOM**	**GAM/ML**
Estimated quantile	5	0.775	0.776	0.768	0.781	0.763	0.773	0.783
	10	0.851	0.854	0.836	0.864	0.835	0.854	0.875
	25	0.94	0.948	0.916	0.967	0.923	0.954	0.99
	50	1.003	1.014	0.971	1.043	0.987	1.026	1.074
	100	1.064	1.077	1.024	1.118	1.049	1.097	1.156
	200	1.122	1.139	1.074	1.192	1.111	1.168	1.238
	1000	1.252	1.275	1.185	1.364	1.25	1.329	1.426
Average quantile	5	0.775	0.778	0.768	0.782	0.763	0.773	0.786
	10	0.85	0.859	0.837	0.866	0.836	0.854	0.881
	25	0.939	0.955	0.916	0.969	0.924	0.953	1
	50	1.001	1.023	0.972	1.045	0.988	1.025	1.087
	100	1.061	1.088	1.024	1.12	1.05	1.096	1.172
	200	1.118	1.152	1.074	1.195	1.111	1.166	1.257
	1000	1.245	1.293	1.184	1.368	1.251	1.326	1.453
Standard deviation	5	0.018	0.019	0.018	0.02	0.017	0.018	0.022
	10	0.022	0.025	0.021	0.025	0.021	0.023	0.029
	25	0.03	0.036	0.026	0.032	0.026	0.03	0.041
	50	0.038	0.045	0.031	0.038	0.031	0.036	0.05
	100	0.046	0.055	0.037	0.044	0.036	0.043	0.06
	200	0.055	0.066	0.043	0.05	0.041	0.05	0.07
	1000	0.076	0.091	0.058	0.064	0.054	0.066	0.093
Goodness-of-fit statistics	CHISQ	16.823	13.278	20.114	14.291	22.139	18.595	15.81
	KS	0.129	0.135	0.121	0.127	0.133	0.14	0.148
	SLSC	0.04	0.043	0.036	0.043	0.046	0.045	0.051
	PPCC1	0.981	0.98	0.985	0.978	0.979	0.975	0.969
	PPCC2	0.98	0.978	0.985	0.978	0.979	0.975	0.969
	LLM	74.286	74.326	73.763	74.215	69.831	72.373	73.241

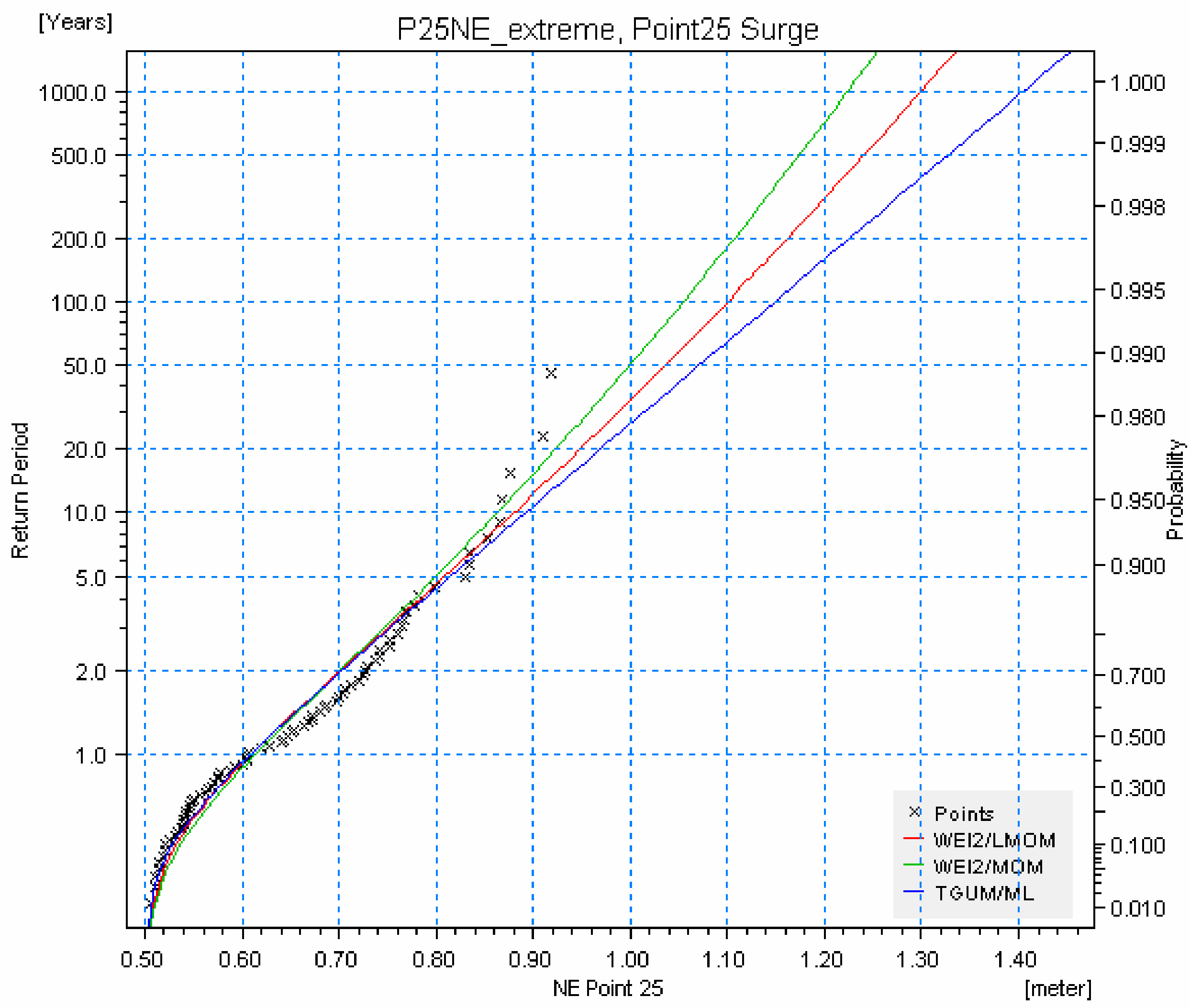
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKEZero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



	Client: OPW	
RPS Consulting Engineers	Project: ICPSS, Phase 3	
Date: 02/05/08	Probability plot	Drawing no. CR0071
Init: C.Robinson		

ICPSS III Surge								
Point 25								
		D/E Combination						
	Return Period [years]	WEI2/LMOM	WEI2/ML	WEI2/MOM	TGUM/ML	GAM/MOM	GAM/LMOM	GAM/ML
Estimated quantile	5	0.795	0.796	0.787	0.8	0.783	0.793	0.803
	10	0.875	0.878	0.859	0.886	0.858	0.878	0.899
	25	0.969	0.975	0.942	0.993	0.949	0.982	1.018
	50	1.036	1.044	0.999	1.071	1.016	1.058	1.105
	100	1.1	1.11	1.054	1.148	1.08	1.133	1.191
	200	1.161	1.175	1.107	1.225	1.144	1.207	1.276
	1000	1.298	1.318	1.223	1.403	1.29	1.376	1.471
Average quantile	5	0.795	0.798	0.788	0.802	0.783	0.793	0.805
	10	0.875	0.881	0.859	0.888	0.858	0.878	0.903
	25	0.968	0.98	0.942	0.995	0.95	0.981	1.024
	50	1.034	1.05	1	1.074	1.016	1.057	1.112
	100	1.096	1.117	1.054	1.151	1.081	1.131	1.2
	200	1.157	1.182	1.107	1.228	1.145	1.205	1.287
	1000	1.291	1.328	1.222	1.407	1.29	1.372	1.487
Standard deviation	5	0.019	0.02	0.019	0.021	0.018	0.019	0.022
	10	0.023	0.026	0.021	0.027	0.022	0.023	0.03
	25	0.031	0.037	0.027	0.034	0.027	0.031	0.041
	50	0.039	0.046	0.032	0.041	0.031	0.037	0.05
	100	0.047	0.056	0.037	0.047	0.036	0.044	0.059
	200	0.056	0.066	0.043	0.054	0.041	0.051	0.068
	1000	0.077	0.092	0.057	0.069	0.054	0.068	0.091
Goodness-of-fit statistics	CHISQ	8.215	7.962	9.481	6.443	15.051	9.228	8.215
	KS	0.084	0.088	0.097	0.08	0.117	0.093	0.101
	SLSC	0.042	0.044	0.038	0.043	0.045	0.045	0.051
	PPCC1	0.982	0.98	0.986	0.979	0.98	0.975	0.97
	PPCC2	0.978	0.976	0.982	0.979	0.98	0.975	0.97
	LLM	71.696	71.736	71.105	71.827	67.038	69.788	70.671

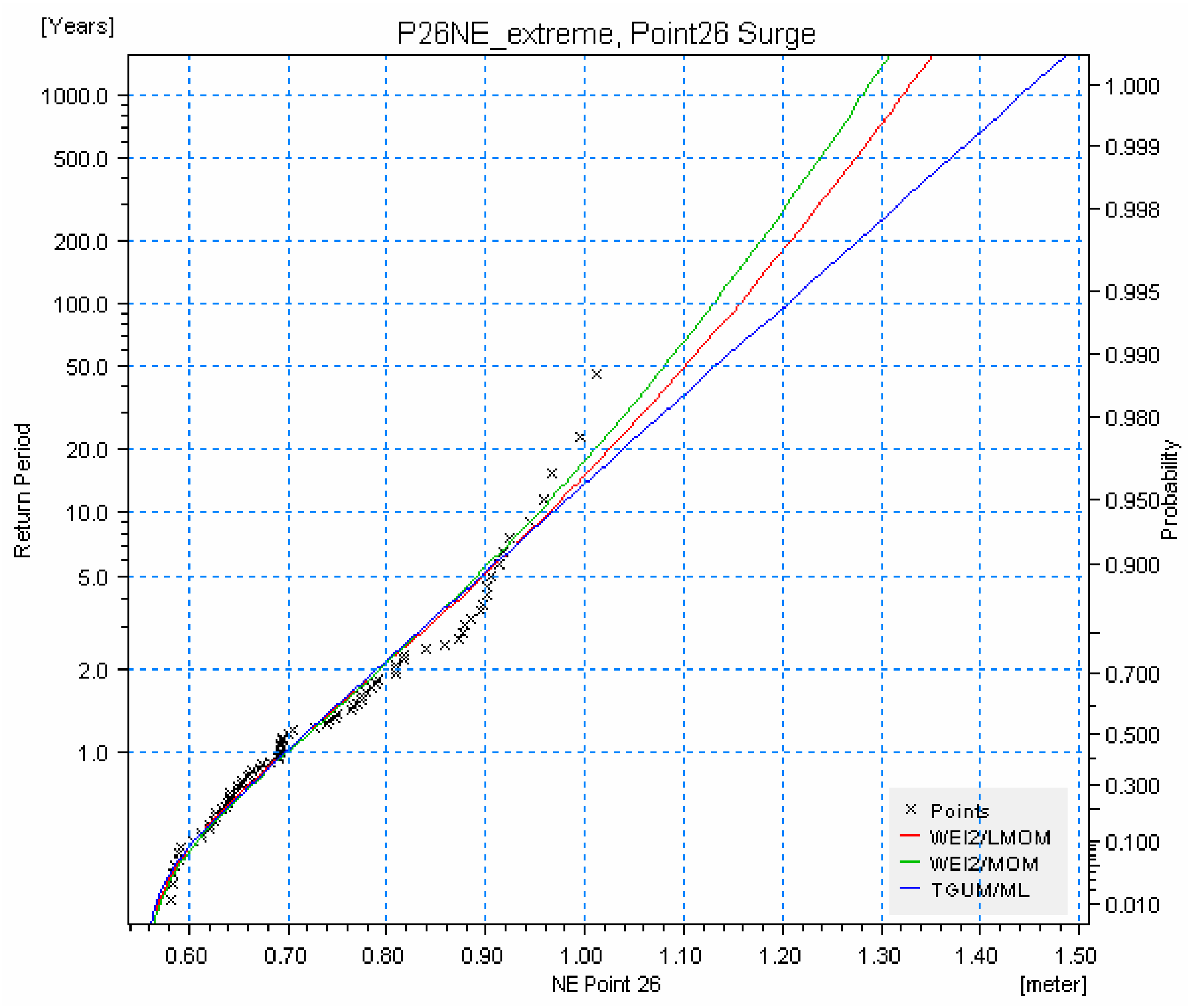
RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW	
		Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

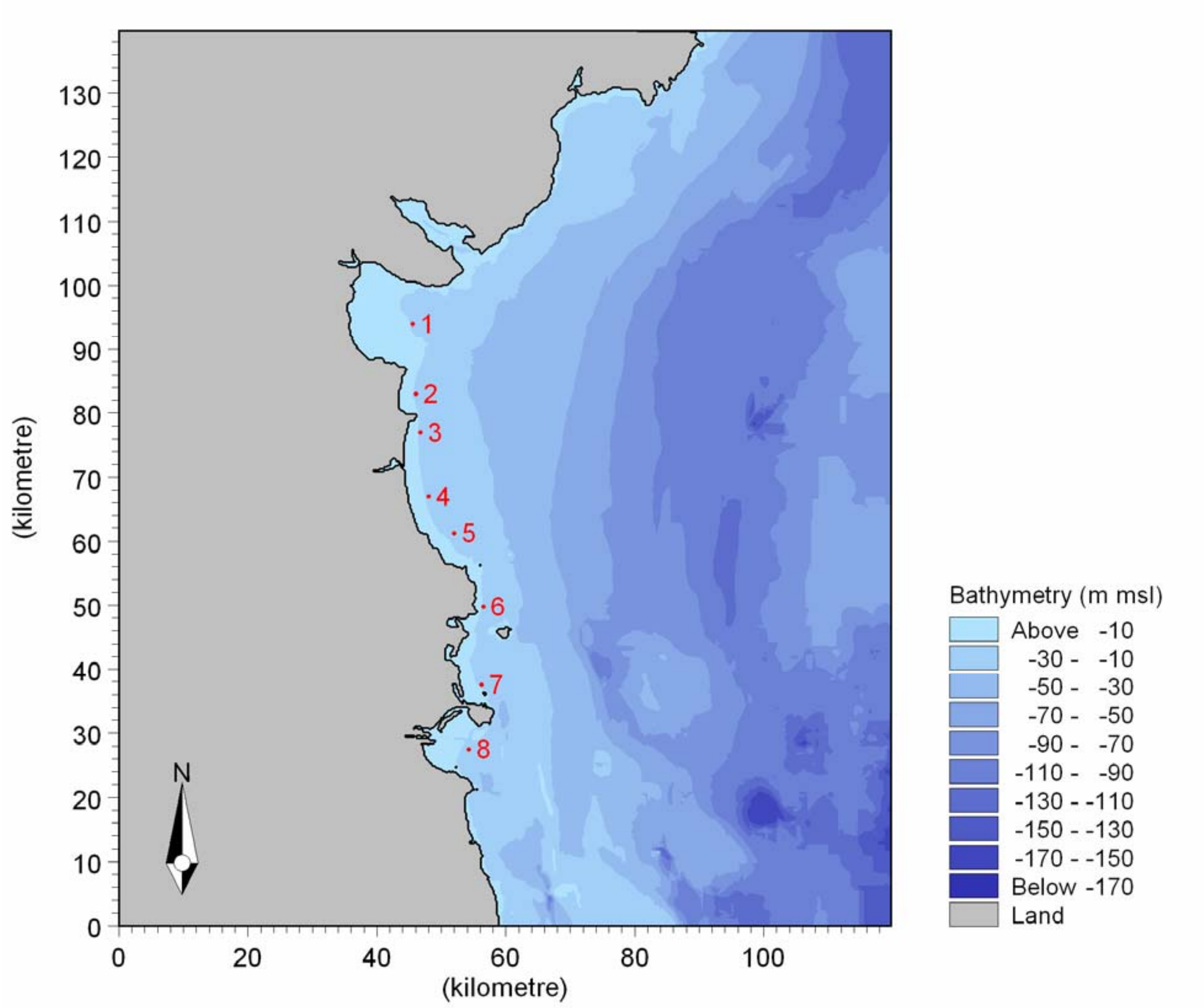
ICPSS III Surge								
Point 26								
		D/E Combination						
	Return Period [years]	WEI2/LMOM	WEI2/ML	WEI2/MOM	TGUM/ML	GAM/MOM	GAM/LMOM	GAM/ML
Estimated quantile	5	0.864	0.869	0.856	0.874	0.851	0.862	0.883
	10	0.941	0.955	0.925	0.962	0.925	0.945	0.988
	25	1.031	1.057	1.005	1.071	1.015	1.048	1.119
	50	1.094	1.129	1.059	1.151	1.079	1.122	1.215
	100	1.153	1.198	1.111	1.23	1.142	1.194	1.31
	200	1.211	1.264	1.16	1.309	1.204	1.266	1.404
	1000	1.337	1.413	1.267	1.491	1.345	1.429	1.621
Average quantile	5	0.864	0.871	0.856	0.876	0.851	0.862	0.885
	10	0.941	0.958	0.926	0.964	0.925	0.945	0.992
	25	1.029	1.061	1.005	1.074	1.015	1.047	1.125
	50	1.091	1.133	1.059	1.154	1.079	1.12	1.223
	100	1.15	1.203	1.111	1.233	1.142	1.192	1.32
	200	1.206	1.27	1.16	1.313	1.204	1.263	1.416
	1000	1.329	1.419	1.266	1.495	1.345	1.425	1.637
Standard deviation	5	0.017	0.019	0.017	0.02	0.017	0.017	0.022
	10	0.021	0.026	0.02	0.025	0.02	0.021	0.03
	25	0.029	0.04	0.024	0.032	0.025	0.028	0.042
	50	0.036	0.052	0.029	0.038	0.029	0.034	0.053
	100	0.044	0.064	0.034	0.044	0.033	0.041	0.063
	200	0.053	0.077	0.04	0.05	0.038	0.047	0.074
	1000	0.074	0.11	0.054	0.065	0.051	0.064	0.101
Goodness-of-fit statistics	CHISQ	21.886	13.532	19.608	15.557	22.646	22.646	15.304
	KS	0.112	0.122	0.108	0.108	0.131	0.125	0.131
	SLSC	0.047	0.054	0.042	0.05	0.051	0.051	0.064
	PPCC1	0.977	0.971	0.982	0.971	0.973	0.968	0.955
	PPCC2	0.973	0.966	0.979	0.971	0.973	0.968	0.955
	LLM	66.342	66.686	65.34	67.645	57.466	62.051	65.07

RPS Consulting Engineers		Client: OPW	MIKEZero
		Project: ICPSS, Phase 3	
	Date: 02/05/08	Probability table	Drawing no. CR0071
	Init: C.Robinson		



RPS Consulting Engineers		Client: OPW Project: ICPSS, Phase 3	MIKE Zero
	Date: 02/05/08	Probability plot	Drawing no. CR0071
	Init: C.Robinson		

Appendix 4: Wave Modelling Tables showing Inshore Wave Climate at 8 Locations



Locations of Eight Wave Modelling Points

Output Point 1 -6.224654 53.92582

	Inshore Climate		
	Hm0	Tm	MWD
1in5	1.936	4.164	32.661
1in20	1.588	3.843	30.458
1in100	1.205	3.442	28.423
1in5	2.538	5.620	62.782
1in20	2.096	5.174	60.880
1in100	1.614	4.615	58.526
1in5	3.879	7.657	85.995
1in20	3.410	7.251	84.602
1in100	2.874	6.732	82.902
1in5	4.481	8.012	98.780
1in20	4.004	7.578	98.303
1in100	3.412	7.026	97.464
1in5	4.518	8.193	111.511
1in20	4.069	7.750	111.750
1in100	3.494	7.185	111.885
1in5	5.257	10.005	120.221
1in20	5.108	9.560	120.163
1in100	4.793	8.860	121.578
1in5	4.667	8.947	132.658
1in20	4.395	8.480	134.043
1in100	3.955	7.871	136.275

Output Point 2 -6.2186 53.82696

	Inshore Climate		
	Hm0	Tm	MWD
1in5	2.559	5.620	38.076
1in20	2.193	5.187	34.867
1in100	1.742	4.649	31.255
1in5	3.413	6.838	59.268
1in20	2.865	6.281	55.493
1in100	2.255	5.587	51.127
1in5	4.771	8.113	77.443
1in20	4.203	7.679	76.413
1in100	3.543	7.128	75.042
1in5	5.271	8.114	91.574
1in20	4.652	7.662	91.541
1in100	3.907	7.088	91.508
1in5	5.171	8.186	106.581
1in20	4.556	7.738	107.332
1in100	3.824	7.174	108.583
1in5	6.507	10.019	116.244
1in20	6.072	9.393	117.823
1in100	5.303	8.580	120.556
1in5	5.459	9.081	129.540
1in20	4.922	8.372	132.163
1in100	4.228	7.673	135.060

Output Point 3 -6.208076 53.773

	Inshore Climate		
	Hm0	Tm	MWD
1in5	2.903	6.200	38.170
1in20	2.458	5.736	35.399
1in100	1.935	5.171	31.871
1in5	3.952	7.149	54.687
1in20	3.296	6.598	51.993
1in100	2.543	5.902	48.656
1in5	5.193	8.164	71.768
1in20	4.558	7.728	70.956
1in100	3.819	7.169	70.003
1in5	5.272	8.083	88.003
1in20	4.639	7.627	88.287
1in100	3.891	7.051	88.703
1in5	4.962	8.146	105.142
1in20	4.380	7.701	106.187
1in100	3.698	7.141	107.735
1in5	6.506	9.885	115.958
1in20	6.012	9.196	118.178
1in100	5.252	8.378	121.140
1in5	5.551	9.011	129.678
1in20	5.030	8.121	132.892
1in100	4.349	7.366	136.885

Output Point 4 -6.190603 53.68307

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.207	6.562	26.367
1in20	2.679	5.949	23.829
1in100	2.061	5.227	20.672
1in5	3.619	6.829	45.819
1in20	2.969	6.310	44.988
1in100	2.271	5.394	41.506
1in5	5.192	8.046	66.758
1in20	4.536	7.566	66.010
1in100	3.760	6.957	65.174
1in5	4.885	7.910	84.977
1in20	4.280	7.420	85.314
1in100	3.521	6.807	86.882
1in5	4.378	7.833	102.929
1in20	3.836	7.373	104.078
1in100	3.198	6.788	105.507
1in5	6.475	10.581	103.174
1in20	6.233	9.958	105.013
1in100	5.732	9.114	107.614
1in5	5.463	9.015	117.344
1in20	5.049	7.989	121.196
1in100	4.379	7.357	124.298

1 in 100 Joint Probability Return Period - Points 1- 4

Where return period refers to water level, Hm0 refers to significant wave height in metres, Tm refers to mean wave period in seconds and MWD is the mean wave direction in degrees from True North.

Output Point 5 **-6.131002** **53.63104**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.629	6.773	23.212
1in20	3.024	6.140	19.798
1in100	2.313	5.407	16.233
1in5	3.788	6.938	44.761
1in20	3.118	6.385	43.340
1in100	2.374	5.495	39.544
1in5	5.226	7.958	67.815
1in20	4.538	7.475	66.868
1in100	3.742	6.868	65.590
1in5	5.061	7.905	86.767
1in20	4.376	7.408	86.655
1in100	3.542	6.783	87.563
1in5	4.362	7.909	101.954
1in20	3.760	7.427	102.977
1in100	3.065	6.822	104.638
1in5	6.829	10.152	107.810
1in20	6.376	9.513	108.595
1in100	5.530	8.855	109.511
1in5	5.175	8.025	123.773
1in20	4.513	7.588	125.176
1in100	3.747	7.065	126.600

Output Point 6 **-6.065012** **53.52728**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.018	7.190	38.096
1in20	2.511	6.602	34.726
1in100	1.944	5.818	30.630
1in5	3.707	7.251	54.059
1in20	3.058	6.643	50.915
1in100	2.334	5.848	46.489
1in5	4.903	7.908	69.080
1in20	4.246	7.416	68.414
1in100	3.502	6.791	67.493
1in5	4.549	7.822	85.311
1in20	3.931	7.327	85.880
1in100	3.213	6.709	87.076
1in5	3.774	7.812	100.084
1in20	3.271	7.329	101.442
1in100	2.693	6.715	103.314
1in5	6.095	10.285	106.020
1in20	5.473	9.688	108.735
1in100	4.742	9.014	112.041
1in5	4.615	9.347	123.817
1in20	4.150	8.682	128.318
1in100	3.589	8.025	134.530

Output Point 7 **-6.070923** **53.41726**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	2.946	6.633	37.150
1in20	2.439	6.098	33.247
1in100	1.891	5.418	28.273
1in5	3.866	7.366	55.526
1in20	3.206	6.768	52.590
1in100	2.478	5.980	48.988
1in5	4.580	7.759	71.273
1in20	3.967	7.281	70.773
1in100	3.269	6.676	70.031
1in5	4.567	7.768	87.664
1in20	3.972	7.278	87.939
1in100	3.264	6.666	88.694
1in5	4.139	7.798	101.876
1in20	3.606	7.325	103.058
1in100	2.991	6.728	104.630
1in5	5.885	10.211	105.430
1in20	5.325	9.660	106.729
1in100	4.586	8.975	108.143
1in5	4.356	9.622	111.912
1in20	3.808	9.079	113.273
1in100	3.142	8.360	115.467

Output Point 8 **-6.102684** **53.32763**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	2.149	5.451	51.670
1in20	1.753	4.959	48.262
1in100	1.327	4.361	43.958
1in5	3.131	7.138	69.269
1in20	2.600	6.557	67.761
1in100	1.978	5.818	64.687
1in5	4.251	7.849	84.322
1in20	3.739	7.368	83.158
1in100	3.092	6.761	81.099
1in5	4.589	7.800	97.917
1in20	4.075	7.327	97.618
1in100	3.375	6.721	96.791
1in5	4.533	7.774	113.748
1in20	4.045	7.311	114.592
1in100	3.397	6.729	115.591
1in5	5.585	9.701	128.471
1in20	5.308	9.198	128.099
1in100	4.872	8.569	128.151
1in5	4.807	8.630	140.341
1in20	4.430	8.258	140.029
1in100	3.943	7.769	139.981

1 in 100 Joint Probability Return Period - Points 5- 8

Where return period refers to water level, Hm0 refers to significant wave height in metres, Tm refers to mean wave period in seconds and MWD is the mean wave direction in degrees from True North.

Output Point 1 **-6.224654** **53.92582**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	2.121	4.325	33.800
1in20	1.800	4.196	34.108
1in100	1.380	3.768	30.373
1in5	2.775	5.839	63.623
1in20	2.439	5.846	64.623
1in100	1.883	5.272	61.981
1in5	4.159	7.888	86.543
1in20	3.707	7.499	85.476
1in100	3.158	7.008	83.741
1in5	4.754	8.259	98.954
1in20	4.306	7.843	98.561
1in100	3.726	7.319	97.825
1in5	4.760	8.445	111.388
1in20	4.362	8.021	111.658
1in100	3.805	7.485	111.869
1in5	5.376	10.414	120.048
1in20	5.279	9.903	120.196
1in100	5.074	9.288	120.701
1in5	4.859	9.261	132.031
1in20	4.647	8.841	133.103
1in100	4.289	8.275	134.931

Output Point 2 **-6.2186** **53.82696**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	2.751	5.862	39.782
1in20	2.377	5.674	38.326
1in100	1.916	5.127	34.329
1in5	3.687	7.118	60.768
1in20	3.271	7.055	59.975
1in100	2.600	6.351	55.728
1in5	5.107	8.362	77.866
1in20	4.551	7.943	77.003
1in100	3.889	7.419	75.724
1in5	5.618	8.370	91.582
1in20	5.033	7.937	91.549
1in100	4.295	7.392	91.508
1in5	5.527	8.441	106.257
1in20	4.933	8.011	106.910
1in100	4.204	7.473	107.990
1in5	6.774	10.492	115.385
1in20	6.457	9.864	116.665
1in100	5.851	9.093	118.822
1in5	5.820	9.591	127.859
1in20	5.356	8.897	130.387
1in100	4.703	8.108	133.433

Output Point 3 **-6.208076** **53.773**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.143	6.435	39.403
1in20	2.737	6.276	38.281
1in100	2.187	5.685	34.889
1in5	4.309	7.417	56.118
1in20	3.836	7.314	55.174
1in100	3.016	6.628	52.005
1in5	5.560	8.414	72.117
1in20	4.946	7.994	71.421
1in100	4.205	7.465	70.490
1in5	5.643	8.342	87.899
1in20	5.026	7.905	88.117
1in100	4.282	7.355	88.496
1in5	5.312	8.401	104.699
1in20	4.737	7.972	105.595
1in100	4.054	7.438	106.998
1in5	6.834	10.423	114.796
1in20	6.435	9.723	116.636
1in100	5.781	8.888	119.394
1in5	5.887	9.475	127.843
1in20	5.448	8.812	130.627
1in100	4.816	7.839	134.488

Output Point 4 **-6.190603** **53.68307**

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.496	6.788	27.097
1in20	3.269	6.820	27.110
1in100	2.557	6.145	24.484
1in5	3.944	7.121	46.436
1in20	3.694	7.126	46.075
1in100	2.870	6.380	44.165
1in5	5.559	8.319	67.148
1in20	4.944	7.866	66.380
1in100	4.171	7.284	65.581
1in5	5.244	8.194	84.841
1in20	4.656	7.722	85.149
1in100	3.943	7.141	85.515
1in5	4.677	8.240	101.430
1in20	4.175	7.657	103.486
1in100	3.539	7.103	104.802
1in5	6.617	10.989	102.561
1in20	6.334	9.802	104.786
1in100	6.116	9.653	106.164
1in5	5.771	9.451	115.530
1in20	5.363	7.979	120.182
1in100	4.855	7.724	122.637

1 in 200 Joint Probability Return Period - Points 1- 4

Where return period refers to water level, Hm0 refers to significant wave height in metres, Tm refers to mean wave period in seconds and MWD is the mean wave direction in degrees from True North.

Output Point 5 -6.131002 53.63104

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.971	6.986	23.874
1in20	3.687	6.985	23.945
1in100	2.871	6.299	20.686
1in5	4.126	7.225	45.587
1in20	3.823	7.217	45.210
1in100	2.981	6.497	43.138
1in5	5.619	8.230	68.404
1in20	4.967	7.776	67.313
1in100	4.162	7.193	66.213
1in5	5.465	8.189	86.839
1in20	4.796	7.714	86.727
1in100	3.998	7.113	86.627
1in5	4.740	8.185	101.331
1in20	4.128	7.724	102.397
1in100	3.425	7.148	103.836
1in5	7.056	10.589	107.536
1in20	6.615	9.328	109.211
1in100	6.113	9.301	108.973
1in5	5.674	8.403	122.301
1in20	4.960	7.398	125.905
1in100	4.249	7.415	125.734

Output Point 6 -6.065012 53.52728

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.277	7.471	39.352
1in20	3.004	7.445	38.308
1in100	2.368	6.743	34.599
1in5	4.031	7.543	54.997
1in20	3.693	7.508	54.161
1in100	2.882	6.777	50.923
1in5	5.300	8.189	69.470
1in20	4.652	7.721	68.748
1in100	3.894	7.126	67.952
1in5	4.926	8.107	85.183
1in20	4.309	7.632	85.578
1in100	3.590	7.040	86.453
1in5	4.082	8.091	99.542
1in20	3.580	7.628	100.757
1in100	2.998	7.045	102.445
1in5	6.453	10.675	105.120
1in20	5.885	9.174	108.444
1in100	5.216	9.479	110.225
1in5	5.009	9.650	121.681
1in20	4.477	8.092	129.307
1in100	3.973	8.515	130.583

Output Point 7 -6.070923 53.41726

	Inshore Climate		
	Hm0	Tm	MWD
1in5	3.175	7.054	39.646
1in20	2.842	6.897	38.256
1in100	2.218	6.240	33.714
1in5	4.212	7.643	56.692
1in20	3.785	7.612	55.606
1in100	2.968	6.883	52.365
1in5	4.955	8.034	71.559
1in20	4.345	7.577	71.030
1in100	3.637	7.000	70.420
1in5	4.934	8.051	87.519
1in20	4.335	7.581	87.839
1in100	3.644	6.991	88.171
1in5	4.478	8.069	101.140
1in20	3.936	7.616	102.387
1in100	3.320	7.047	103.798
1in5	6.231	10.607	104.852
1in20	5.569	8.819	107.505
1in100	5.091	9.433	107.350
1in5	4.747	9.997	111.250
1in20	3.920	8.034	116.170
1in100	3.582	8.837	114.137

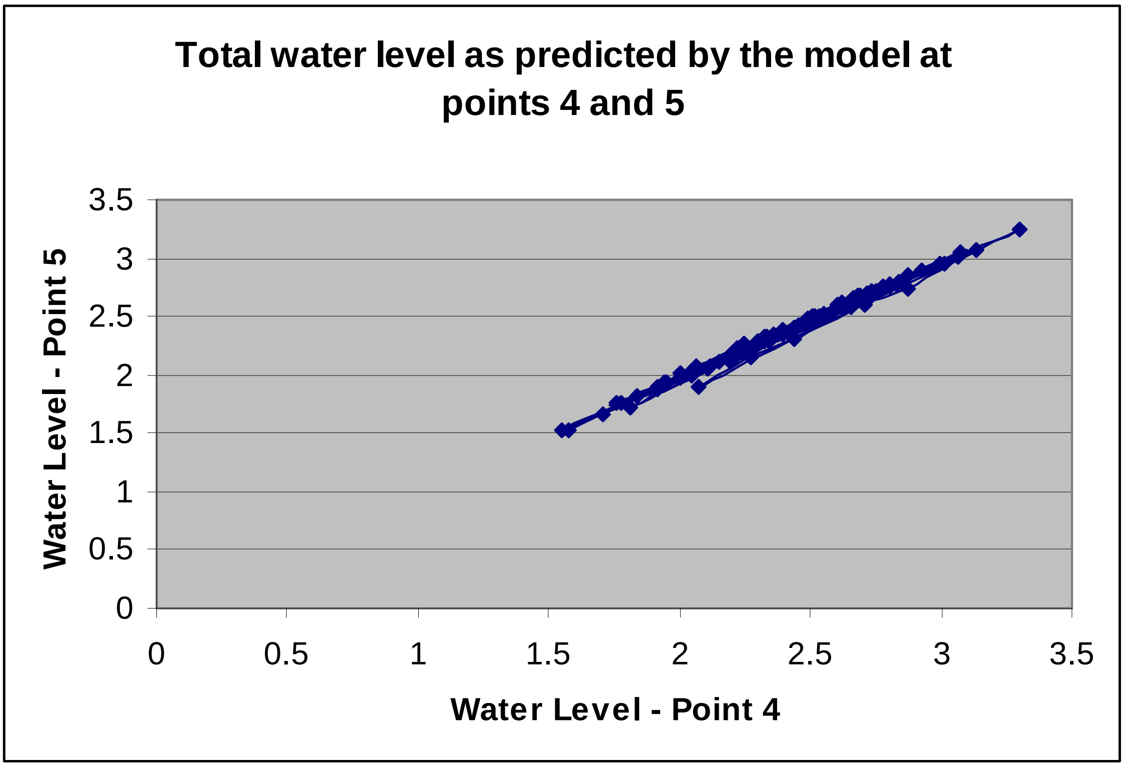
Output Point 8 -6.102684 53.32763

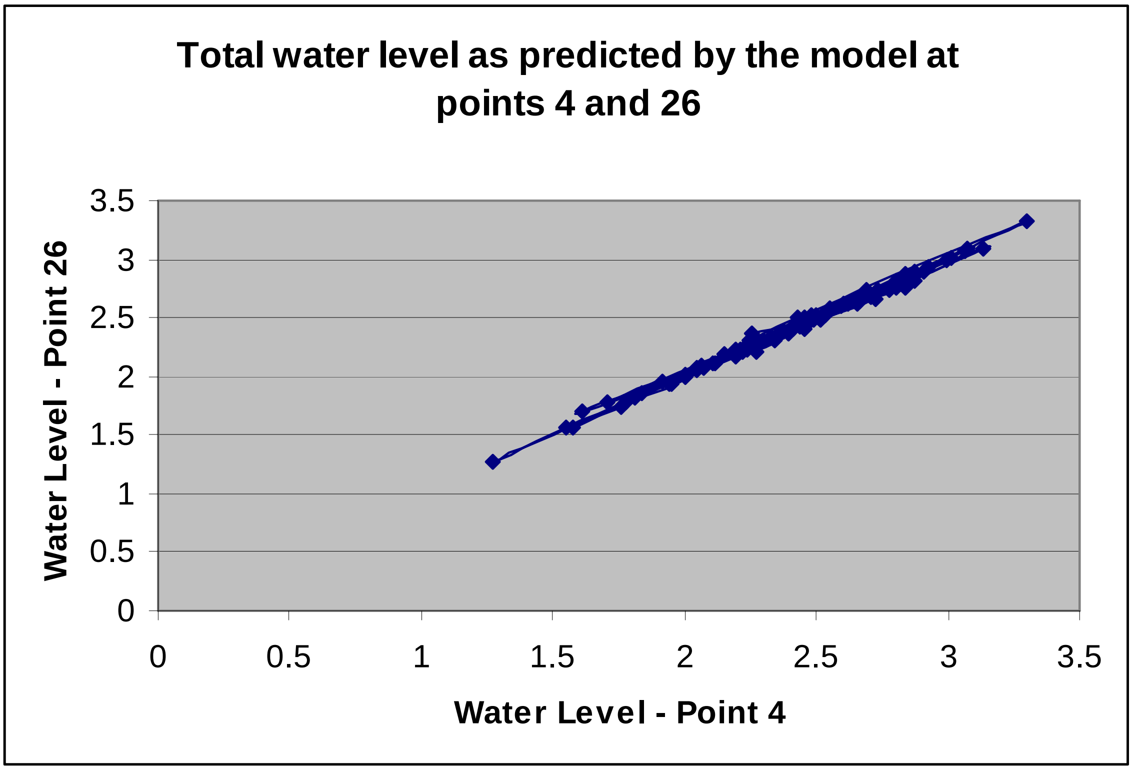
	Inshore Climate		
	Hm0	Tm	MWD
1in5	2.356	5.678	52.699
1in20	2.040	5.621	52.858
1in100	1.560	4.977	48.314
1in5	3.399	7.365	69.686
1in20	3.029	7.323	69.535
1in100	2.376	6.629	67.493
1in5	4.541	8.125	84.790
1in20	4.067	7.664	83.792
1in100	3.440	7.086	82.165
1in5	4.871	8.074	97.986
1in20	4.413	7.619	97.794
1in100	3.755	7.047	97.272
1in5	4.812	8.045	113.283
1in20	4.366	7.597	114.111
1in100	3.754	7.042	115.071
1in5	5.794	10.074	128.893
1in20	5.596	8.233	131.153
1in100	5.210	8.998	127.998
1in5	5.091	8.908	140.600
1in20	4.812	7.553	142.671
1in100	4.289	8.106	139.931

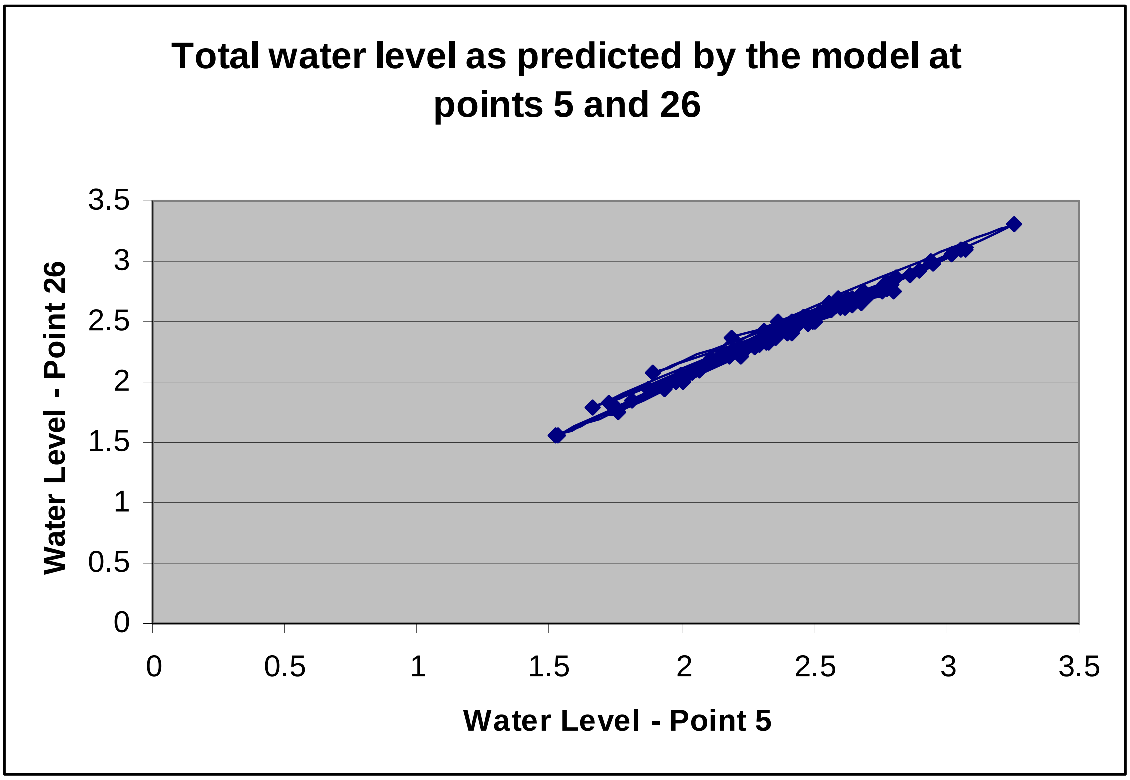
1 in 200 Joint Probability Return Period - Points 5- 8

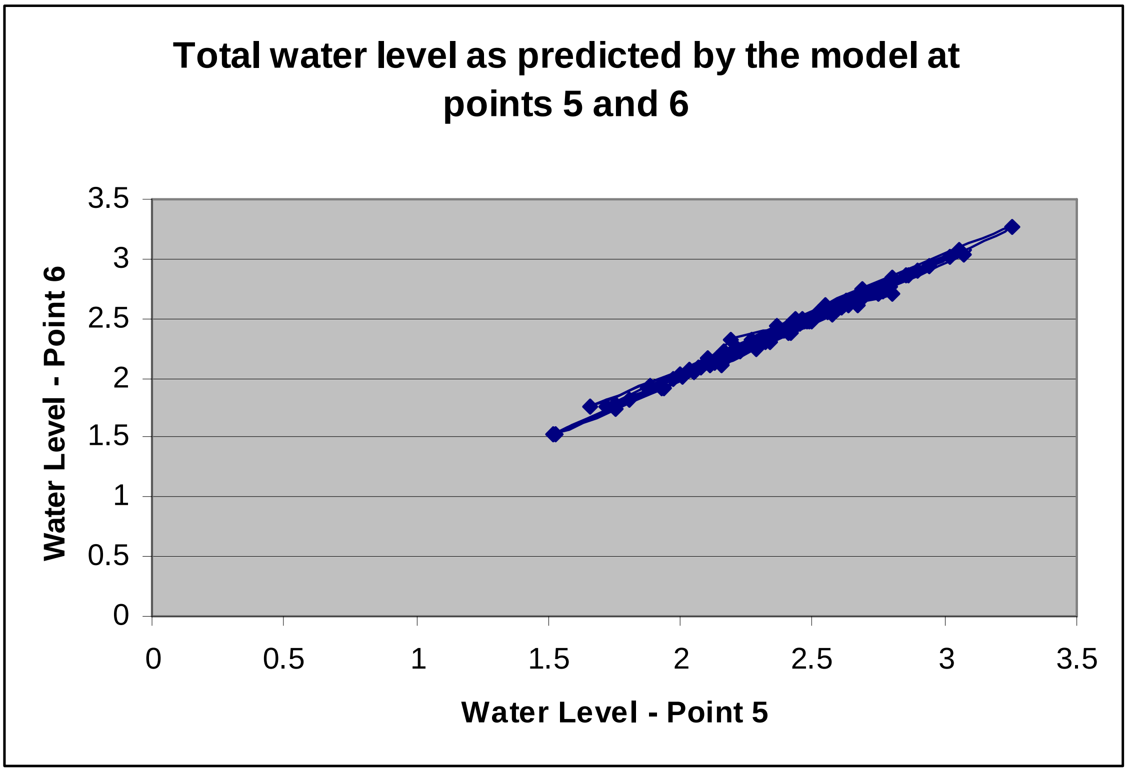
Where return period refers to water level, Hm0 refers to significant wave height in metres, Tm refers to mean wave period in seconds and MWD is the mean wave direction in degrees from True North.

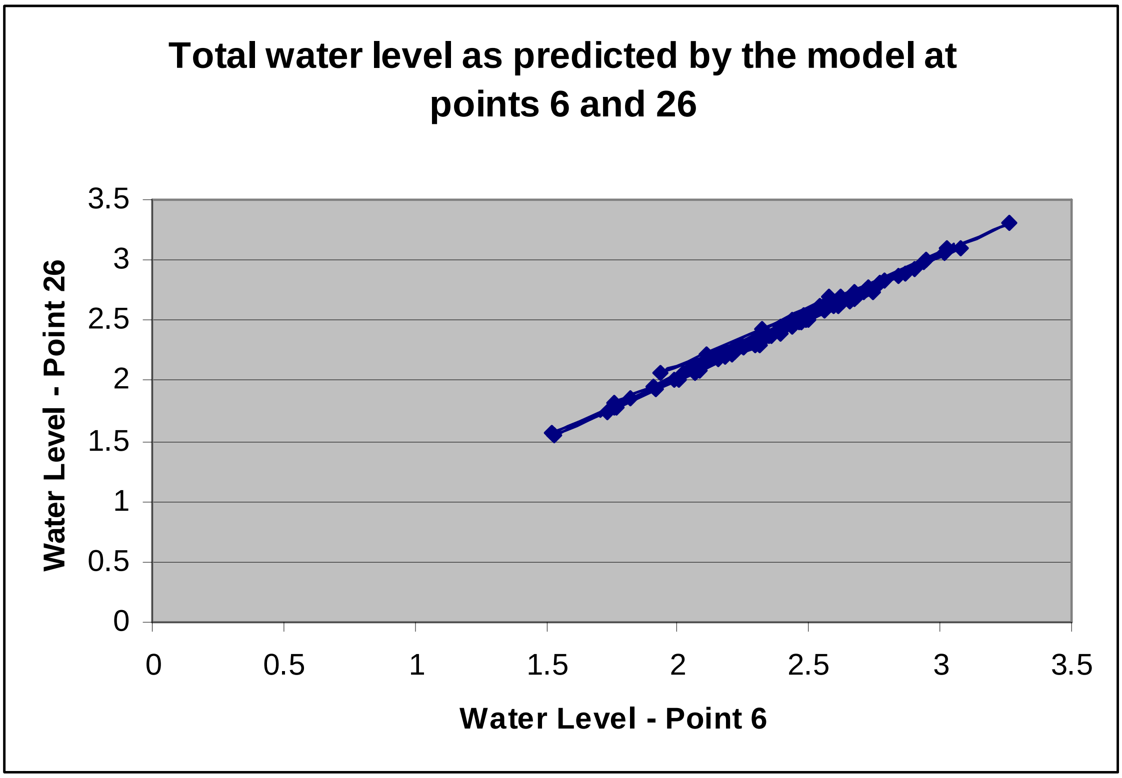
Appendix 5: Correlation Plots for Points 4, 5, 6 and 17

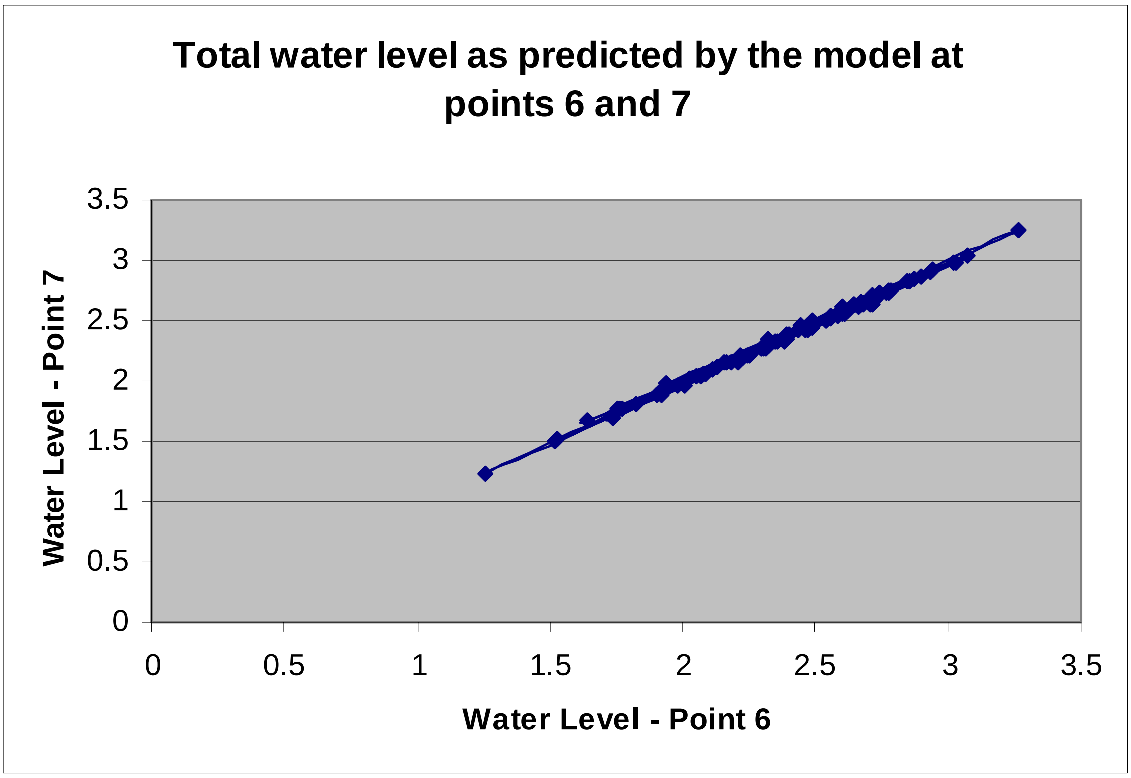

Total water level as predicted by the model at points 4 and 5
Water Level - Point 5
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
Water Level - Point 4

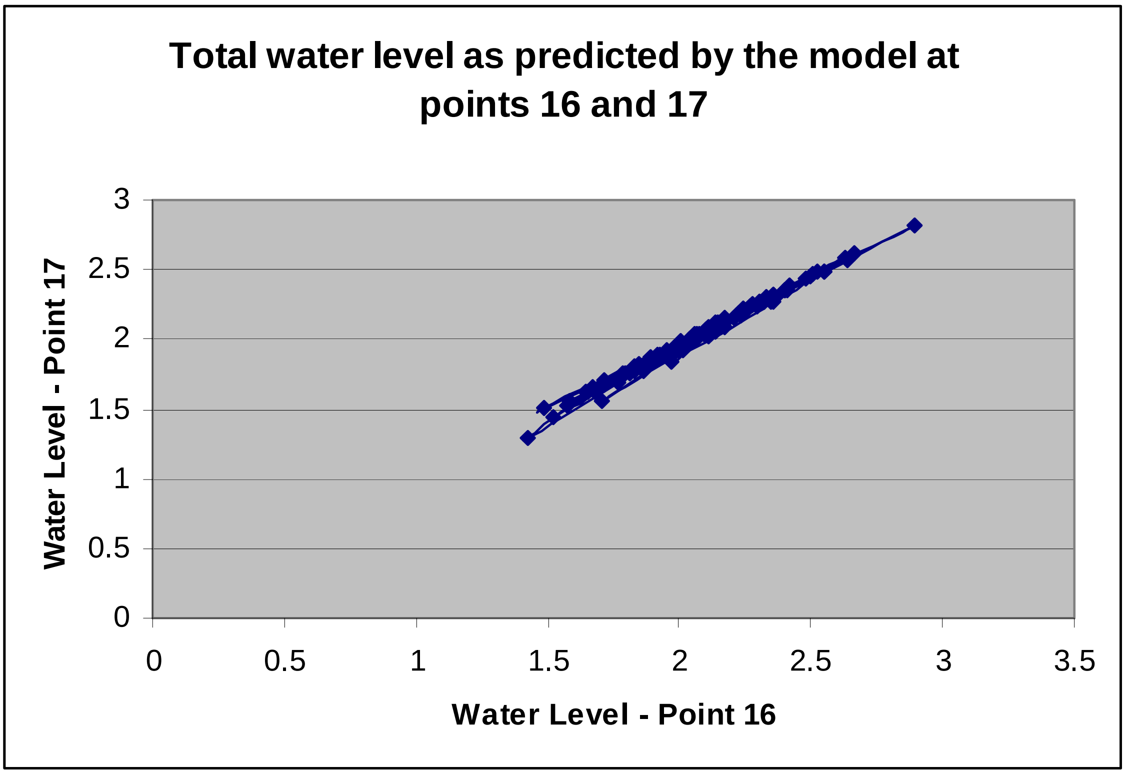

Total water level as predicted by the model at points 4 and 26
Water Level - Point 26
3.5
3
2.5
2
1.5
1
0.5
0
0
0.5
1
1.5
2
2.5
3
3.5
Water Level - Point 4

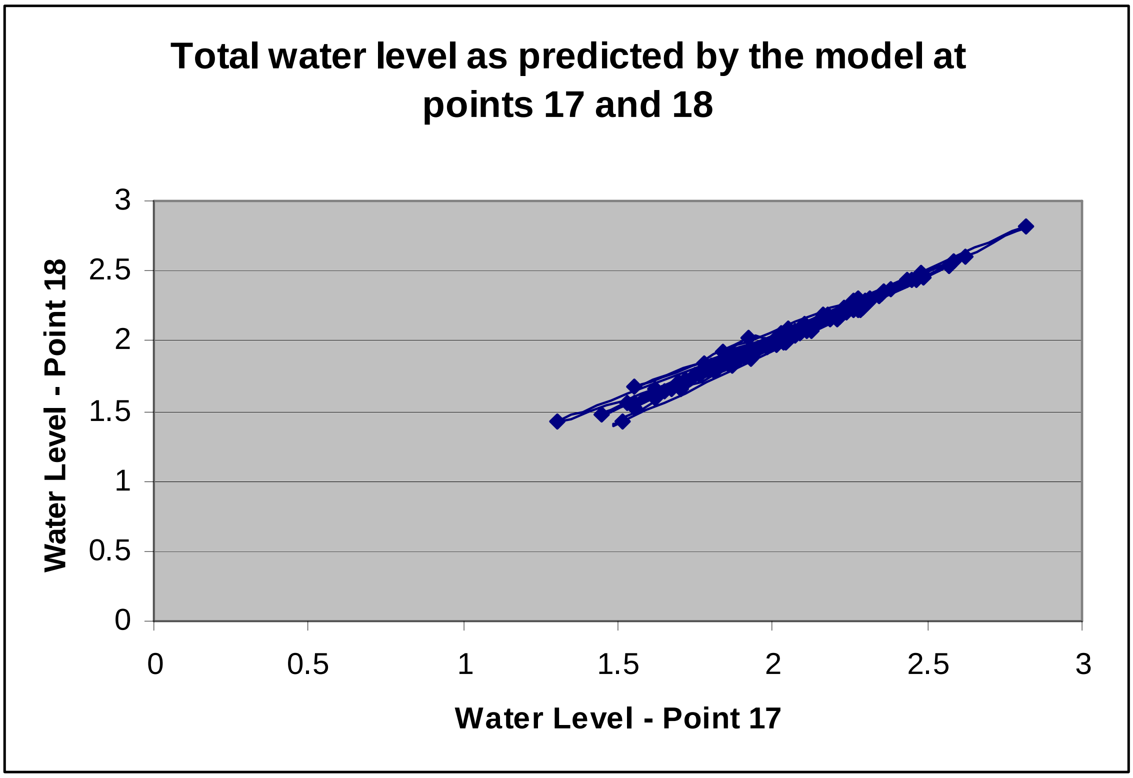

Total water level as predicted by the model at points 5 and 26
Water Level - Point 26
Water Level - Point 5
0
0.5
1
1.5
2
2.5
3
3.5


Total water level as predicted by the model at points 5 and 6
Water Level - Point 6
Water Level - Point 5
0
0.5
1
1.5
2
2.5
3
3.5


Total water level as predicted by the model at points 6 and 26
Water Level - Point 26
Water Level - Point 6
0
0.5
1
1.5
2
2.5
3
3.5


Total water level as predicted by the model at points 6 and 7
Water Level - Point 7
Water Level - Point 6
0
0.5
1
1.5
2
2.5
3
3.5


Total water level as predicted by the model at points 16 and 17
Water Level - Point 17
Water Level - Point 16
0
0.5
1
1.5
2
2.5
3
3.5


Total water level as predicted by the model at points 17 and 18
Water Level - Point 18
Water Level - Point 17
0
0.5
1
1.5
2
2.5
3

Appendix 6: Quality Control Survey Report

Appendix 6

Quality Control Survey Report

1.0 Introduction

Quality control assessments were undertaken to verify the accuracy of the north east coast Digital Terrain Model (DTM) and also to verify the accuracy of the flood extents generated by RPS from the combination of the predicted extreme water levels with the DTM. These assessments were focussed on five main urban centres considered to be vulnerable to coastal flooding.

To facilitate these assessments, the client conducted a Quality Control (QC) survey for six sample areas on the north east coast; namely Port Oriel, Balbriggan, Malahide, Drogheda, Dundalk and Dublin; recording the level of hard surfaces in the vicinity of the 0.5% AEP flood extent. The survey data was processed by the client and used for comparing the accuracy of the DTM with these points as well as the alignment of the flood extent. This provided an indication of the likely accuracy of the flood extents generated from the DTM.

This report presents the methodology and results of the QC survey together with the results of the assessment of both the DTM and flood extent accuracy relative to the QC survey points.

2.0 Methodology

RPS used the north east coast DTM to generate the flood extents for the north east coast. This DTM was derived using medium resolution topographic LiDAR data flown by BLOM Aerofilms Ltd in 2006.

The client carried out QC surveys of areas along the north east coast, with the results used to assess the accuracy of the DTM. This section outlines the methodologies used by the client in carrying out these surveys.

2.1 Survey Methodology

The client carried out several topographic QC surveys, between 2006 and 2008 using a DSNP Scorpio 6002 MK & SK GPS system and Thales Navigation Z-max Surveying System. These systems are Real Time Kinematic (RTK) Satellite Survey Systems. During the surveys, QC points were collected from hard surfaces only including the centreline of footpaths, edges of roads, entrances to industrial areas, car parks and piers.

Each road was covered by at least one survey line with level spacing of typically 5 metres. The QC survey was to be carried out to a vertical accuracy of ±50mm and a horizontal accuracy of ±50mm.

In the DTM survey specification the minimum accuracy required for elevation data was specified as ±0.2m. Additionally, all DTM models were to have a target vertical accuracy of not greater than 0.15m i.e. display an RMSE less than 0.15m with 99% of all points within two times the RMSE.

During the QC survey, known OSI GPS passive control stations at Balbriggan, Malahide, Drogheda, Dundalk, Howth and Dun Laoghaire were used. Working from Drogheda and Ardee passive control stations, a new local base station was set up at Port Oriel. The stations were used as a basis for survey control and set up; station co-ordinates and elevations are presented in Table 1.

Table 1: Passive control stations used by OPW for North East Coast QC Survey

Station name	Easting (m)	Northing (m)	Height (m)
Port Oriel	317207.442	284628.789	3.239
Balbriggan	319907.096	264166.280	11.469
Malahide	322781.667	246314.020	3.215
Drogheda	308932.672	276204.875	35.771
Dundalk	308291.414	307804.956	4.024
Howth	328890.213	239468.551	4.041
Dun Laoghaire	324808.924	228637.167	6.059

2.2 Survey Data and Accuracy Statistics

The QC survey data was used to quality control the DTM and flood extents in two ways. Initially, the survey points at each location were compared to the equivalent DTM elevation at the same location. This enabled a vertical accuracy assessment of the DTM to be made relative to the recorded survey point data.

The difference between the DTM and the QC survey points is referred to as height difference for the purpose of this report, such that all positive values describe areas where the DTM underestimated elevation and negative values where the DTM overestimated elevation. A number of rogue points discovered during this assessment were discarded, allowing more reliable statistics of height difference to be calculated including the mean, maximum, minimum, standard deviation, 95th percentile, upper and lower 95% confidence limits (estimated using the 2.5% and 97.5% percentile values), upper and lower 99% confidence limits (estimated using the 0.5% and 99.5% percentile values) and the RMSE (Root Mean Squared Error).

Rogue points identified and removed from the analysis included those located beyond the spatial limits of the DTM, on the periphery of the DTM, over water (i.e. located on bridges) or in areas where a known land use change had occurred between the time of the LiDAR data acquisition (2006) and the topographic surveys (2006-2008).

3.0 Comparison of DTM and Survey Data

The results of the assessment of the north east coast DTM vertical accuracy is presented below for each of the six urban centres; Port Oriel, Balbriggan, Malahide, Drogheda, Dundalk and Dublin. The spatial distribution of the recorded survey points at each location is shown in Figures 8 to 14 of Appendix 6A together with the height difference calculated between each survey point and DTM. Each point is colour-coded to show the difference between survey height and DTM height, with green and blue reflecting positive differences in excess of the tolerance and red and orange showing negative differences in excess of the tolerance. Points meeting the specified tolerance of ±0.2m are displayed in yellow.

3.1 Port Oriel

The Port Oriel survey data was compared with the DTM elevations at the same locations and height difference statistics were calculated. The results of this analysis for Port Oriel are shown in Table 2.

Table 2: Port Oriel Height Difference Statistics

HEIGHT DIFFERENCE (METRES)	
Mean	0.020
Maximum	2.423
Minimum	-0.877
Standard Deviation	0.218
95^{th} Percentile	0.157
Upper 95% Confidence Limit	0.283
Lower 95% Confidence Limit	-0.267
Upper 99% Confidence Limit	1.530
Lower 99% Confidence Limit	-0.337
RMSE	0.219
Count	487
No. Survey Points outside tolerance (± 0.2m)	35 (7.2%)

The statistics in Table 2 are based on the comparison of 487 survey points. Many of the larger height differences were found close to the edges of the DTM and around piers and jetties as would be expected. The RMSE value of +0.22m is just outside the specified tolerance value. The accuracy of the DTM at Port Oriel is between -0.27m and +0.28m at the 95% confidence limit and between -0.34m and +1.53m at the 99% confidence limit.

The distribution of height difference values for Port Oriel is shown in Figure 1.

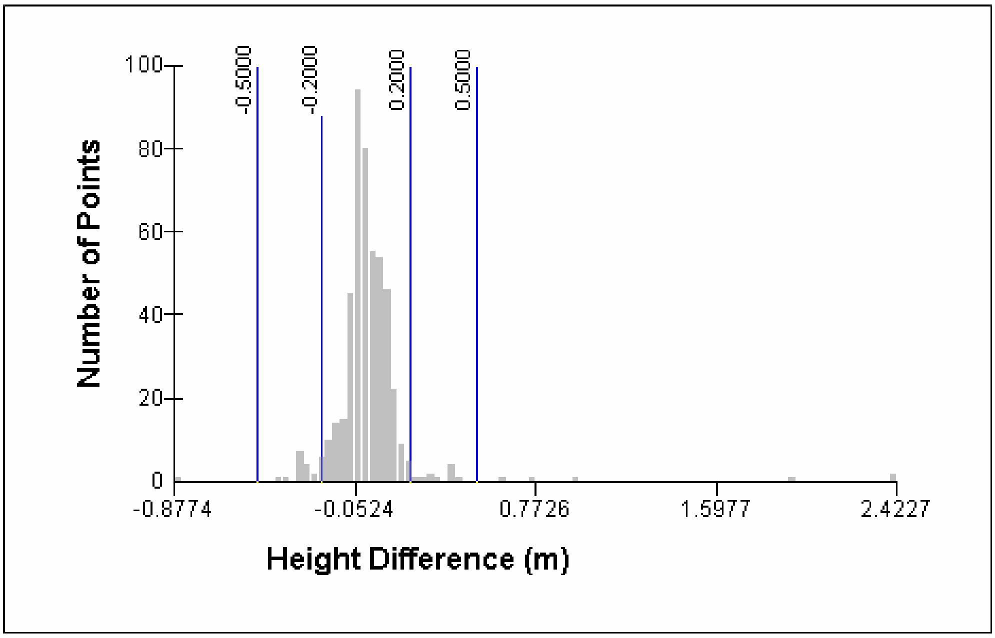


Figure 1: Port Oriel Height Difference Distribution

3.2 Balbriggan

The Balbriggan survey data was compared with the DTM elevations at the same locations and height difference statistics were calculated. The results of this analysis for Balbriggan are shown in Table 3.

Table 3: Balbriggan Height Difference Statistics

HEIGHT DIFFERENCE (METRES)	
Mean	0.017
Maximum	0.140
Minimum	-0.392
Standard Deviation	0.063
95th Percentile	0.095
Upper 95% Confidence Limit	0.117
Lower 95% Confidence Limit	-0.112
Upper 99% Confidence Limit	0.138
Lower 99% Confidence Limit	-0.230
RMSE	0.065
Count	242
No. Survey Points outside tolerance (± 0.2m)	2 (0.8%)

The statistics in Table 3 are based on the comparison of 242 survey points. It is apparent that the mean height difference and standard deviation values are low and the RMSE value (+0.07m) meets the specified tolerance. The accuracy of the DTM at Balbriggan is between -0.11m and +0.12m at the 95% confidence limit and between -0.23m and +0.14m at the 99% confidence limit.

The distribution of height difference values for Balbriggan is shown in Figure 2.

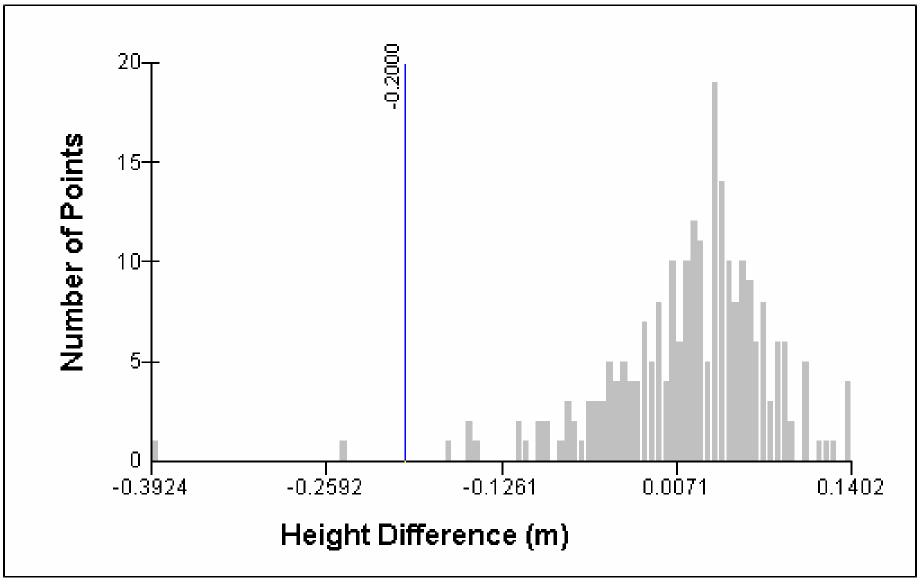


Figure 2: Balbriggan Height Difference Distribution

3.3 Malahide

The Malahide survey data was compared with the DTM elevations at the same locations and height difference statistics were calculated. The results of this analysis for Malahide are shown in Table 4.

Table 4: Malahide Height Difference Statistics

HEIGHT DIFFERENCE (METRES)	
Mean	-0.013
Maximum	1.072
Minimum	-0.371
Standard Deviation	0.116
95th Percentile	0.113
Upper 95% Confidence Limit	0.228
Lower 95% Confidence Limit	-0.175
Upper 99% Confidence Limit	0.671
Lower 99% Confidence Limit	-0.247
RMSE	0.116
Count	972
No. Survey Points outside tolerance (± 0.2m)	41 (4.2%)

The statistics in Table 4 are based on the comparison of 972 QC survey points. The mean height difference and standard deviation values are low and the RMSE value (+0.12m) meets the specified tolerance. The accuracy of the DTM at Malahide is between -0.18m and +0.23m at the 95% confidence limit and between -0.25m and +0.67m at the 99% confidence limit.

The distribution of height difference values for Malahide is shown in Figure 3.

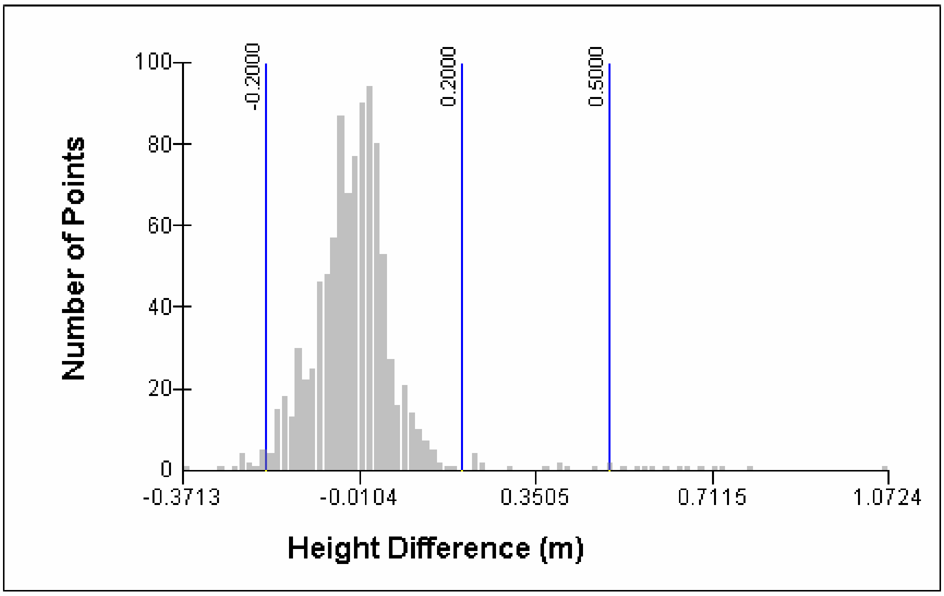


Figure 3: Malahide Height Difference Distribution

3.4 Drogheda

The Drogheda survey data was compared with the DTM elevations at the same locations and height difference statistics were calculated. The results of this analysis for Drogheda are shown in Table 5.

Table 5: Drogheda Height Difference Statistics

HEIGHT DIFFERENCE (METRES)	
Mean	0.104
Maximum	0.632
Minimum	-0.175
Standard Deviation	0.083
95th Percentile	0.209
Upper 95% Confidence Limit	0.283
Lower 95% Confidence Limit	-0.057
Upper 99% Confidence Limit	0.463
Lower 99% Confidence Limit	-0.134
RMSE	0.133
Count	333
No. Survey Points outside tolerance (± 0.2m)	19 (5.7%)

The statistics in Table 5 are based on the comparison of 333 survey points out of a total of 366 gathered. A total of 33 points were deemed invalid and discarded from the analysis, due to their location above bridges (19) and along the DTM boundary (14).

The mean height difference and standard deviation values are low and the RMSE of +0.13m meets the specified tolerance. The accuracy of the DTM at Drogheda is between -0.06m and +0.28m at the 95% confidence limit and between -0.13m and +0.46m at the 99% confidence limits.

The distribution of height difference values for Drogheda is shown in Figure 4.

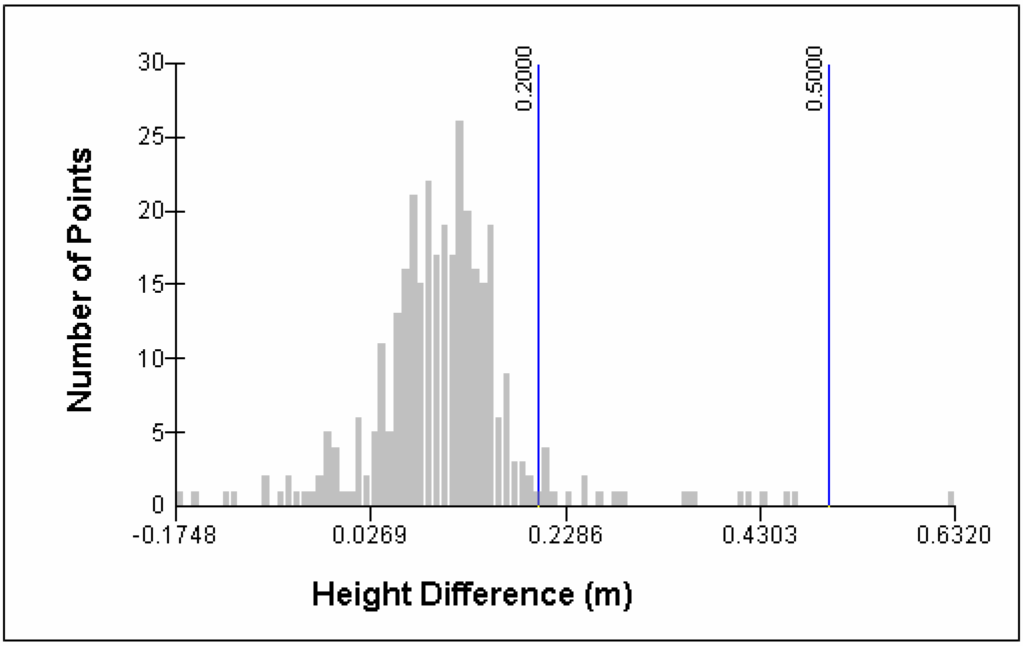


Figure 4: Drogheda Height Difference Distribution

3.5 Dundalk (2006)

The Dundalk (2006) survey data was compared with the DTM elevations at the same locations and height difference statistics were calculated. The results of this analysis for Dundalk (2006) are shown in Table 6.

Table 6: Dundalk (2006) Height Difference Statistics

HEIGHT DIFFERENCE (METRES)	
Mean	0.043
Maximum	3.515
Minimum	-1.558
Standard Deviation	0.239
95th Percentile	0.348
Upper 95% Confidence Limit	0.469
Lower 95% Confidence Limit	-0.376
Upper 99% Confidence Limit	0.545
Lower 99% Confidence Limit	-0.504
RMSE	0.243
Count	610
No. Survey Points outside tolerance (± 0.2m)	149 (24.4%)

The statistics in Table 6 are based on the comparison of 610 survey points out of a total of 630. A total of 20 points were deemed invalid and discarded from the analysis due to their location at the peripheral of the DTM (16 points) or above water on bridges (4 points).

The mean height difference is low but the RMSE value of +0.24m is just outside the specified tolerance. The accuracy of the DTM at Dundalk using the 2006 QC survey data is between -0.38m and +0.47m at the 95% confidence limit and between -0.50m and +0.55m at the 99% confidence limits.

The distribution of height difference values for Dundalk (2006) is shown in Figure 5.

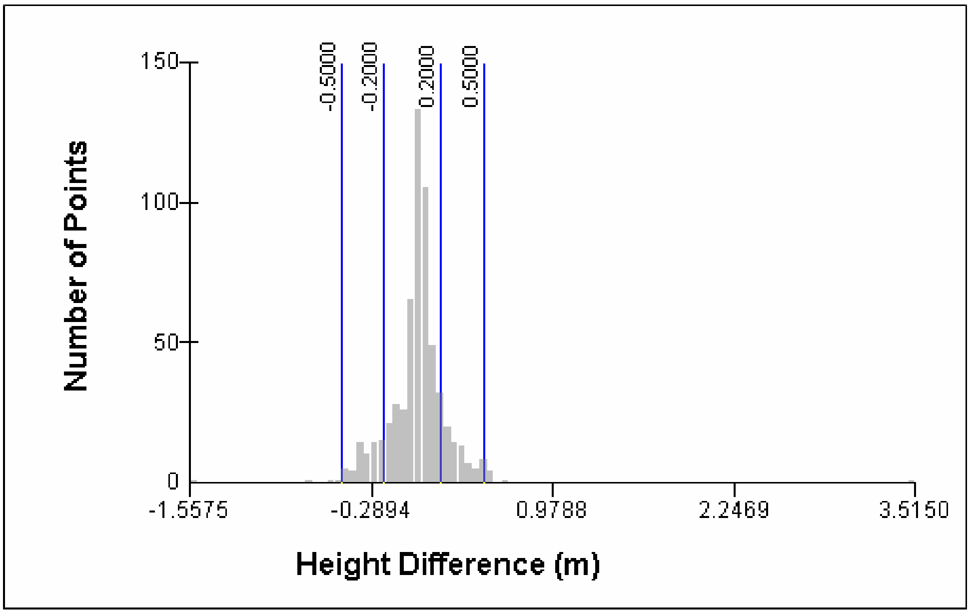


Figure 5: Dundalk (2006) Height Difference Distribution

3.6 Dundalk (2008)

The Dundalk (2008) survey data was compared with the DTM elevations at the same locations and height difference statistics were calculated. The results of this analysis for Dundalk (2008) are shown in Table 7.

Table 7: Dundalk (2008) Height Difference Statistics

HEIGHT DIFFERENCE (METRES)	
Mean	-0.040
Maximum	1.177
Minimum	-0.466
Standard Deviation	0.092
95^{th} Percentile	0.065
Upper 95% Confidence Limit	0.102
Lower 95% Confidence Limit	-0.190
Upper 99% Confidence Limit	0.436
Lower 99% Confidence Limit	-0.237
RMSE	0.103
Count	1371
No. Survey Points outside tolerance (± 0.2m)	33 (2.4%)

The statistics in Table 7 are based on the comparison of 1371 survey points out of a total of 1380. A total of 9 points were discarded from the analysis as they were gathered from a location which had been developed since the LiDAR data was flown in 2006.

The mean height difference and standard deviation values are both very low and the RMSE value of +0.10m clearly meets the specified tolerance. The accuracy of the DTM at Dundalk using the 2008 QC survey data is between -0.19m and +0.10m at the 95% confidence limit and between -0.24m and +0.44m at the 99% confidence limits.

The distribution of height difference values for Dundalk (2008) is shown in Figure 6.

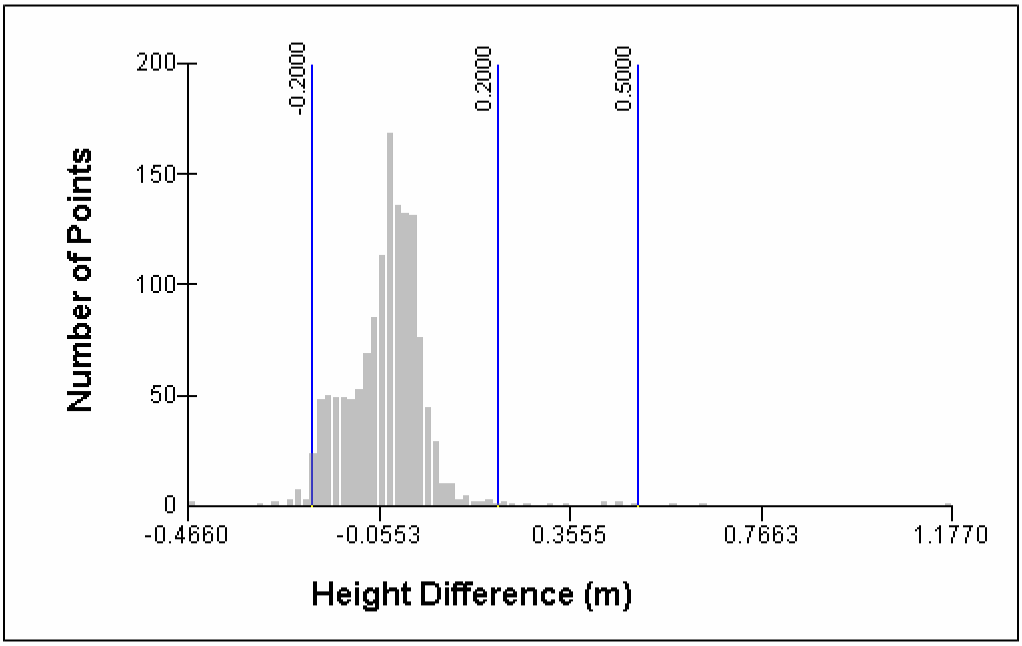


Figure 6: Dundalk (2008) Height Difference Distribution

3.7 Dublin

The Dublin survey data was compared with the DTM elevations at the same locations and height difference statistics were calculated. The results of this analysis for Dublin are shown in Table 8.

Table 8: Dublin Height Difference Statistics

HEIGHT DIFFERENCE (METRES)	
Mean	0.091
Maximum	1.268
Minimum	-0.179
Standard Deviation	0.084
95th Percentile	0.206
Upper 95% Confidence Limit	0.235
Lower 95% Confidence Limit	-0.060
Upper 99% Confidence Limit	0.345
Lower 99% Confidence Limit	-0.115
RMSE	0.123
Count	1828
No. Survey Points outside tolerance (± 0.2m)	110 (6.01%)

The statistics in Table 8 are based on the comparison of 1828 survey points out of a total of 1922. A total of 92 points were discarded from the analysis as they were gathered from a location which had been developed since the LiDAR data was flown in 2006 or were on the edge of the DTM.

The mean height difference and standard deviation values are both very low and the RMSE value of +0.12m clearly meets the specified tolerance. The accuracy of the DTM at Dublin using the 2008 QC survey data is between -0.06m and +0.24m at the 95% confidence limit and between -0.12m and +0.35m at the 99% confidence limits.

The distribution of height difference values for Dublin is shown in Figure 7.

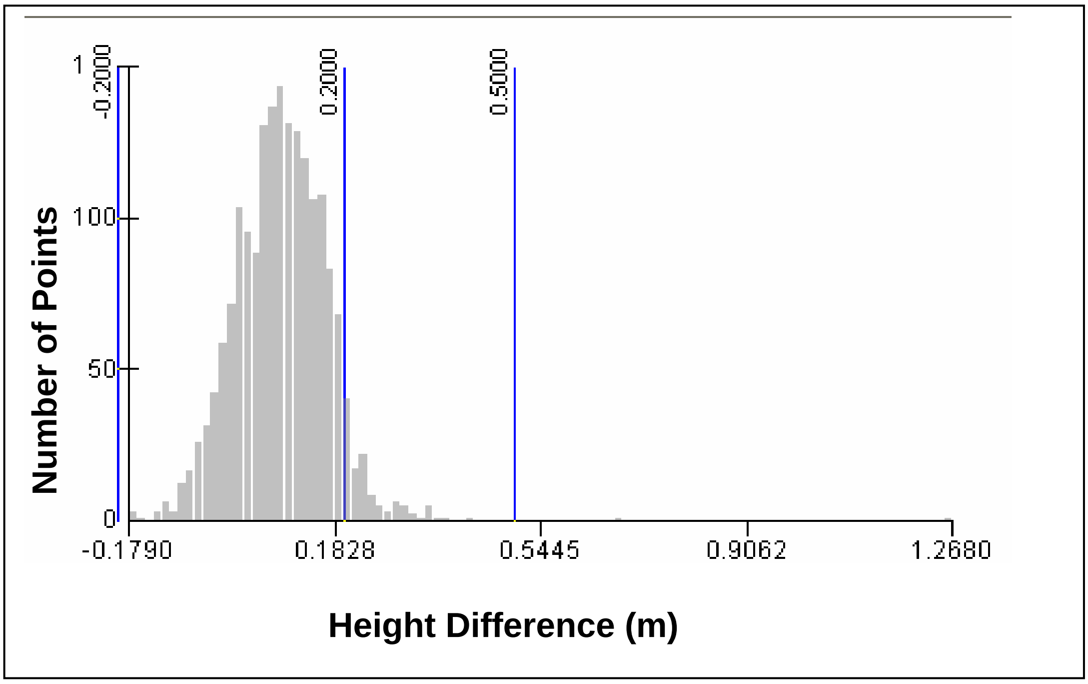


Figure 7: Dublin Height Difference Distribution

3.8 Summary of Results

The overall results of the assessment of the DTM vertical accuracy in the main urban centres and other surveyed areas along the north east coast, based on comparison with the quality control survey data, are summarised in Table 9.

Table 9 shows the calculated height difference statistics, including the maximums, minimums, standard deviations, 95th percentiles and means for each of the areas together with the combined statistics for all twelve areas. The total number of survey points used in the analysis is also shown in Table 9.

Table 9: Statistical Results for 6 Urban Areas

	Port Oriel	Balbriggan	Malahide	Drogheda	Dundalk (2006)	Dundalk (2008)	Dublin	Total
Original No. Points	487	242	972	366	630	1380	1922	5999
Final No. Points	487	242	972	333	610	1371	1828	5843
Removed Points	0	0	0	33	20	9	92	154
Maximum	2.423	0.140	1.072	0.632	3.515	1.177	1.268	3.515
Minimum	-0.877	-0.392	-0.371	-0.175	-1.558	-0.466	-0.179	-1.558
Mean	0.020	0.017	-0.013	0.104	0.043	-0.040	0.091	0.030
Standard Deviation	0.218	0.063	0.116	0.083	0.239	0.092	0.084	0.152
95th Percentile	0.157	0.095	0.113	0.209	0.348	0.065	0.206	0.196
Upper 95% Confidence limit	0.283	0.117	0.228	0.283	0.469	0.102	0.235	0.255
Lower 95% Confidence limit	-0.267	-0.112	-0.175	-0.057	-0.376	-0.190	-0.060	-0.187
Upper 99% Confidence limit	1.530	0.138	0.671	0.463	0.545	0.436	0.345	0.522
Lower 99% Confidence limit	-0.337	-0.230	-0.247	-0.134	-0.504	-0.237	-0.115	-0.350
RMSE	0.219	0.065	0.116	0.133	0.243	0.103	0.123	0.144

For all six locations mean height difference and standard deviation values range between -0.04m and +0.10m and between +0.06m and +0.24m respectively. Maximum height differences range between 0.14m to 3.52m and minimum height differences range between -1.56m to -0.18m. The RMSE of height difference values in general is low, ranging from 0.07m at Balbriggan to 0.24m at Dundalk (2006).

At Balbriggan only 0.8% of the QC survey points lie outside of the specified tolerance range (±0.2m) compared to 4.2% and 7.2% of points at Malahide and Port Oriel respectively. The corresponding figures for Drogheda, Dundalk and Dublin are 5.7%, 24.4% (Dundalk 2006), 2.4% (Dundalk 2008) and 6.0% respectively.

The results also indicate that at the 95% confidence limit the accuracy of the DTM varies from between:

- -0.27m to +0.28m at Port Oriel
- -0.18m to +0.23m at Malahide
- -0.11m to +0.12m at Balbriggan
- -0.06m to 0.28m at Drogheda
- -0.38m to +0.47m at Dundalk (2006)
- -0.19m to +0.10m at Dundalk (2008).
- -0.06 to +0.24m at Dublin

At the 99% confidence limit the accuracy of the DTM varies from between:

- -0.34m to +1.53m at Port Oriel
- -0.25m to +0.67m at Malahide
- -0.23m to +0.14m at Balbriggan
- -0.13m to +0.46m at Drogheda
- -0.50m to 0.55m at Dundalk (2006)
- -0.24m to +0.44m at Dundalk (2008)
- -0.12m to +0.35m at Dublin

Combining all locations, at the 95% confidence limit the accuracy of the DTM varies between -0.19m to 0.25m and between -0.35m to 0.52m at the 99% confidence limit. The overall RMSE is 0.144m.

4.0 Comparison of Flood Extents and Survey Data

To assess the accuracy of the flood extents generated from the DTM, a level comparison was also undertaken between the flood extents and survey points for twelve locations. This was done by selecting a sample area from different urban centres and comparing flood extent and survey levels within. The results of this assessment are shown in Figures 15 to 38 of Appendix 6B. The assessment was undertaken for both flood extents associated with the 0.5% and 0.1% AEP. These figures show the spatial distribution of the survey points relative to the flood extents in each sample area. The results for each location centre are outlined below.

4.1 Cruisetown (Port Oriel Survey Points)

The results of the flood extent accuracy assessment for Cruisetown are shown in Figures 15 and 16. These figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.78m O.D. Malin for 0.1% AEP and 3.55m O.D. Malin for 0.5% AEP in the selected area. Figure 15 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 16 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that less than ten percent of the yellow points lie outside the 0.5% AEP flood extent and one of the green points lies outside the 0.1% AEP flood extents.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 1m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be approximately 0.1m.

4.2 Malahide Area 1

The results of the flood extent accuracy assessment for Malahide are shown in Figures 17 and 18. These figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.42m O.D. Malin for 0.1% AEP and 3.21m O.D. Malin for 0.5% AEP in the selected area. Figure 17 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 18 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that approximately five percent of the yellow points lie outside the 0.5% AEP flood extent and two of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 2.1m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be approximately 0.4m.

4.3 Donabate (Malahide Survey Points)

The results of the flood extent accuracy assessment for Malahide are shown in Figures 19 and 20. These figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.49m O.D. Malin for 0.1% AEP and 3.25m O.D. Malin for 0.5% AEP in the selected area. Figure 19 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 20 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that no more than ten percent of the yellow points lie outside the 0.5% AEP flood extent and less than ten percent of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 2.6m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be approximately 2.3m.

4.4 Drogheda Area 1

The results of the flood extent accuracy assessment for Drogheda area 1 are shown in Figures 21 and 22. These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.69m O.D. Malin for 0.1% AEP and 3.48m O.D. Malin for 0.5% AEP in the selected area. Figure 21 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 22 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that only two of the yellow points lie outside the 0.5% AEP flood extent and none of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 0.6m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be 0m.

4.5 Drogheda Area 2

The results of the flood extent accuracy assessment for Drogheda area 2 are shown in Figures 23 and 24.These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.69m O.D. Malin for 0.1% AEP and 3.48m O.D. Malin for 0.5% AEP in the selected area. Figure 23 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 24 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that none of the yellow points lie outside the 0.5% AEP flood extent and none of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was therefore 0m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was also shown to be 0m.

4.6 Dundalk Area 1 (Dundalk 2008 Survey Points)

The results of the flood extent accuracy assessment for Dundalk area 1 are shown in Figures 25 and 26. These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.93m O.D. Malin for 0.1% AEP and 3.71m O.D. Malin for 0.5% AEP in the selected area. Figure 25 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 26 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that two of the yellow points lie outside the 0.5% AEP flood extent and none of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 0.5m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be 0m.

4.7 Dundalk Area 2 (Dundalk 2006 and 2008 Survey Points)

The results of the flood extent accuracy assessment for Dundalk area 2 are shown in Figures 27 and 28. These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.94m O.D. Malin for 0.1% AEP and 3.72m O.D. Malin for 0.5% AEP in the selected area. Figure 27 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 28 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that one of the yellow points lies outside the 0.5% AEP flood extent and five of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 0.4m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be approximately 1.8m.

4.8 Dundalk Area 3 (Dundalk 2008 Survey Points)

The results of the flood extent accuracy assessment for Dundalk area 3 are shown in Figures 29 and 30. These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.93m O.D. Malin for 0.1% AEP and 3.71m O.D. Malin for 0.5% AEP in the selected area. Figure 29 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 30 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that no more than ten percent of the yellow points lie outside the 0.5% AEP flood extent and less than ten percent of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 6.8m. The maximum horizontal distance between the

0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be approximately 7.4m.

4.9 Ballsbridge (Dublin Survey Points)

The results of the flood extent accuracy assessment for Ballsbridge are shown in Figures 31 and 32. These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.43m O.D. Malin for 0.1% AEP and 3.2m O.D. Malin for 0.5% AEP in the selected area. Figure 31 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 32 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that one of the yellow points lies outside the 0.5% AEP flood extent and one of the green points lies outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 0.6m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be approximately 1.8m.

4.10 Clontarf (Dublin Survey Points)

The results of the flood extent accuracy assessment for Clontarf are shown in Figures 33 and 34. These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.44m O.D. Malin for 0.1% AEP and 3.21m O.D. Malin for 0.5% AEP in the selected area. Figure 33 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 34 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that no more than ten percent of the yellow points lie outside the 0.5% AEP flood extent and no more than ten percent of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 21.3m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be approximately 7.8m.

4.11 Portmarnock (Dublin Survey Points)

The results of the flood extent accuracy assessment for Portmarnock are shown in Figures 35 and 36. These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.4m O.D. Malin for 0.1% AEP and 3.17m O.D. Malin for 0.5% AEP in the selected area. Figure 35 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 36 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that none of the yellow points lie outside the 0.5% AEP flood extent and none of the green points lie outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was therefore 0m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was also shown to be 0m.

4.12 Sydney Parade (Dublin Survey Points)

The results of the flood extent accuracy assessment for Sydney Parade are shown in Figures 37 and 38. These Figures show the flood extents produced from the DTM for the 0.5% and 0.1% AEP and the predicted flood levels associated with these events i.e. 3.40m O.D. Malin for 0.1% AEP and 3.16m O.D. Malin for 0.5% AEP in the selected area. Figure 37 highlights those survey points in yellow which should fall within the 0.5% AEP flood extent and Figure 38 shows those survey points in green which should fall within the 0.1% AEP flood extent. In the sample area selected it can be seen that five of the yellow points lie outside the 0.5% AEP flood extent and one of the green points lies outside the 0.1% AEP flood extent.

The maximum horizontal distance between the 0.5% AEP flood extent and those survey points shown outside of this flood extent but below the 0.5% flood level was found to be approximately 3.0m. The maximum horizontal distance between the 0.1% AEP flood extent and those survey points shown outside of this flood extent but below the 0.1% flood level was shown to be approximately 0.5 m.

Table 10: Horizontal Accuracy of Flood Extents

LOCATION	0.5% AEP	0.1% AEP
Cruisetown (Port Oriel Survey Points)	0.8m	0.1m
Malahide Area 1	2.1m	0.4m
Donabate (Malahide Survey Points)	2.3m	2.6m
Drogheda Area 1	0.6m	0m
Drogheda Area 2	0m	0m
Dundalk Area 1 (2008 Survey Points)	0.5m	0m
Dundalk Area 2 (2006 and 2008 Survey Points)	0.4m	1.8m
Dundalk Area 3 (2008 Survey Points)	6.8m	7.4m
Ballsbridge (Dublin Survey Points)	0.6m	1.8m
Clontarf (Dublin Survey Points)	21.3m	7.8m
Portmarnock (Dublin Survey Points)	0m	0m
Sydney Parade (Dublin Survey Points)	3.0m	0.5m

It can be seen from Table 10 that all the areas have high horizontal accuracy of between 0m and 21.3m for both 0.5% AEP and 0.1% AEP. The Clontarf area has the lowest horizontal accuracy of 21.3m and 7.8m for 0.5% AEP and 0.1% AEP respectively while two of the areas (Drogheda Area 2 and Portmarnock) have values of 0m for both 0.5% AEP and 0.1% AEP.

5.0 Conclusion

Based on the additional ground survey carried out in the six urban areas as part of this study it can be concluded that the DTM is of the accuracy expected and provides in general a very good basis for the generation of flood extents.

For all six locations, mean height difference and standard deviation values range between -0.04m to 0.104m and 0.063m to 0.239m respectively. Maximum height differences range between 0.140m to 3.515m and minimum height differences range between -1.558m to -0.175m. The RMSE of height difference values is in general low, ranging from 0.065m at Balbriggan to 0.243m at Dundalk (2006). The results also indicate that at the 95% confidence limit, the accuracy of the DTM varies from between -0.376m at Dundalk (2006) to 0.469m at Dundalk (2006). At the 99% confidence limit the accuracy of the DTM varies from between -0.504m for Dundalk (2006) to 1.530m at Port Oriel.

Combining all locations, at the 95% confidence limit the accuracy of the DTM varies between -0.187m to 0.255m and between -0.350m to 0.522m at the 99% confidence limit. The overall RMSE is 0.144m.

Horizontal accuracy of the flood extents for 0.5% AEP ranged from as accurate as 0 metres at Drogheda Area 2 and Portmarnock to 21.3m at Clontarf, showing a high level of horizontal accuracy across the flood extent. For 0.1% AEP, horizontal accuracy ranged from 0 metres at Dundalk Area 1, Drogheda Area 1 and Area 2, and Portmarnock to 7.8 metres at Clontarf. For both 0.5% and 0.1% AEP's, all the areas had high horizontal accuracy with the exception of Clontarf which had the lowest accuracy for both.

APPENDIX 6A: Figures 8 to 14

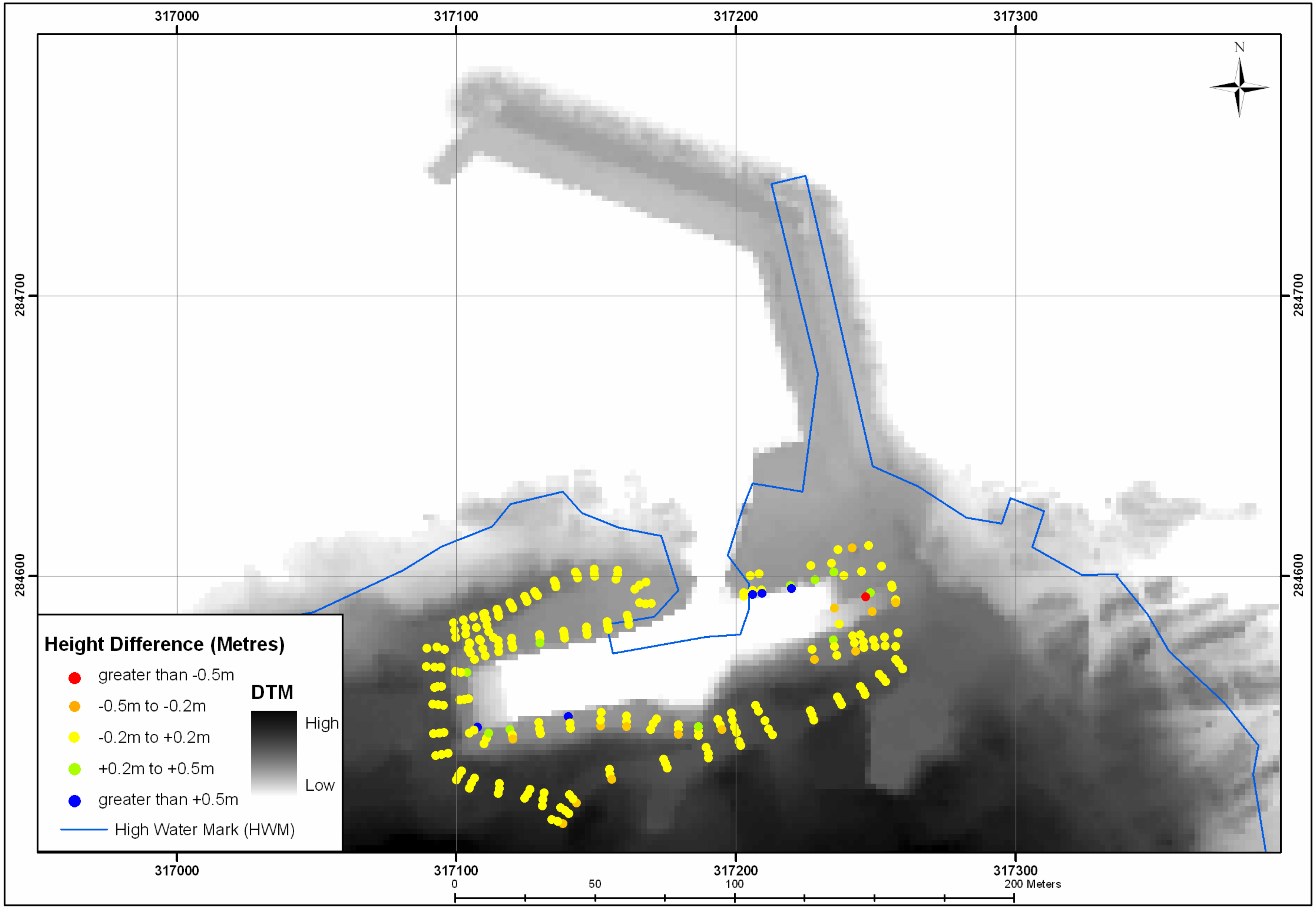


Figure 8: Comparison of DTM and QC Survey Data – Port Oriel, Co. Louth

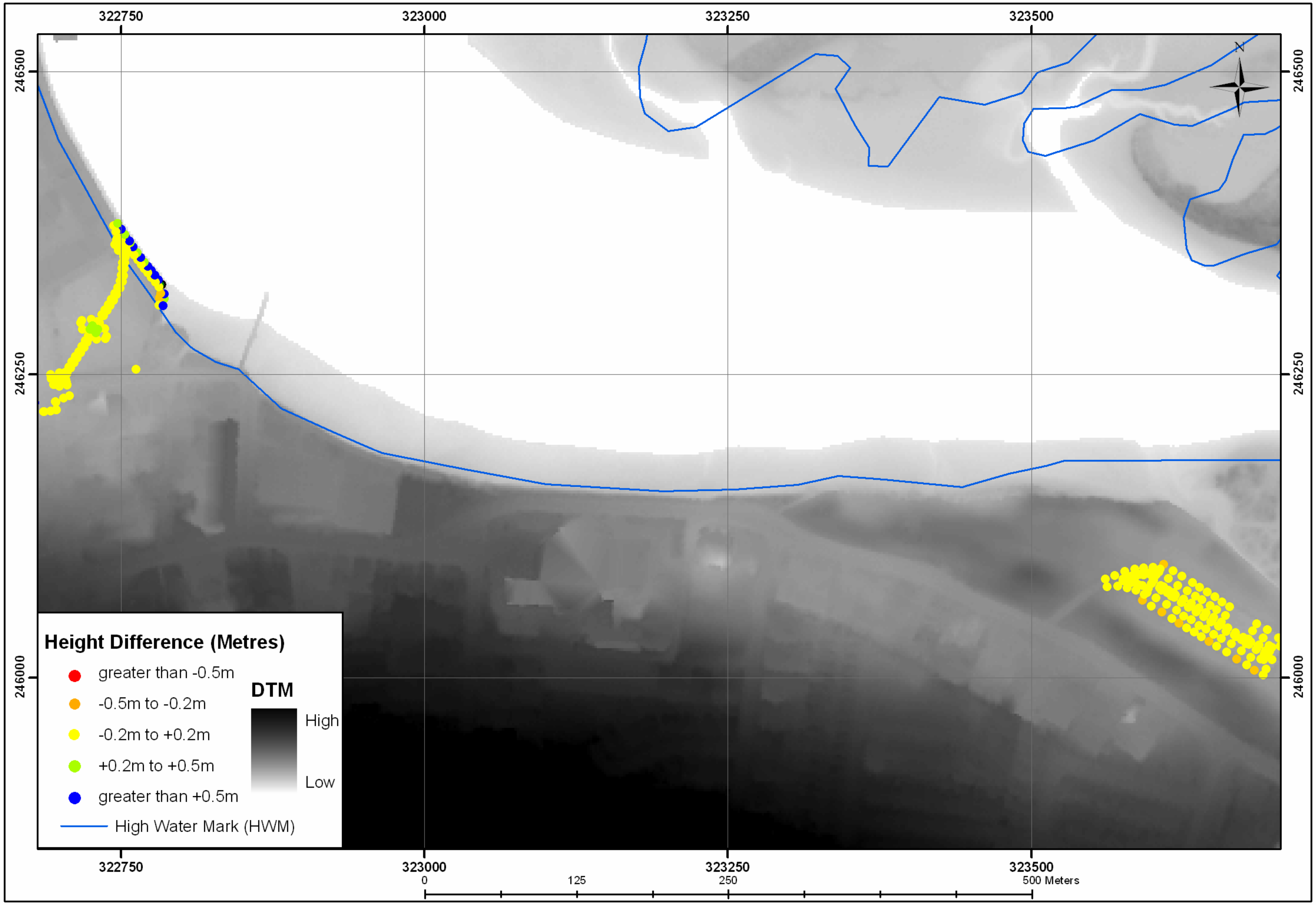


Figure 9: Comparison of DTM and QC Survey Data – Malahide, Co. Dublin

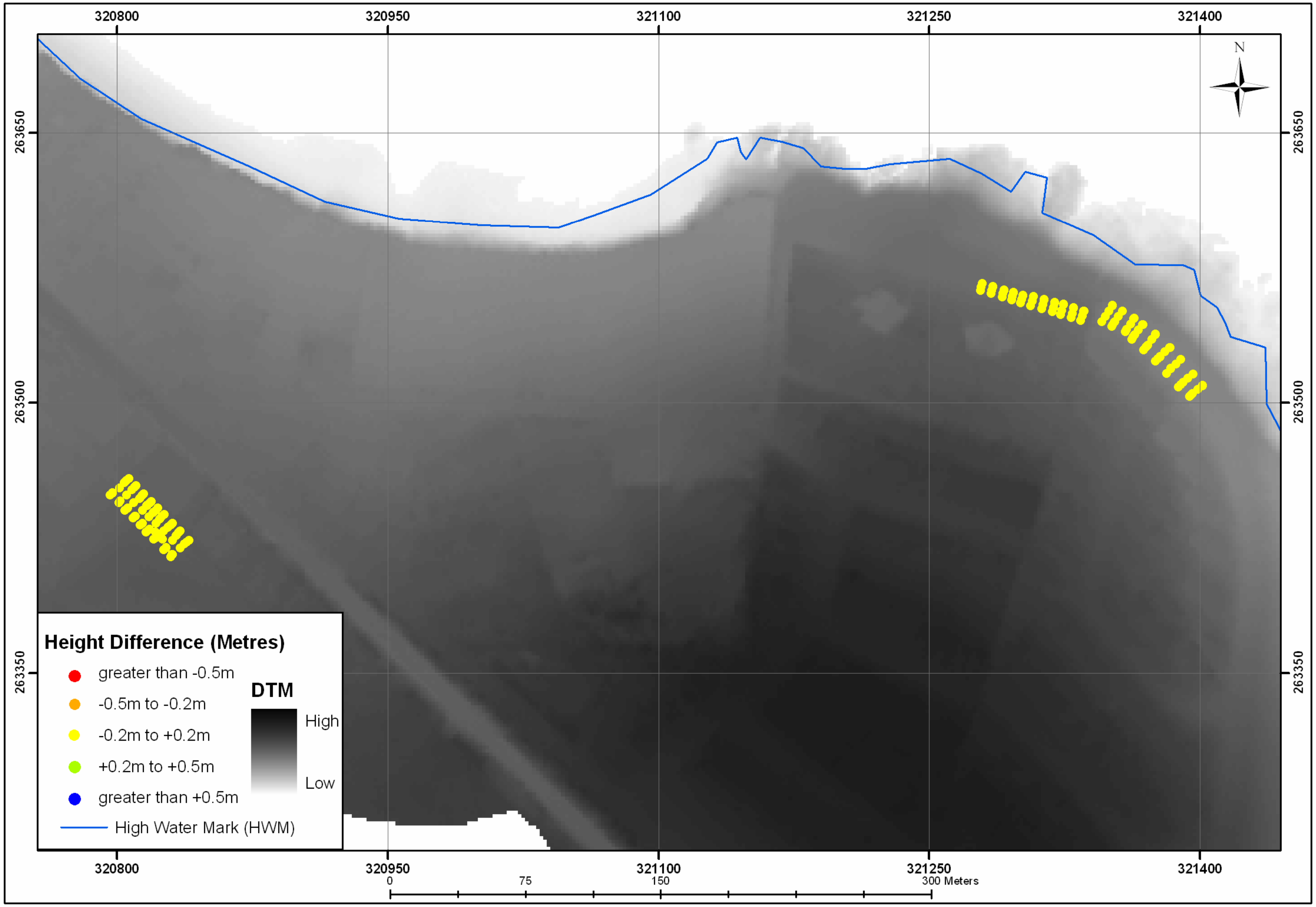


Figure 10: Comparison of DTM and QC Survey Data – Balbriggan, Co. Dublin

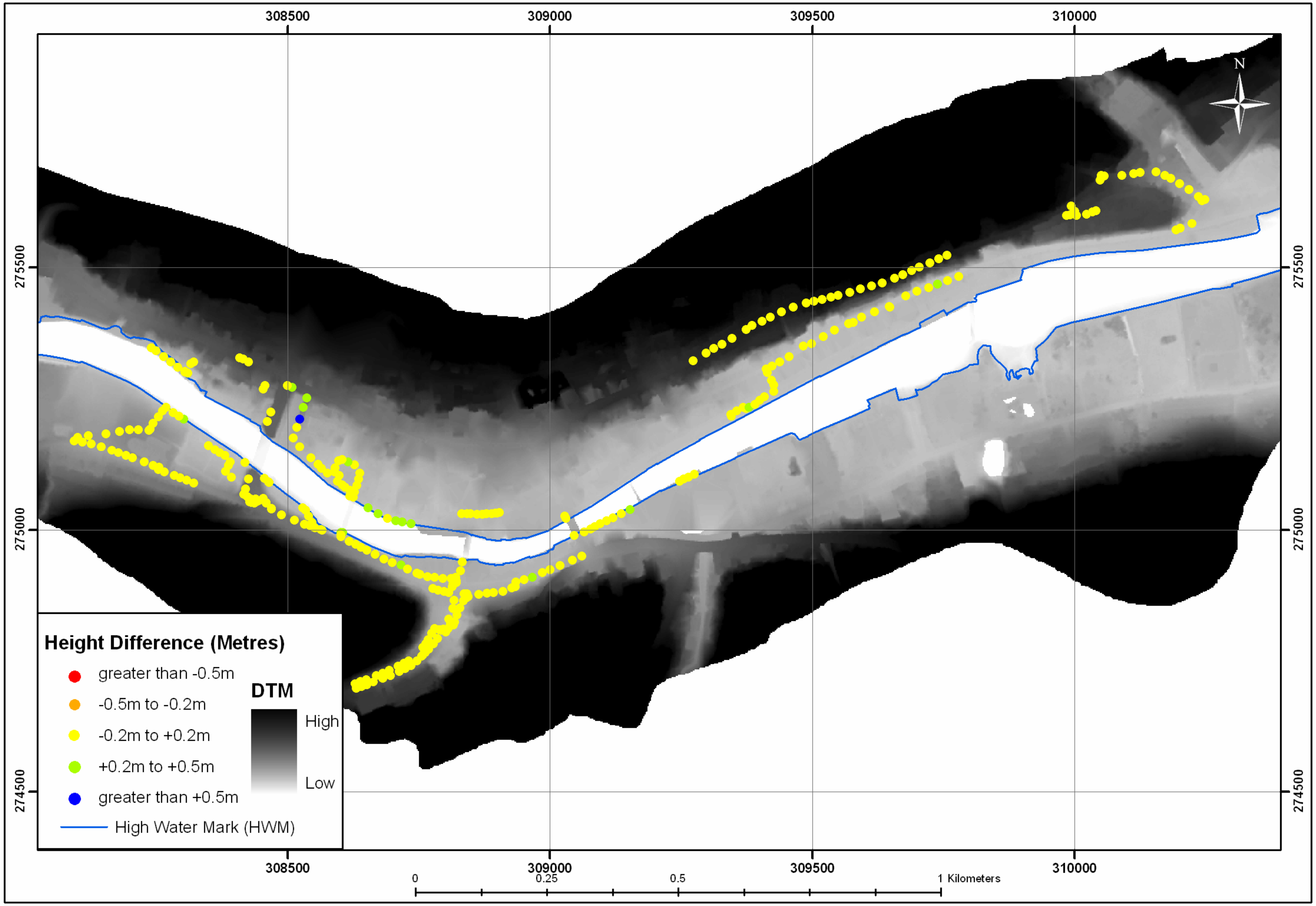


Figure 11: Comparison of DTM and QC Survey Data – Drogheda

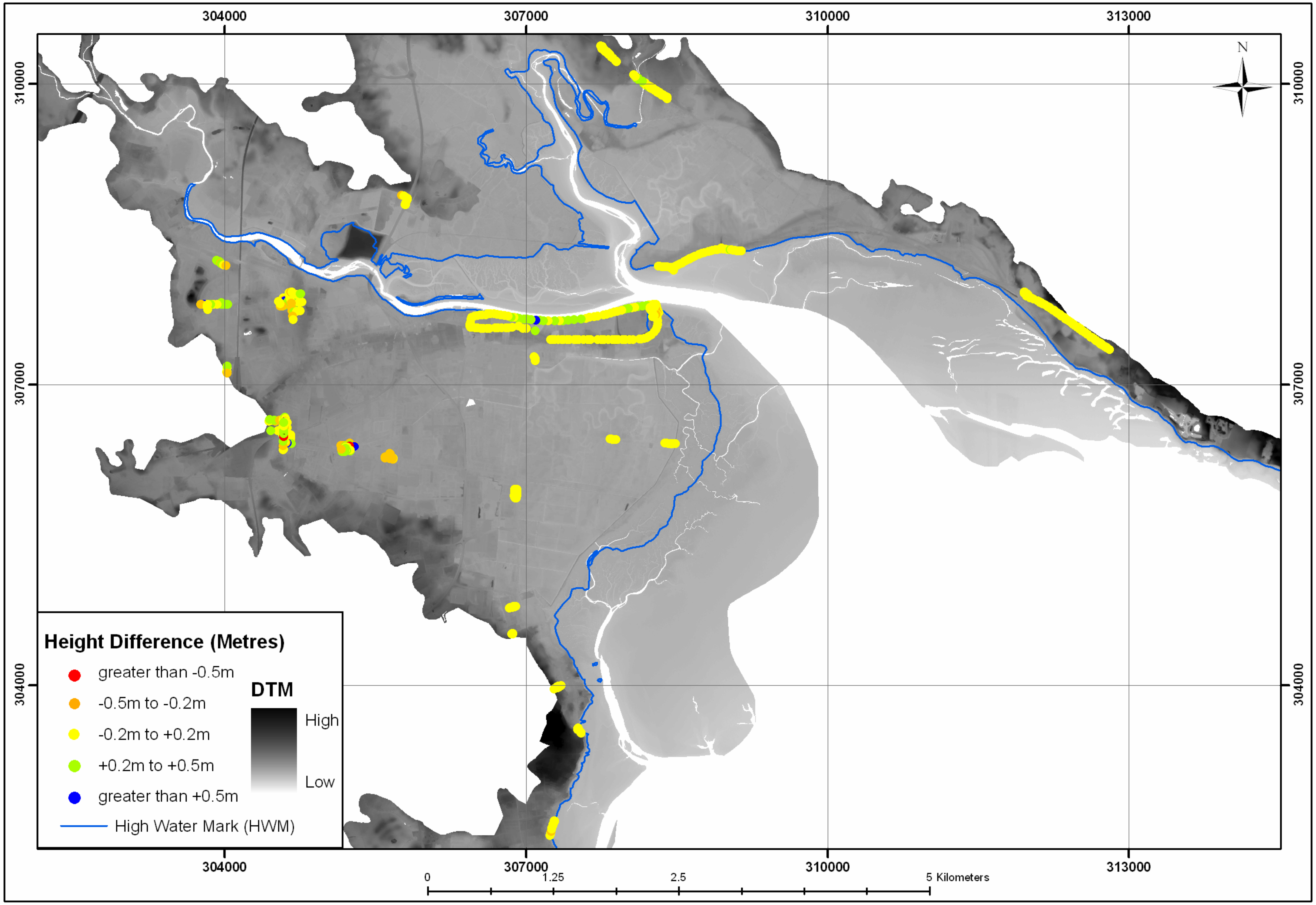


Figure 12: Comparison of DTM and QC Survey Data – Dundalk (2006)

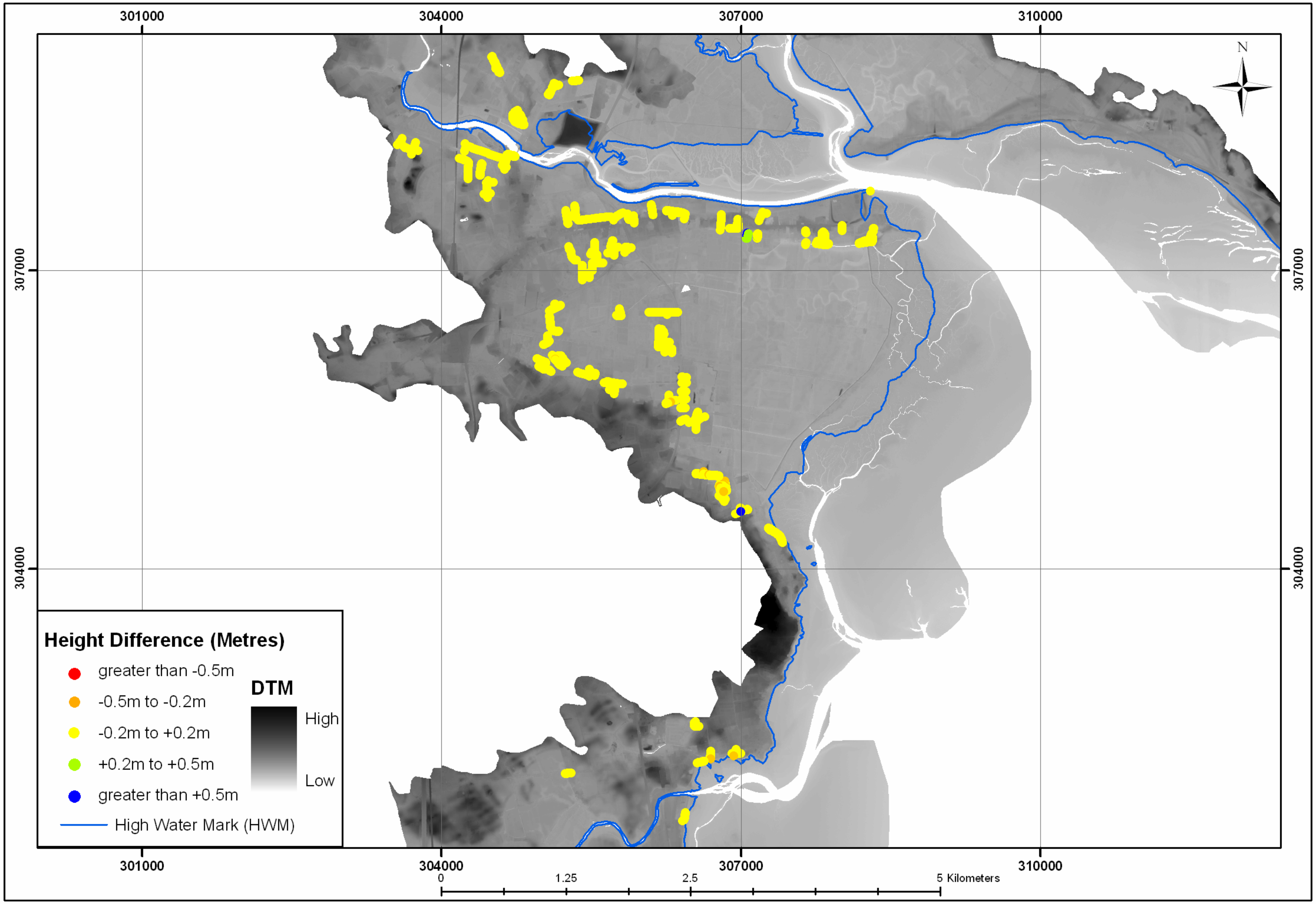


Figure 13: Comparison of DTM and QC Survey Data – Dundalk (2008)

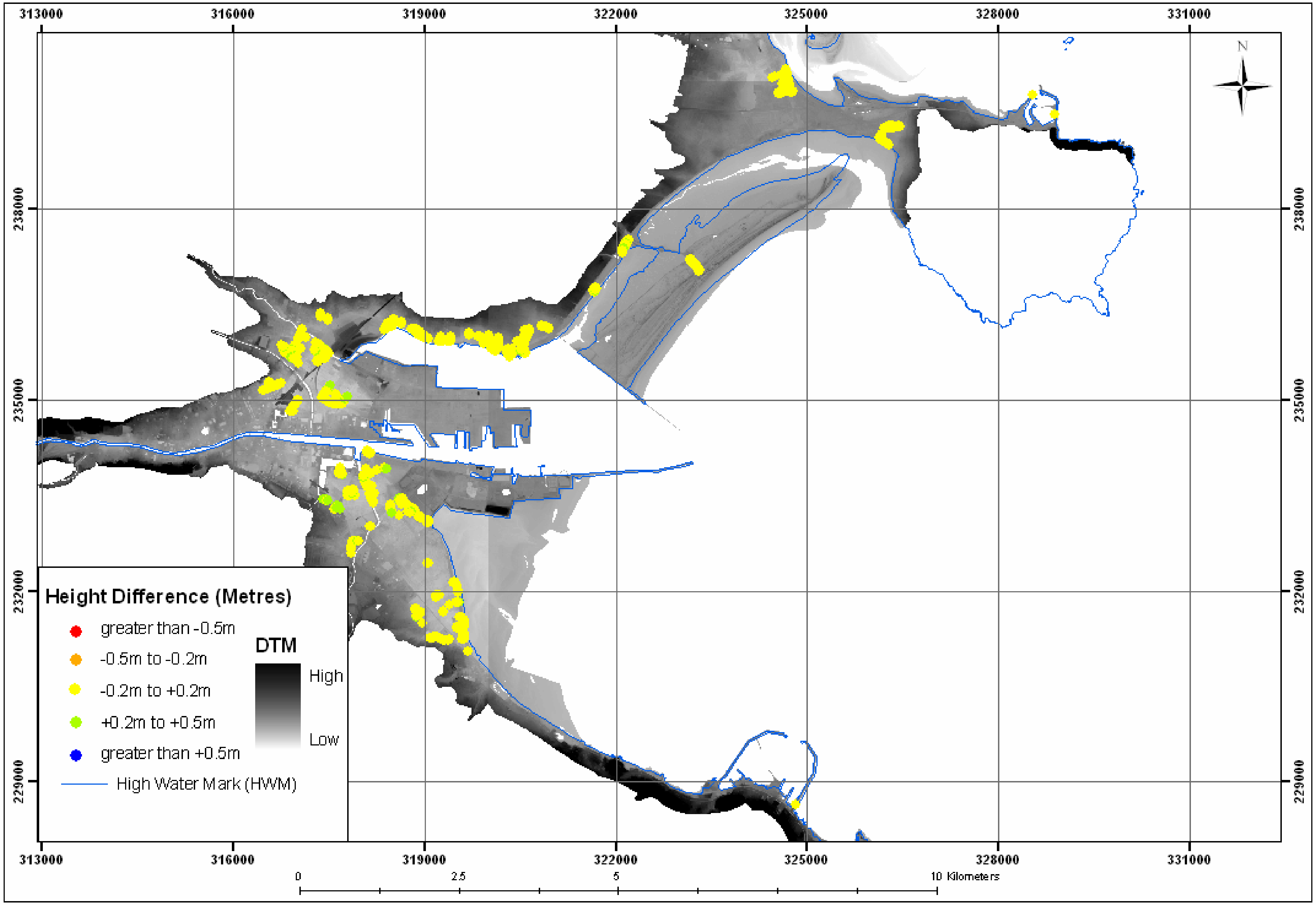


Figure 14: Comparison of DTM and QC Survey Data – Dublin

APPENDIX 6B : Figures 15 to 38

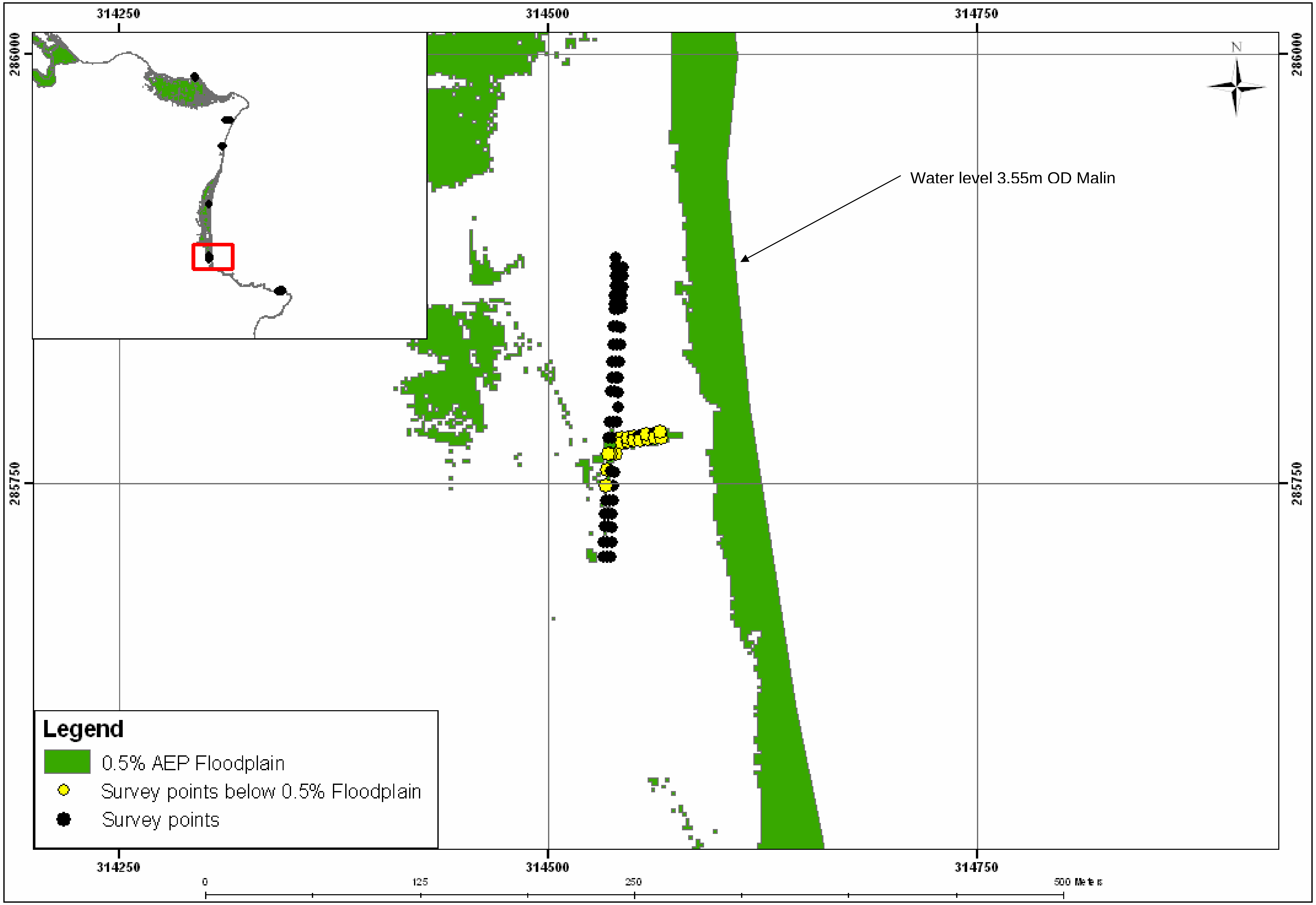


Figure 15: Comparison of 0.5% AEP Floodplain and Survey Data – Cruisetown (Port Oriel Survey Points)

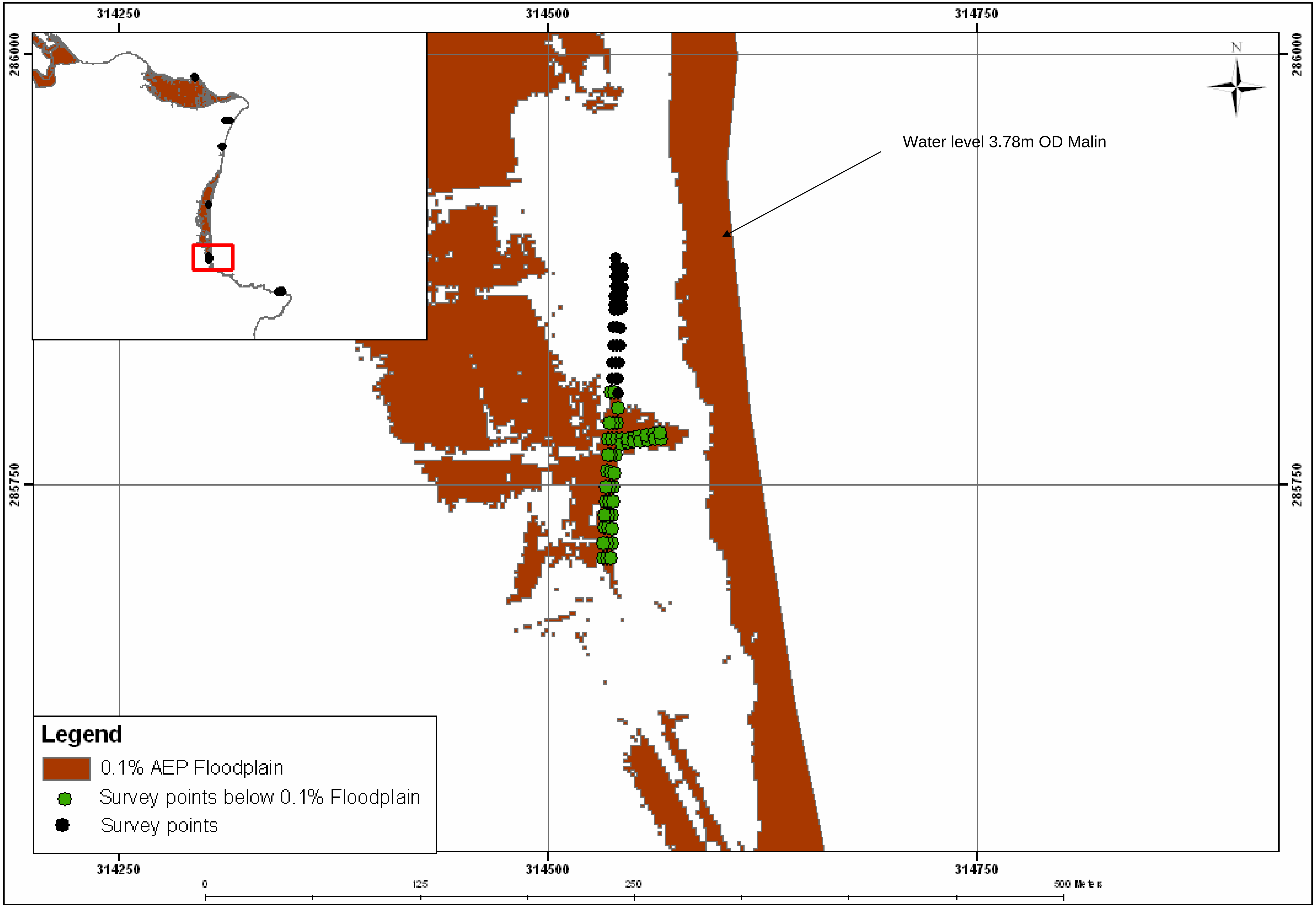


Figure 16: Comparison of 0.1% AEP Floodplain and Survey Data – Cruisetown (Port Oriel Survey Points)

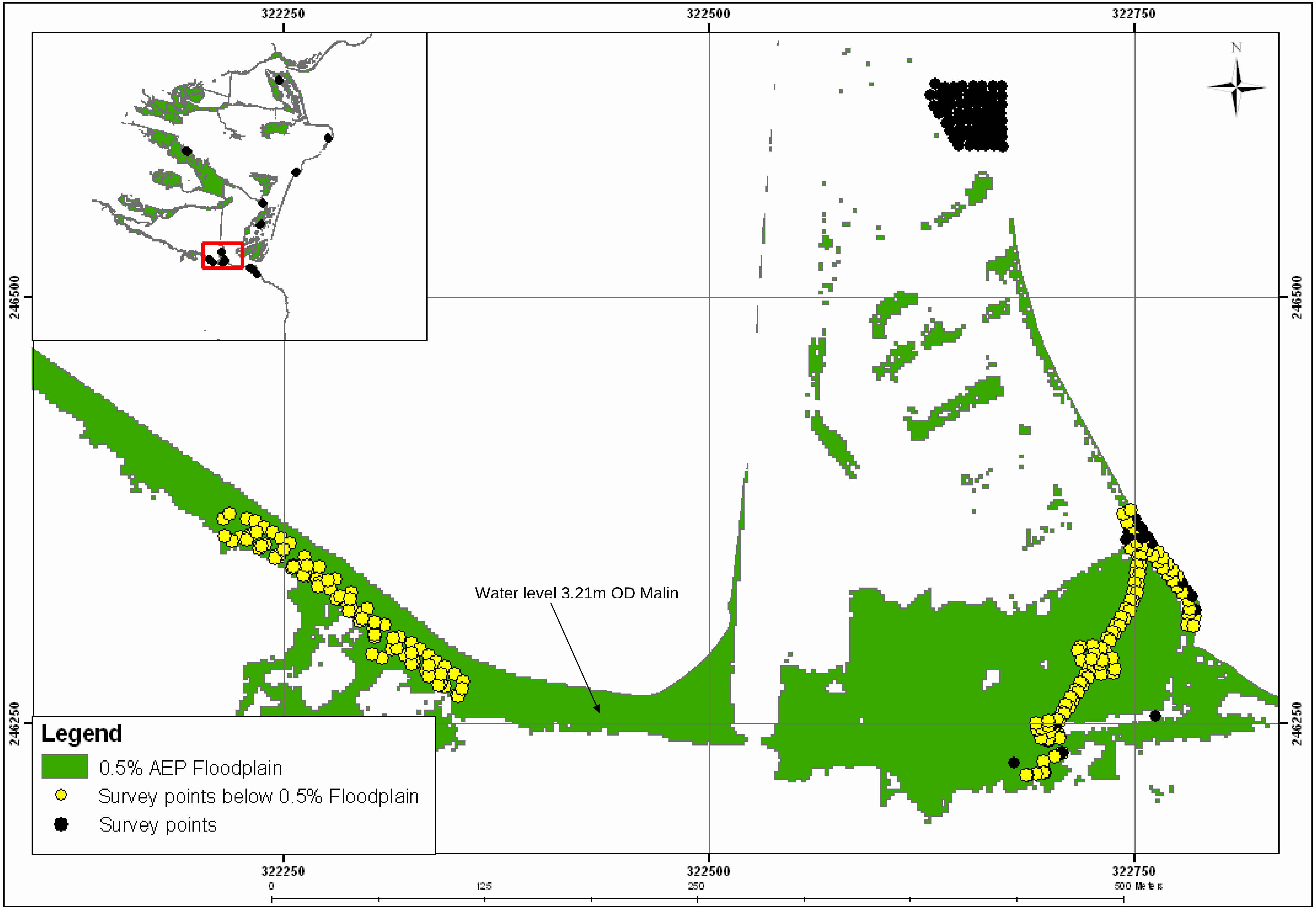


Figure 17: Comparison of 0.5% AEP Floodplain and Survey Data – Malahide Area 1

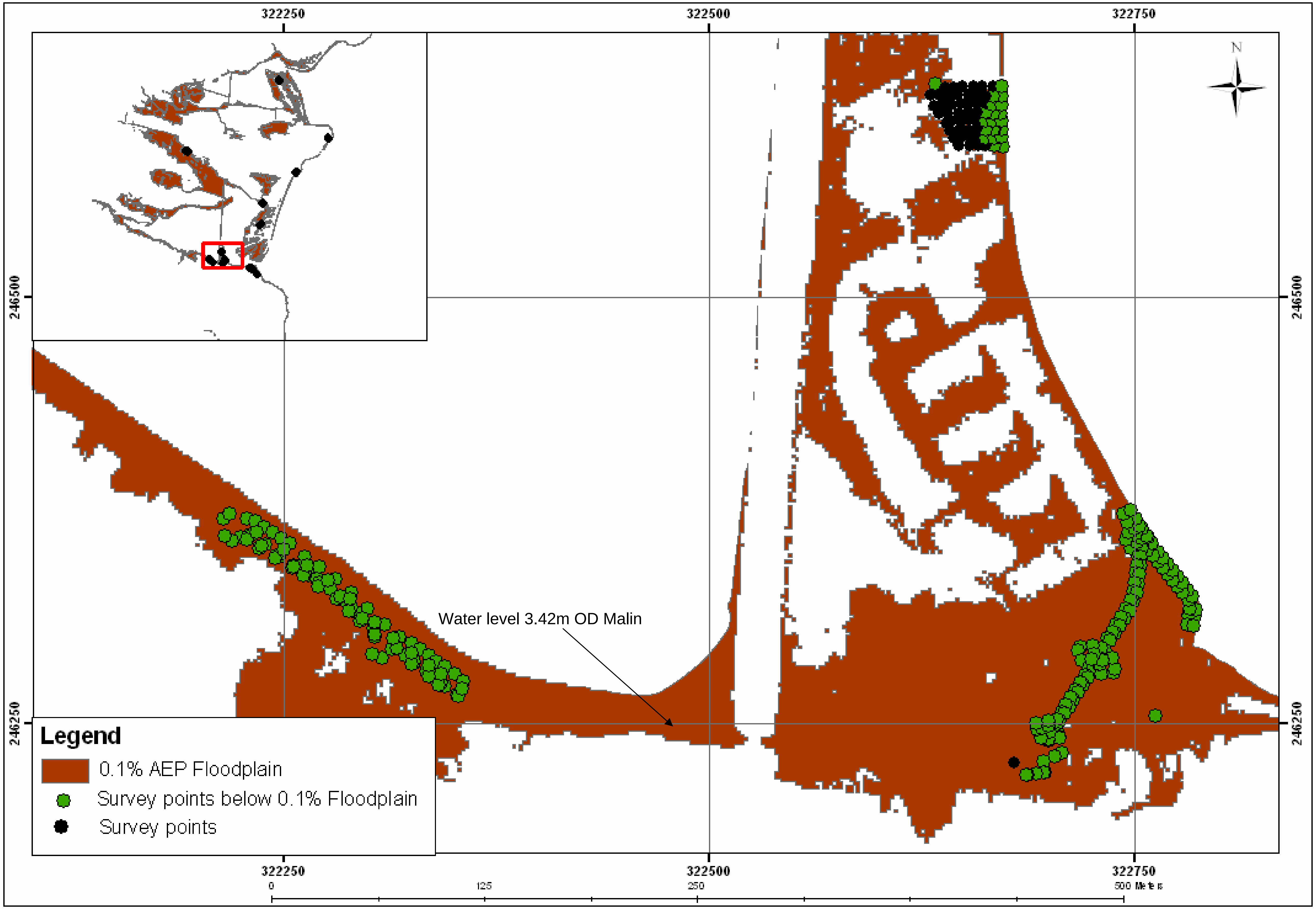


Figure 18: Comparison of 0.1% AEP Floodplain and Survey Data – Malahide Area 1

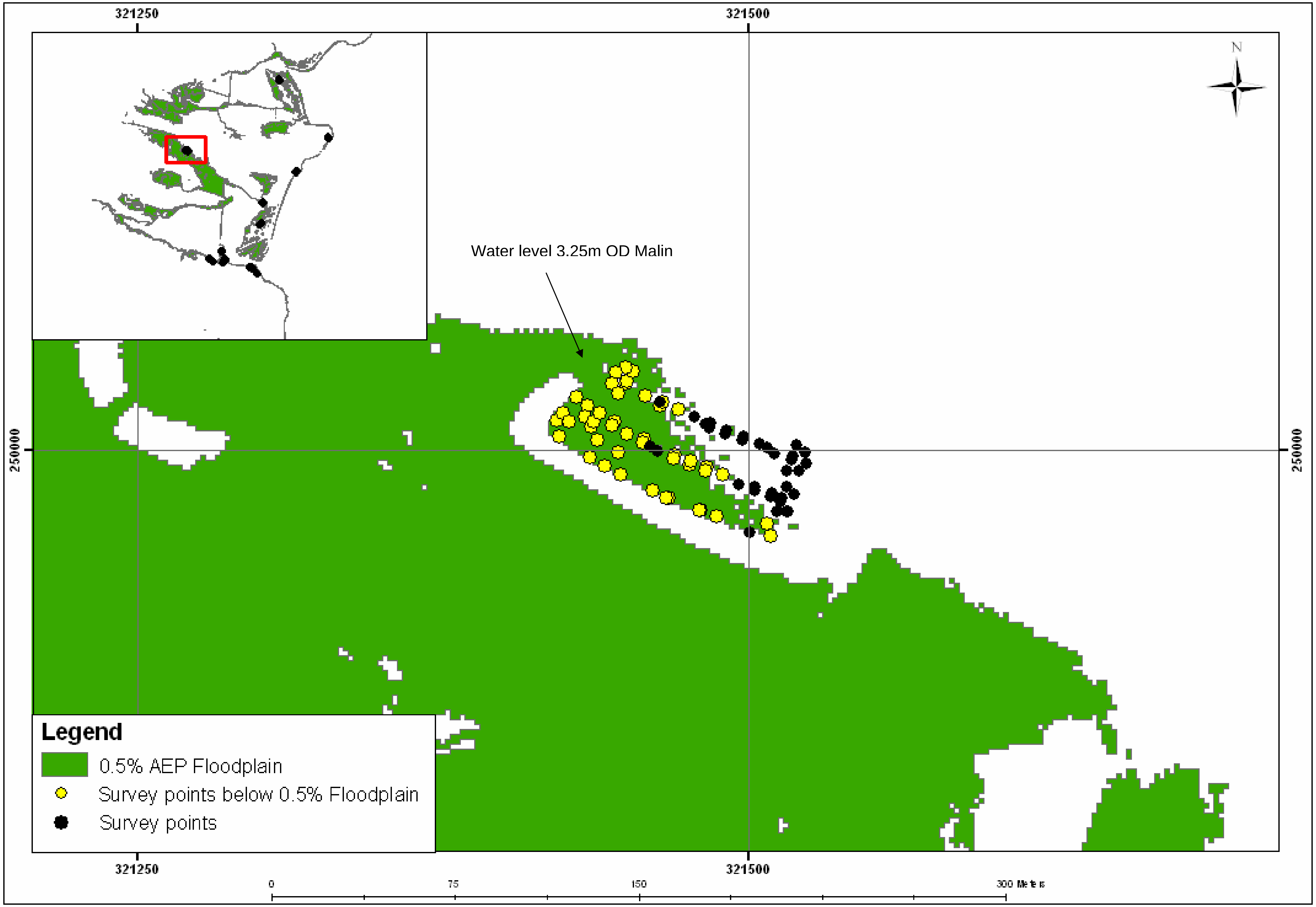


Figure 19: Comparison of 0.5% AEP Floodplain and Survey Data – Donabate Area (Malahide Survey Points)

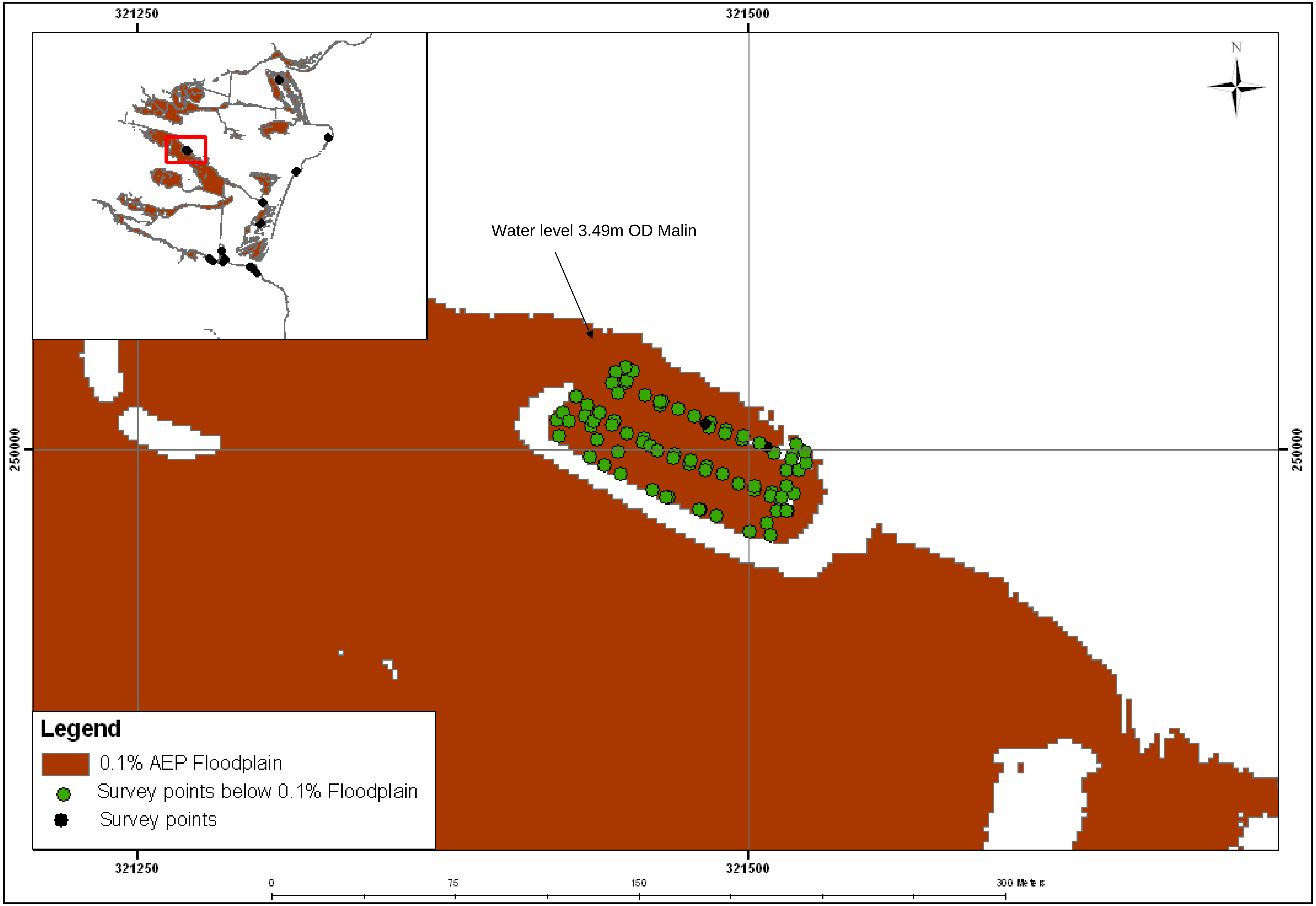


Figure 20: Comparison of 0.1% AEP Floodplain and Survey Data – Donabate Area (Malahide Survey Points)

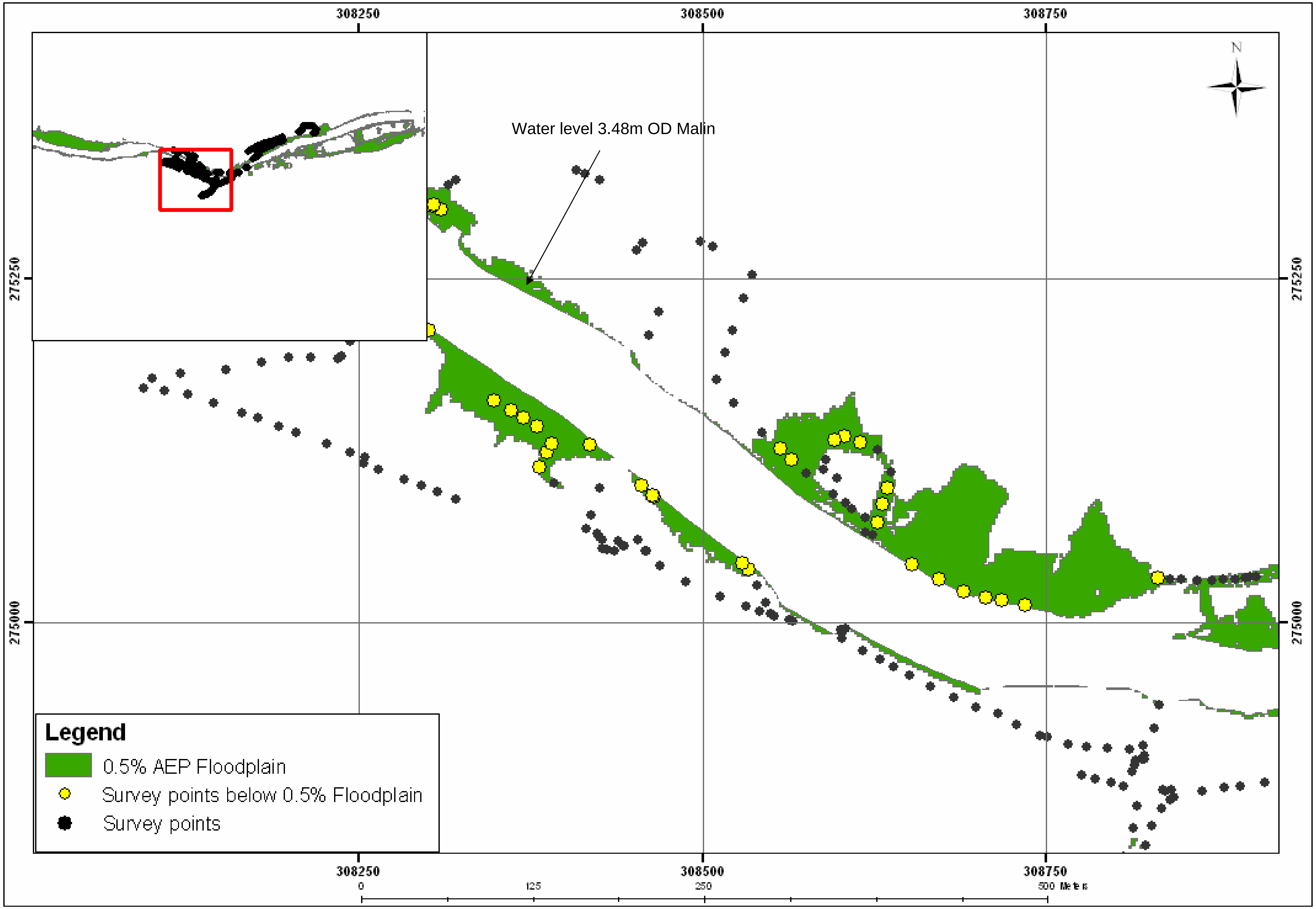


Figure 21: Comparison of 0.5% AEP Floodplain and Survey Data – Drogheda Area 1

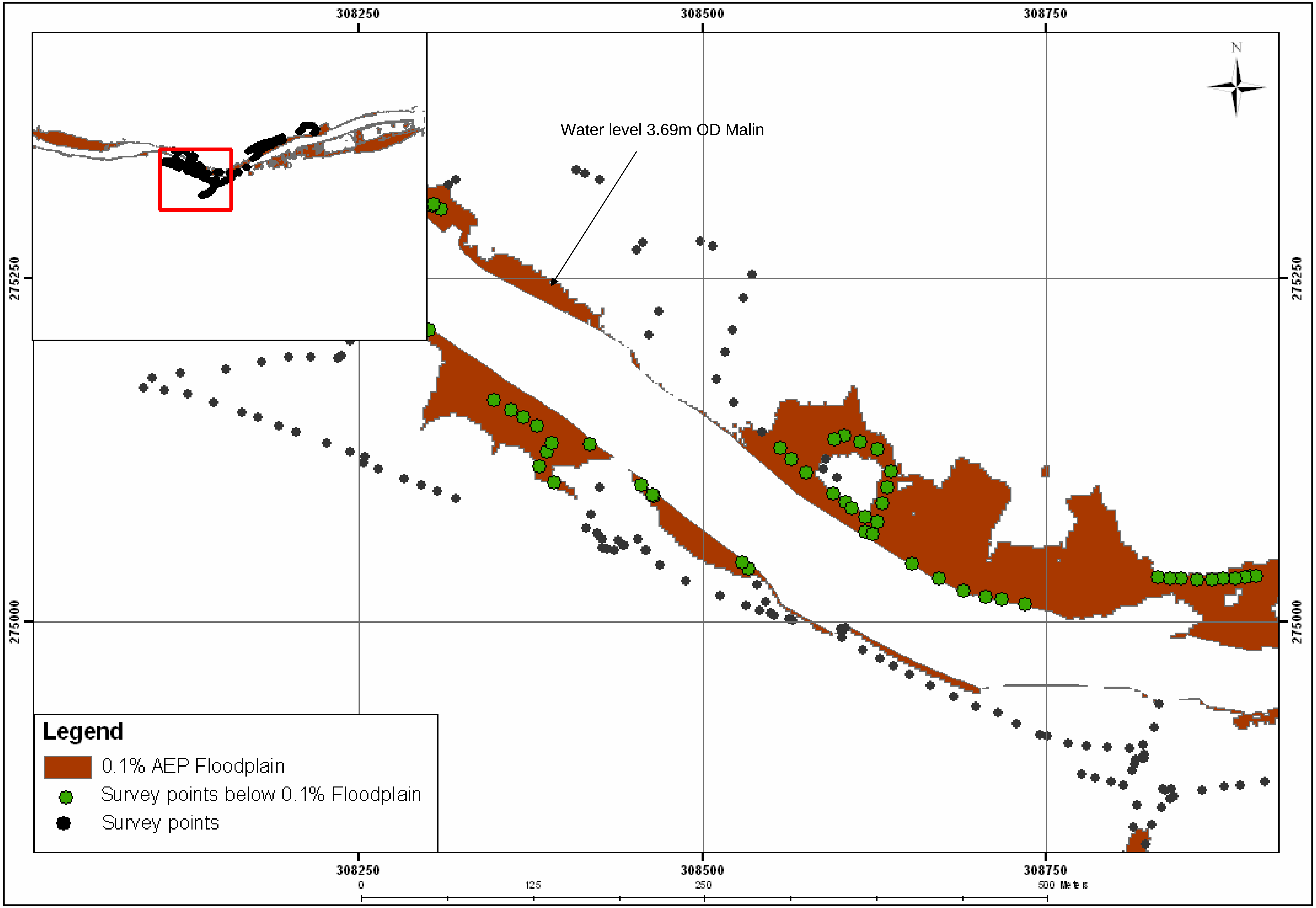


Figure 22: Comparison of 0.1% AEP Floodplain and Survey Data – Drogheda Area 1

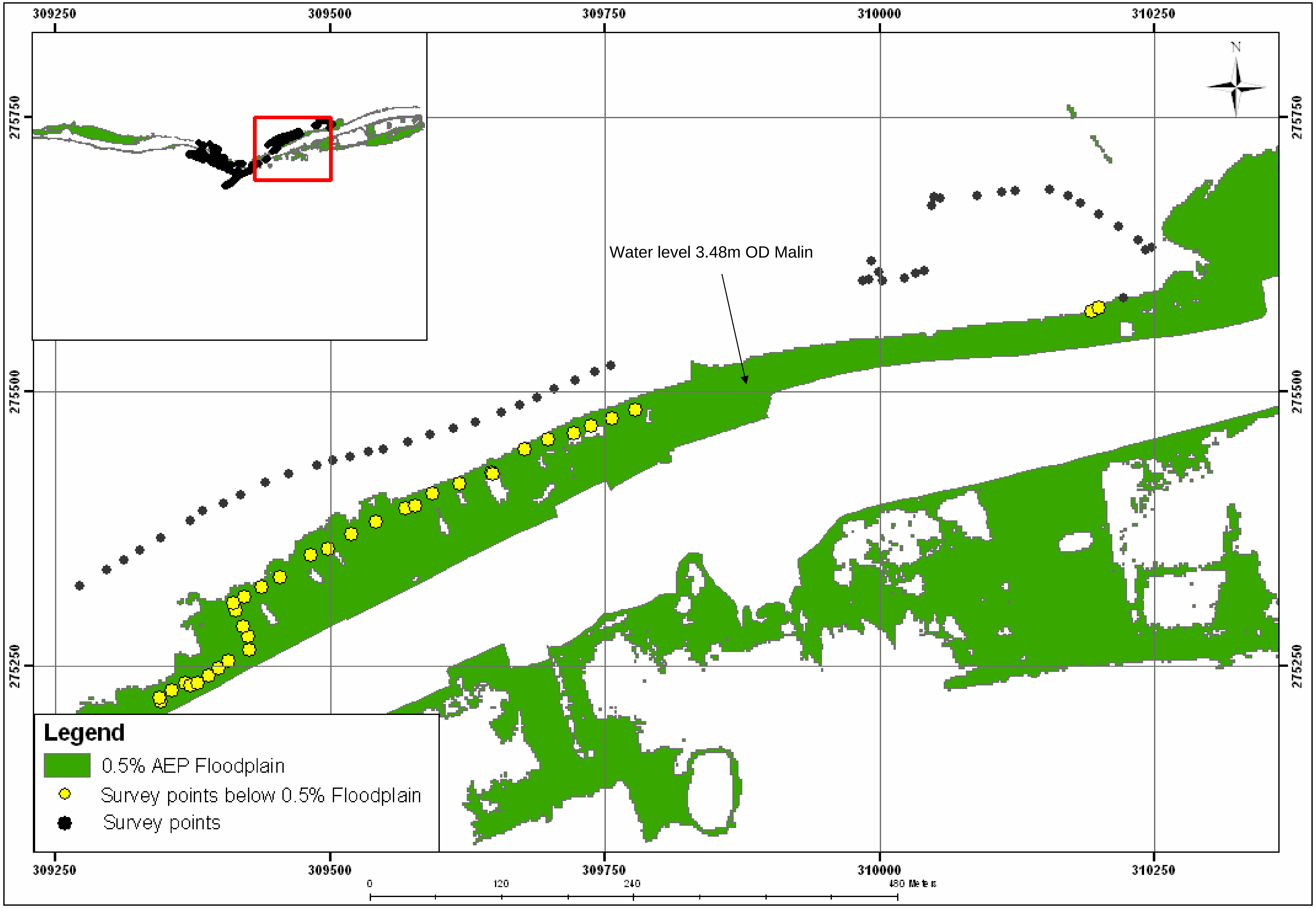


Figure 23: Comparison of 0.5% AEP Floodplain and Survey Data – Drogheda Area 2

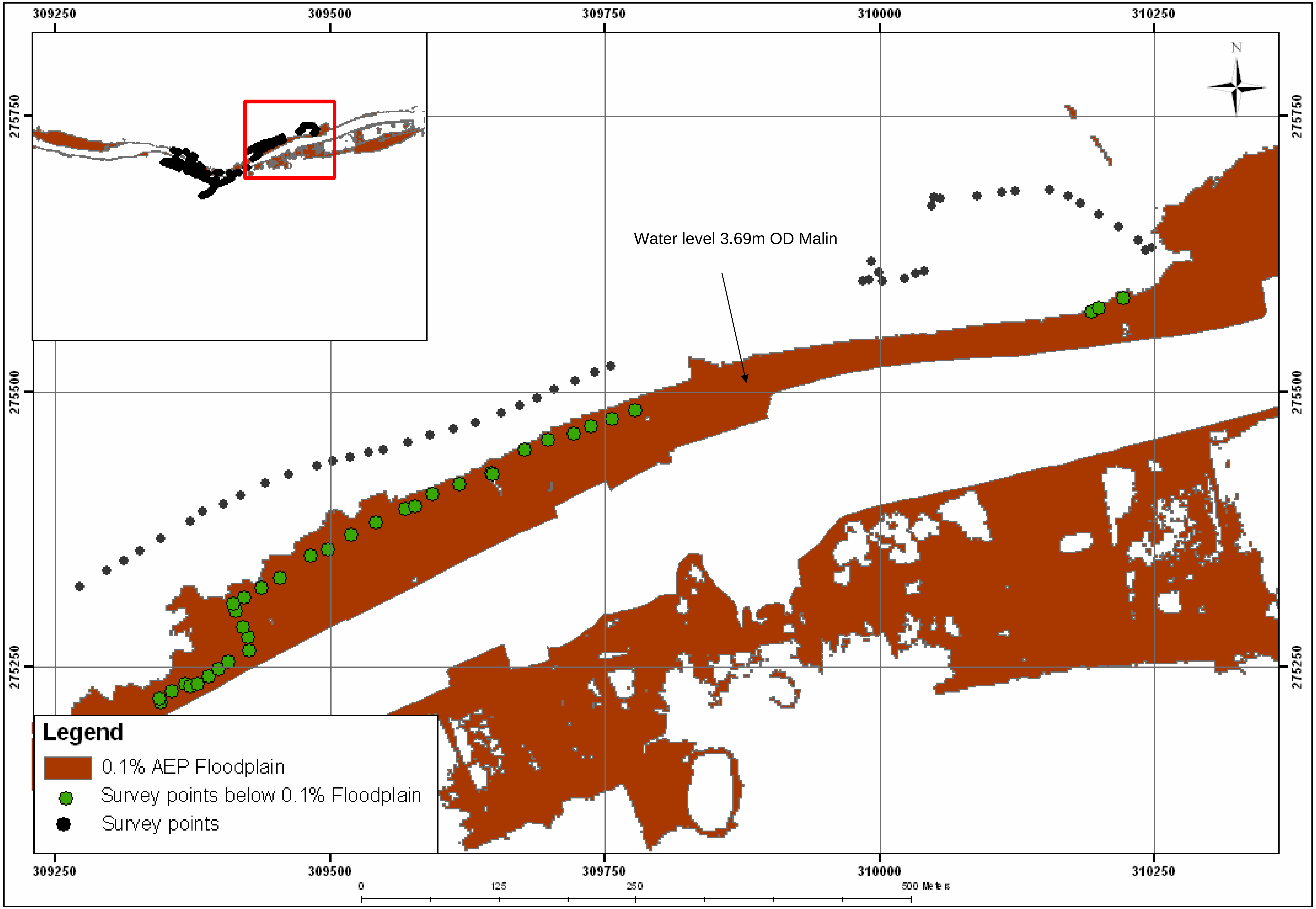


Figure 24: Comparison of 0.1% AEP Floodplain and Survey Data – Drogheda Area 2

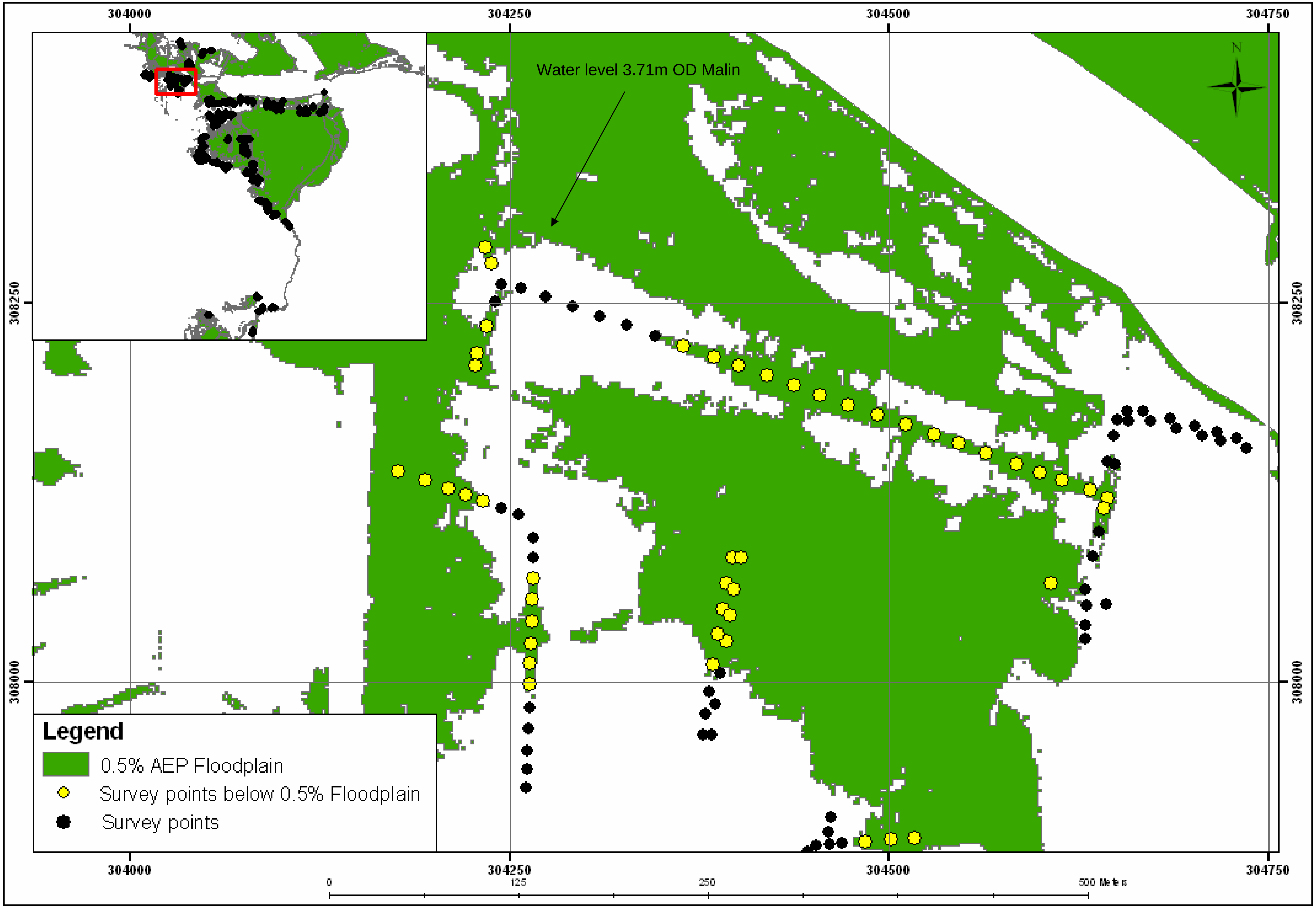


Figure 25: Comparison of 0.5% AEP Floodplain and Survey Data – Dundalk Area 1 (2008 Survey Points)

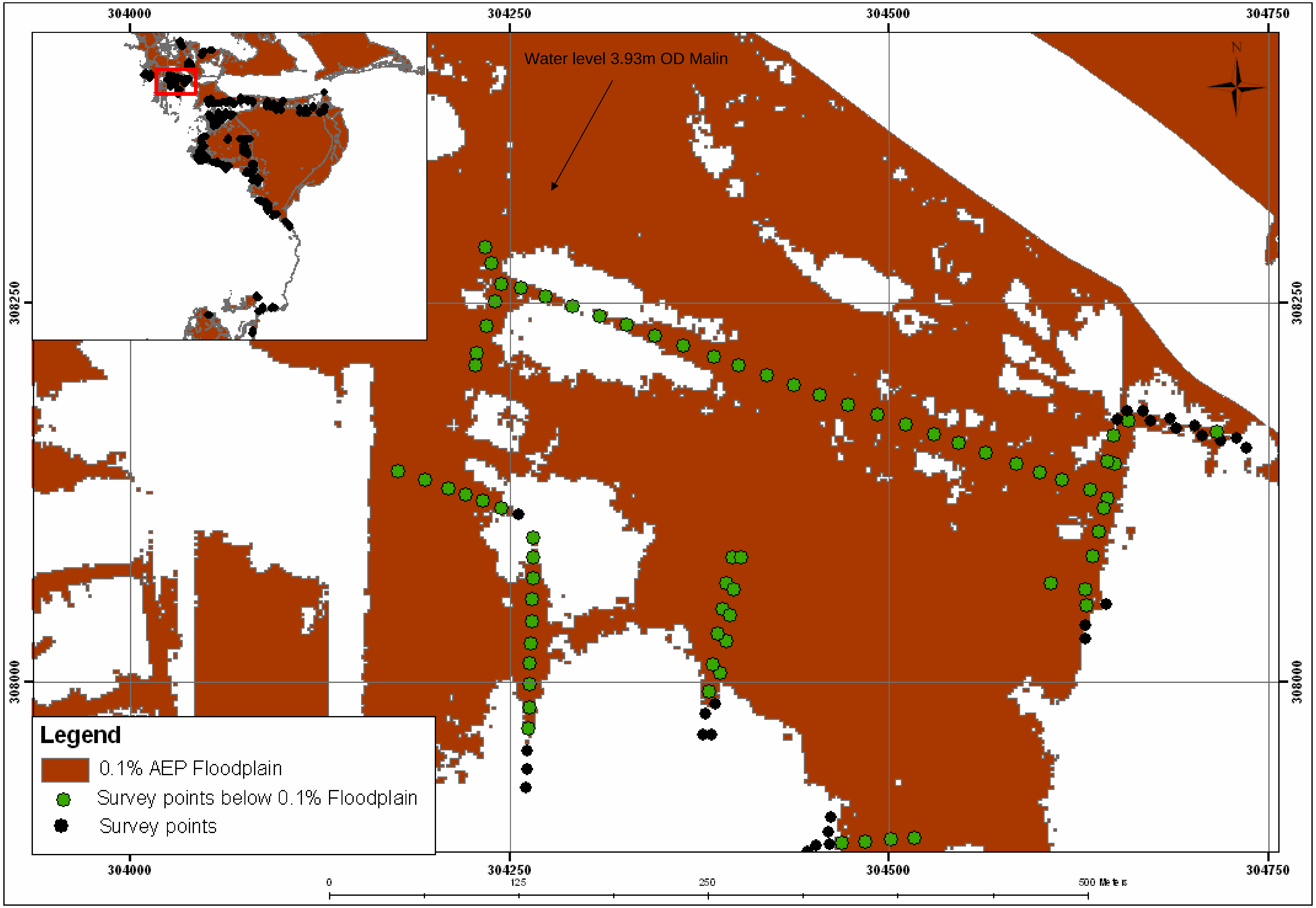


Figure 26: Comparison of 0.1% AEP Floodplain and Survey Data – Dundalk Area 1 (2008 Survey Points)

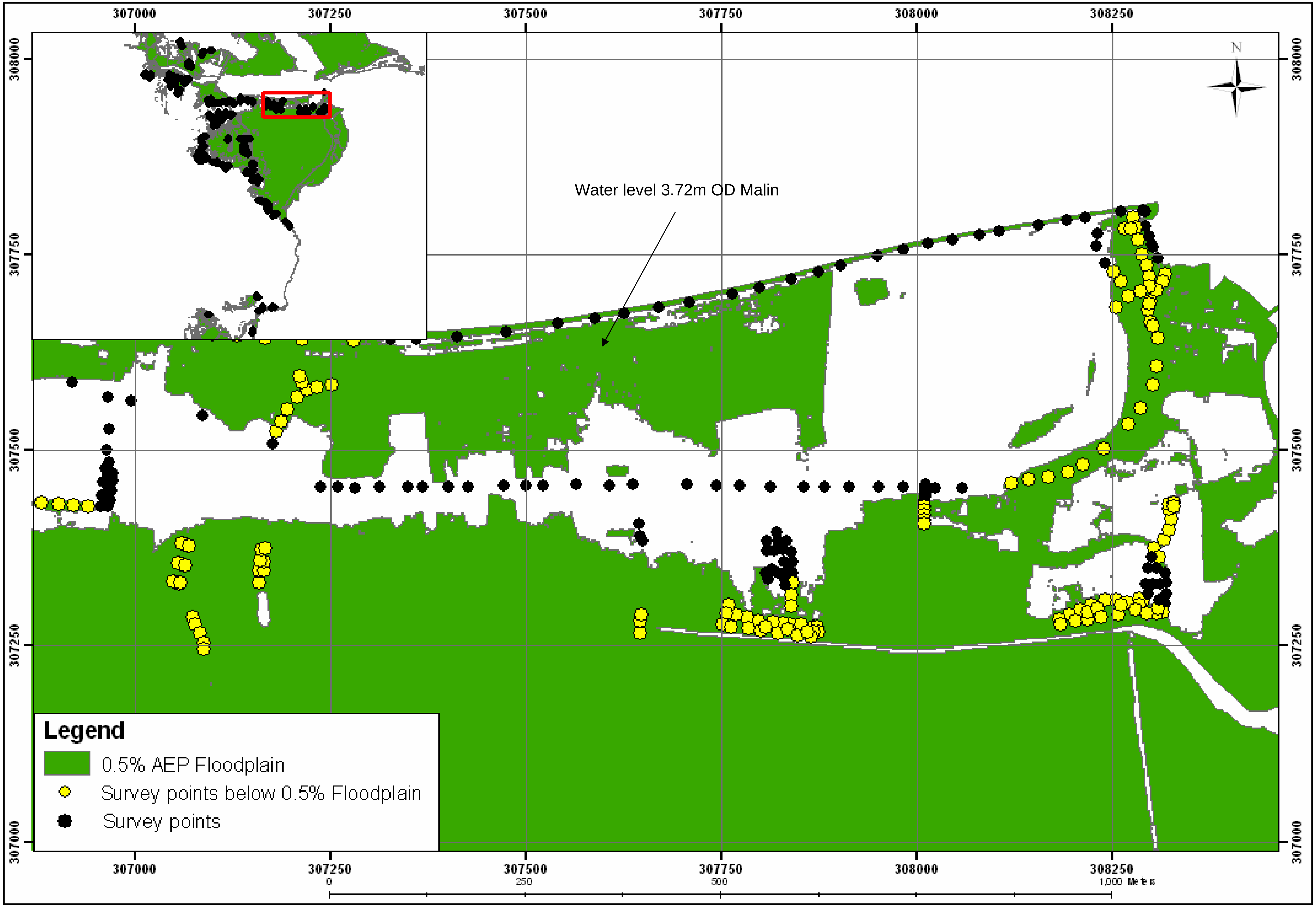


Figure 27: Comparison of 0.5% AEP Floodplain and Survey Data – Dundalk Area 2 (2006 and 2008 Survey Points)

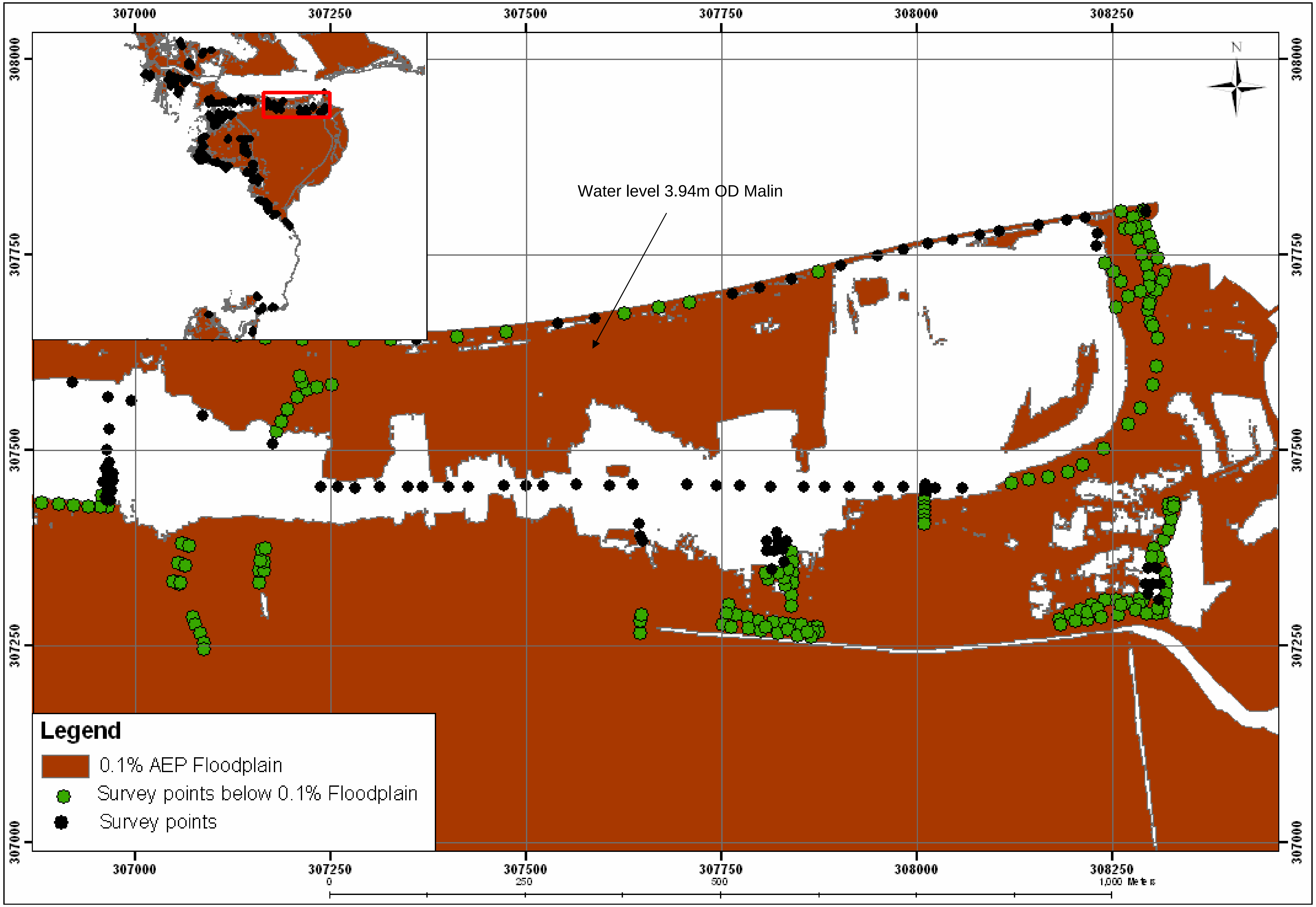


Figure 28: Comparison of 0.1% AEP Floodplain and Survey Data – Dundalk Area 2 (2006 and 2008 Survey Points)

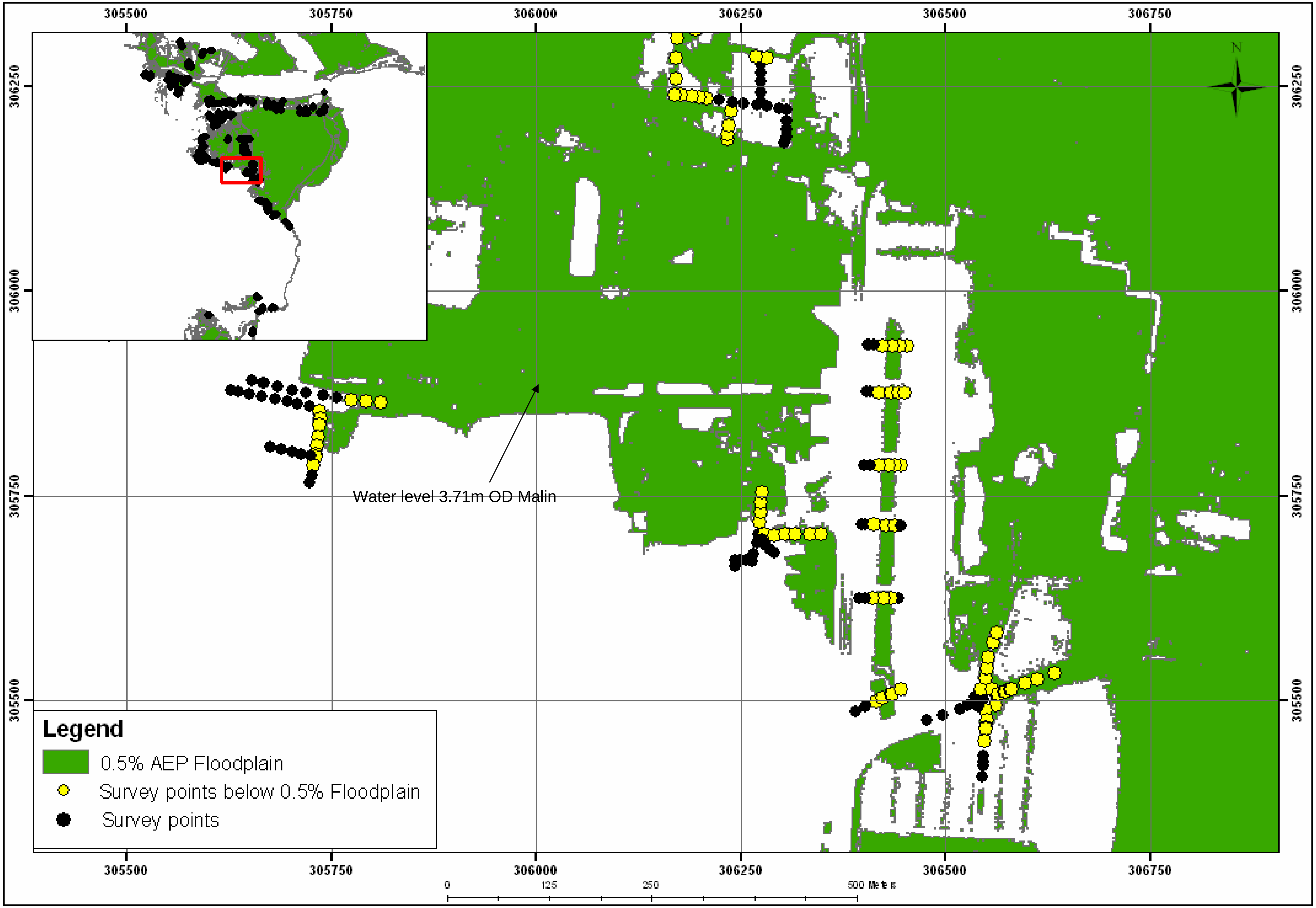


Figure 29: Comparison of 0.5% AEP Floodplain and Survey Data – Dundalk Area 3 (2008 Survey Points)

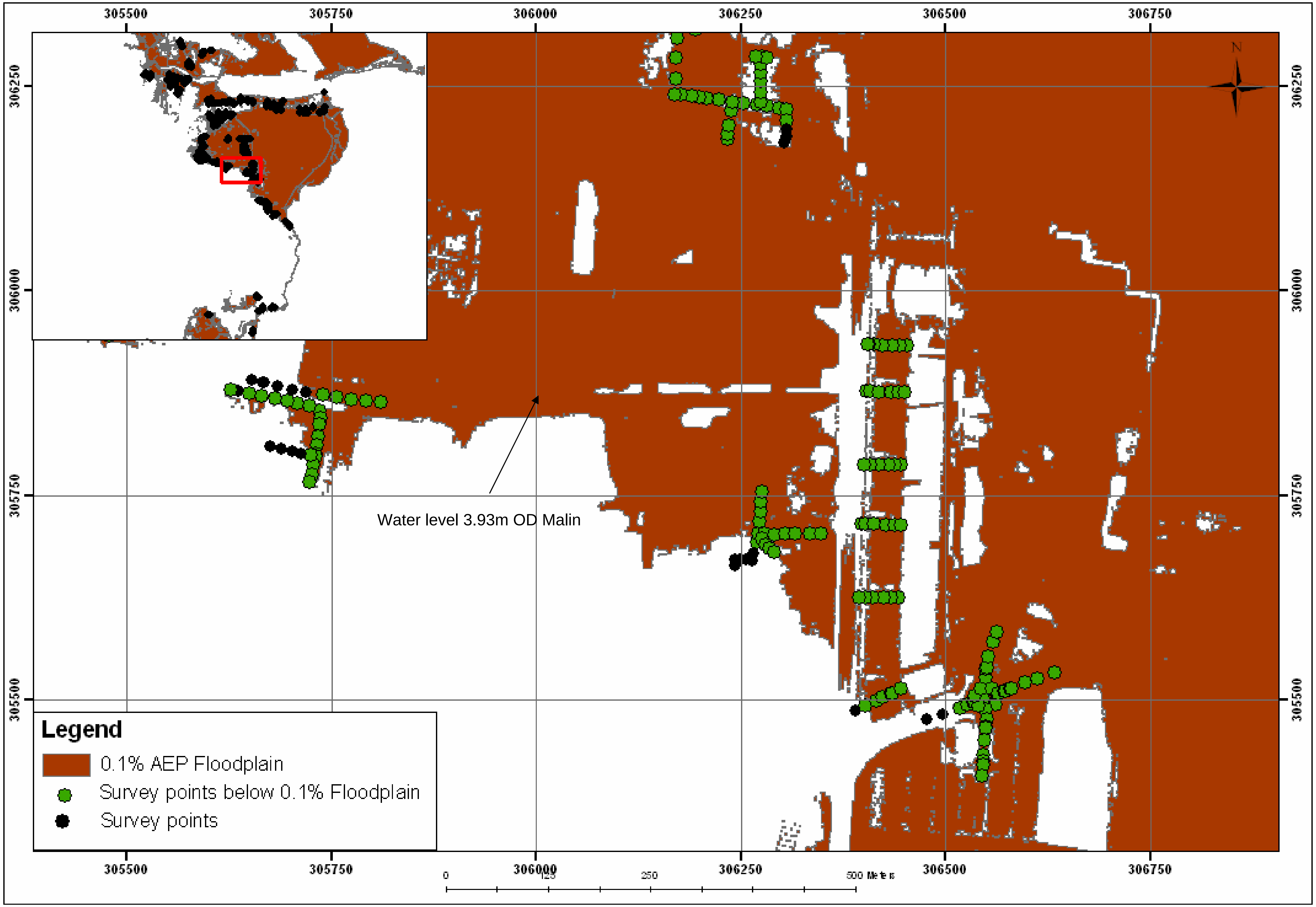


Figure 30: Comparison of 0.1% AEP Floodplain and Survey Data – Dundalk Area 3 (2008 Survey Points)

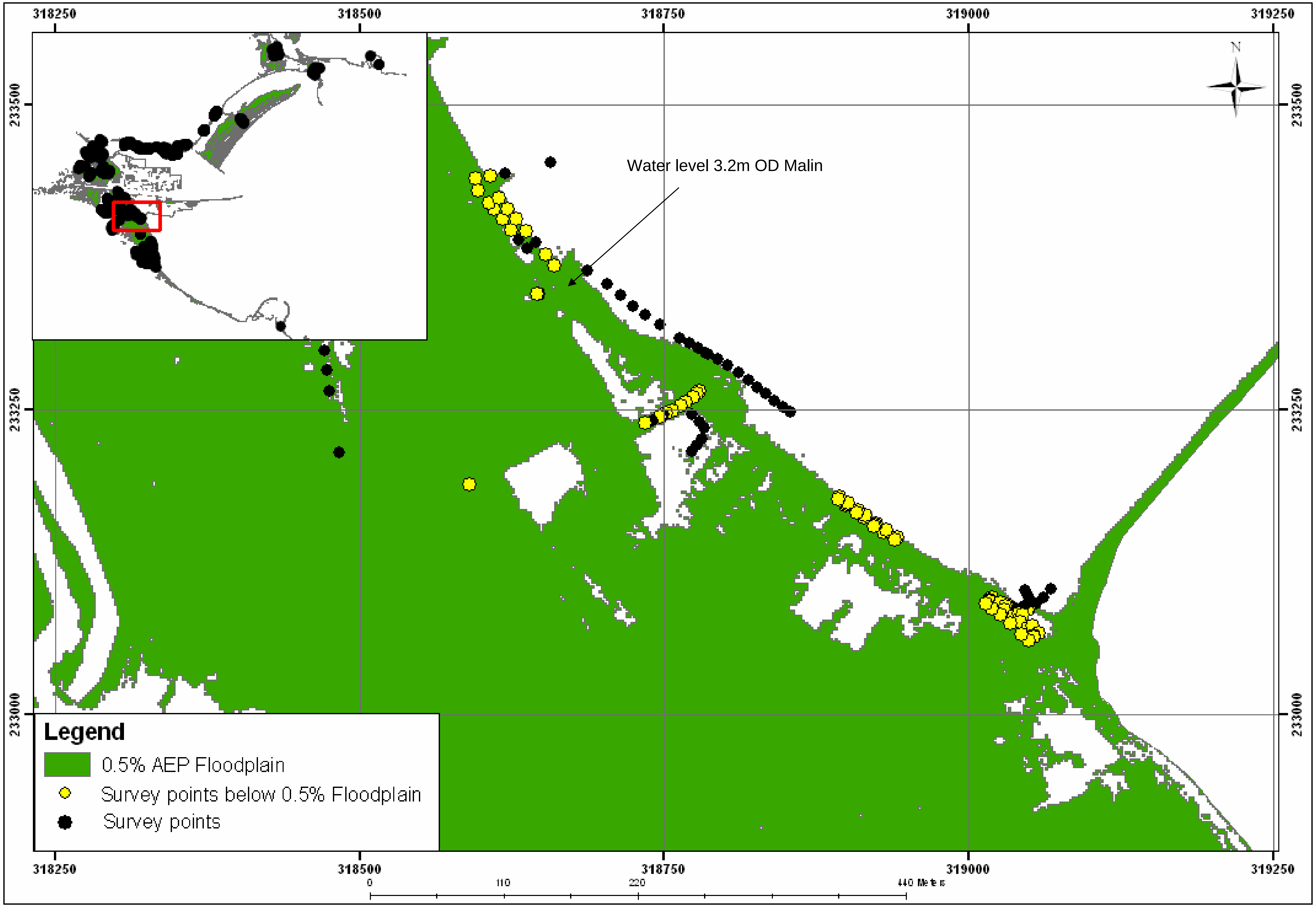


Figure 31: Comparison of 0.5% AEP Floodplain and Survey Data – Ballsbridge (Dublin Survey Points)

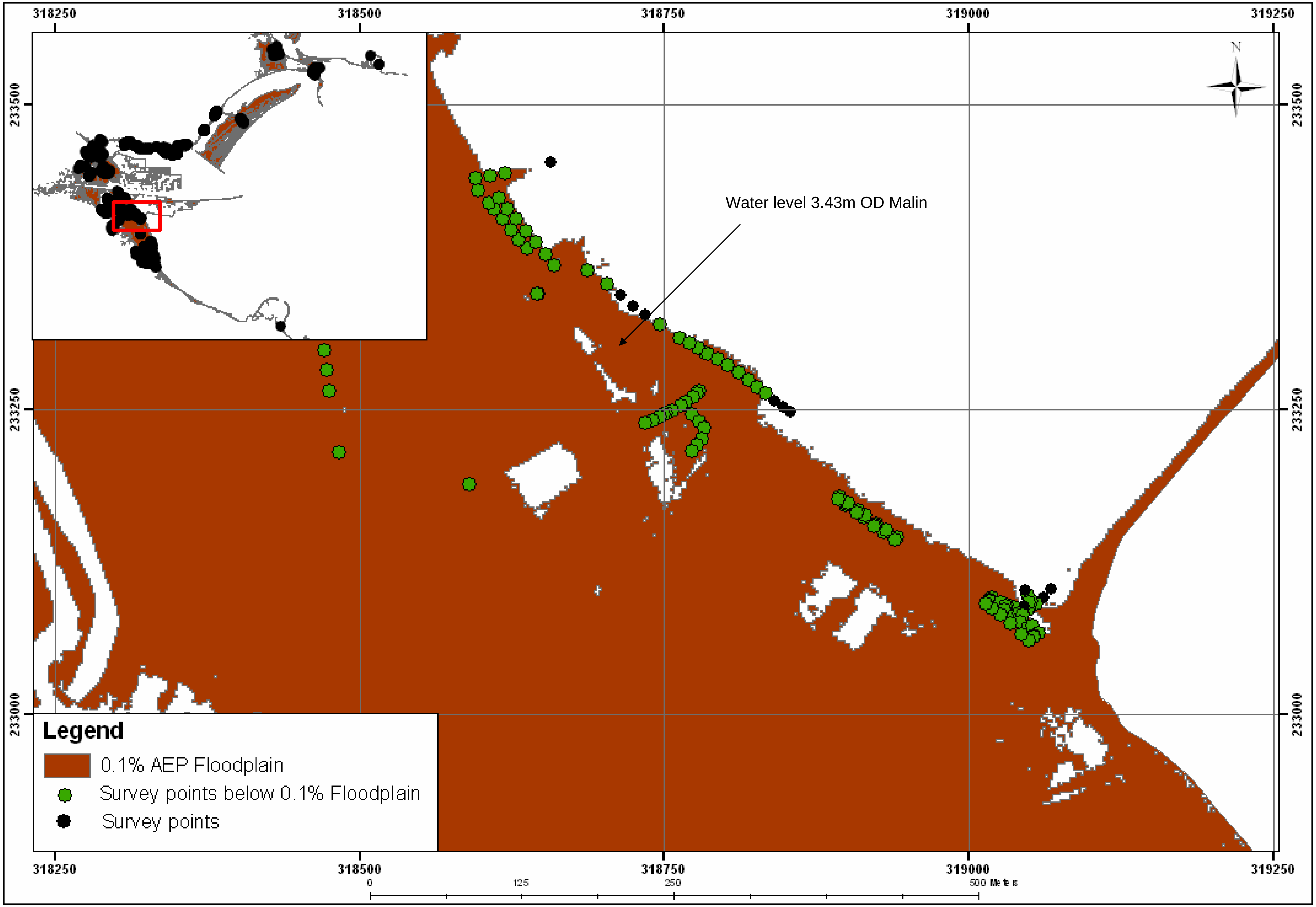


Figure 32: Comparison of 0.1% AEP Floodplain and Survey Data – Ballsbridge (Dublin Survey Points)

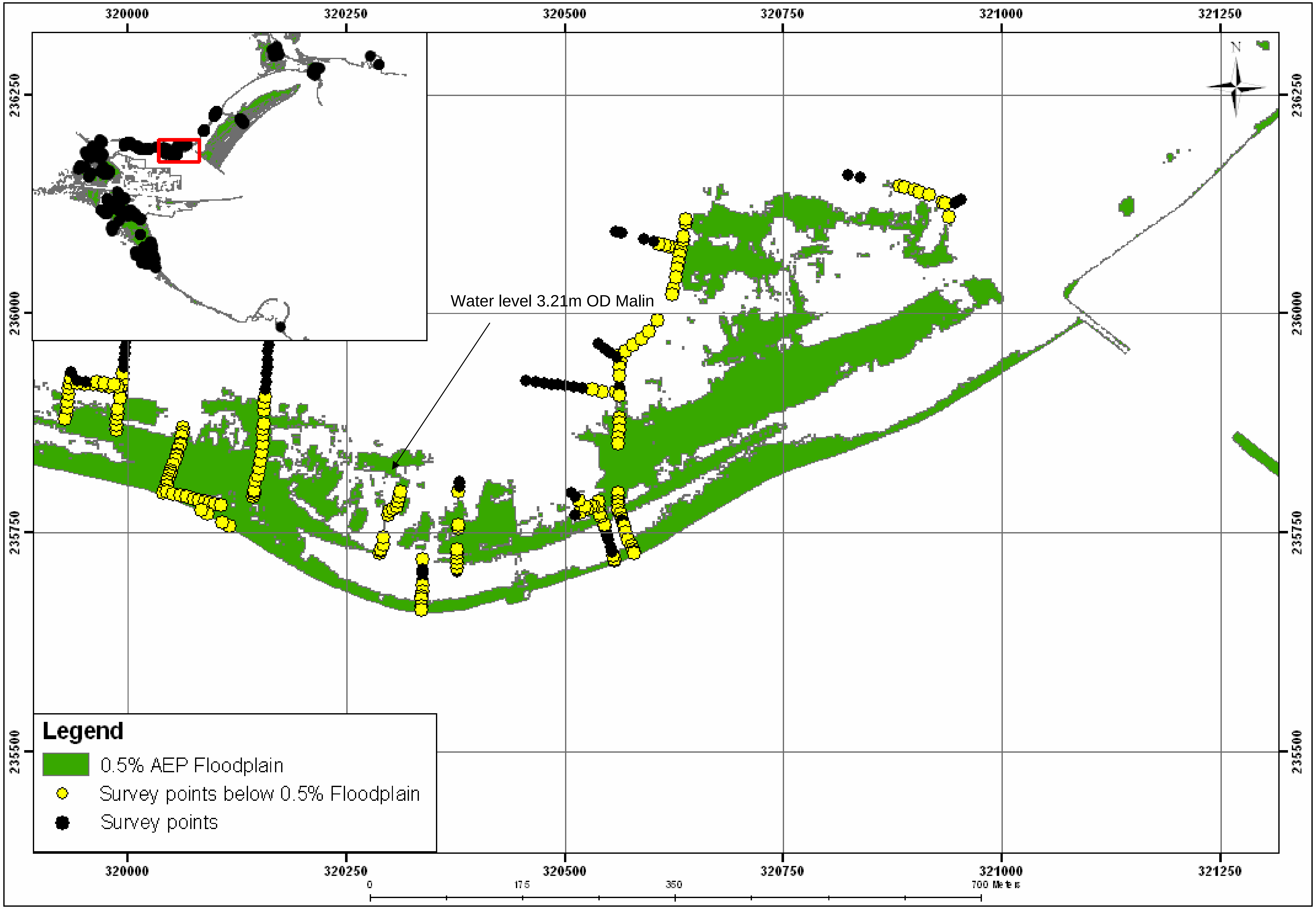


Figure 33: Comparison of 0.5% AEP Floodplain and Survey Data – Clontarf (Dublin Survey Points)

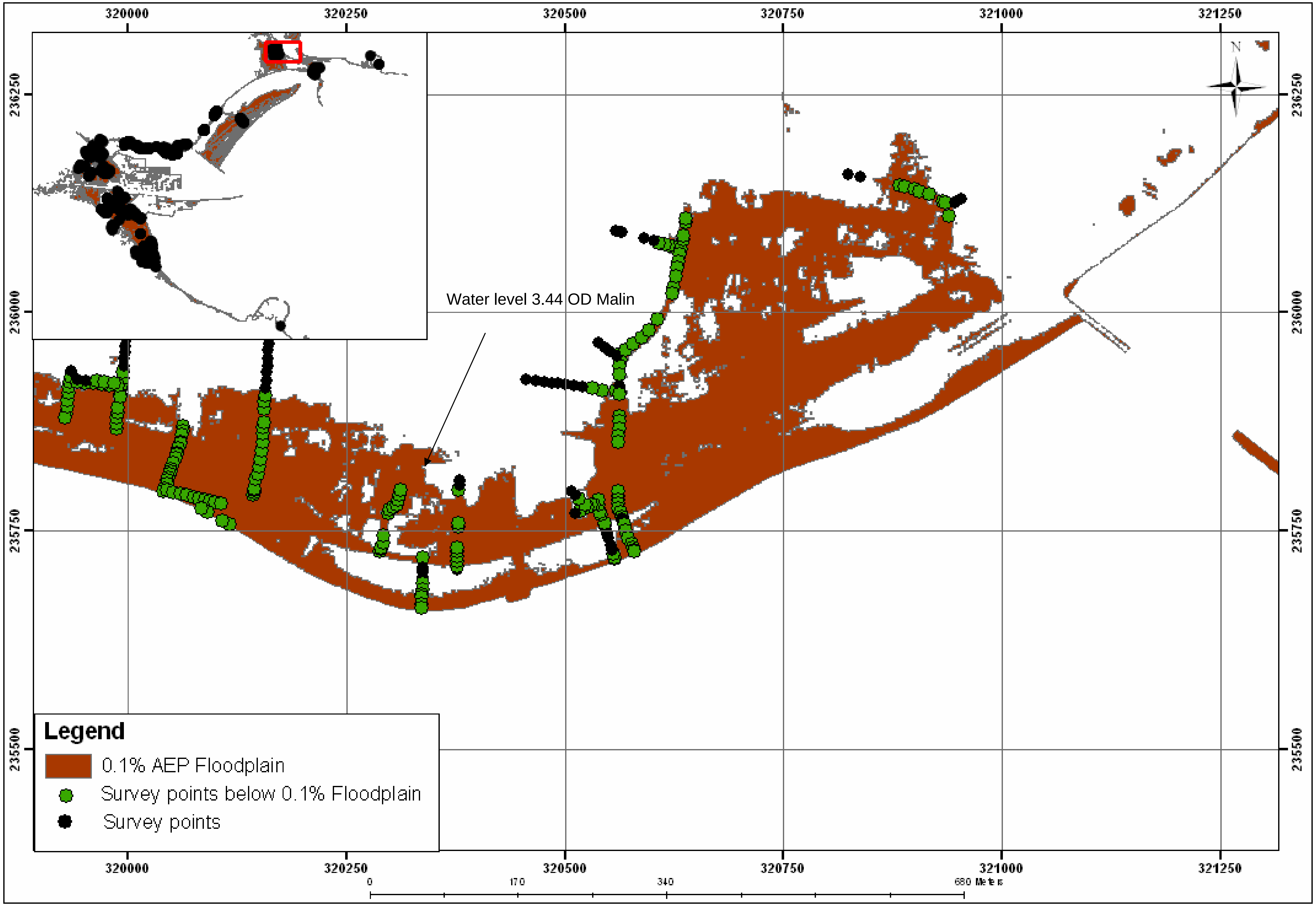


Figure 34: Comparison of 0.1% AEP Floodplain and Survey Data – Clontarf (Dublin Survey Points)

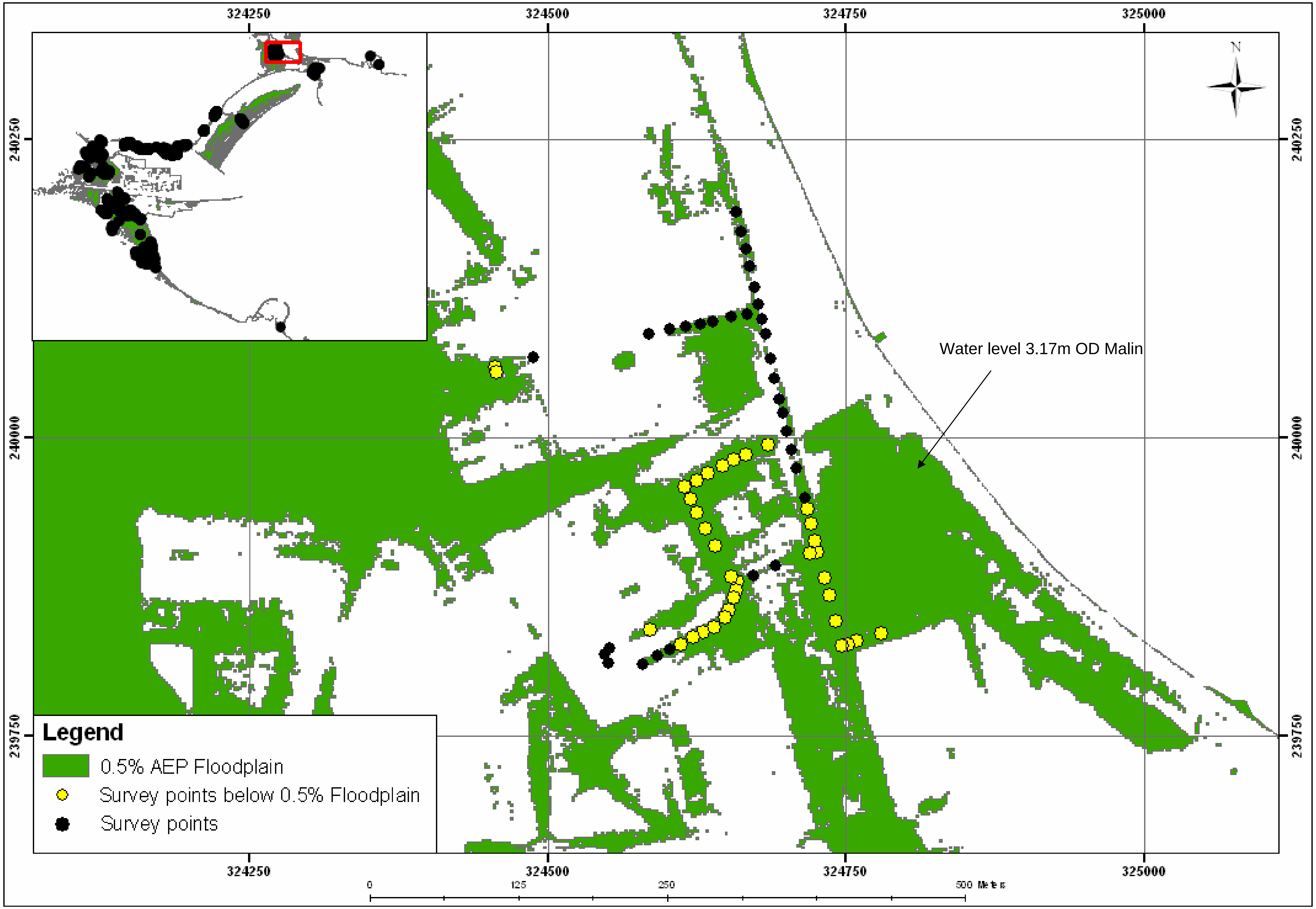


Figure 35: Comparison of 0.5% AEP Floodplain and Survey Data – Portmarnock (Dublin Survey Points)

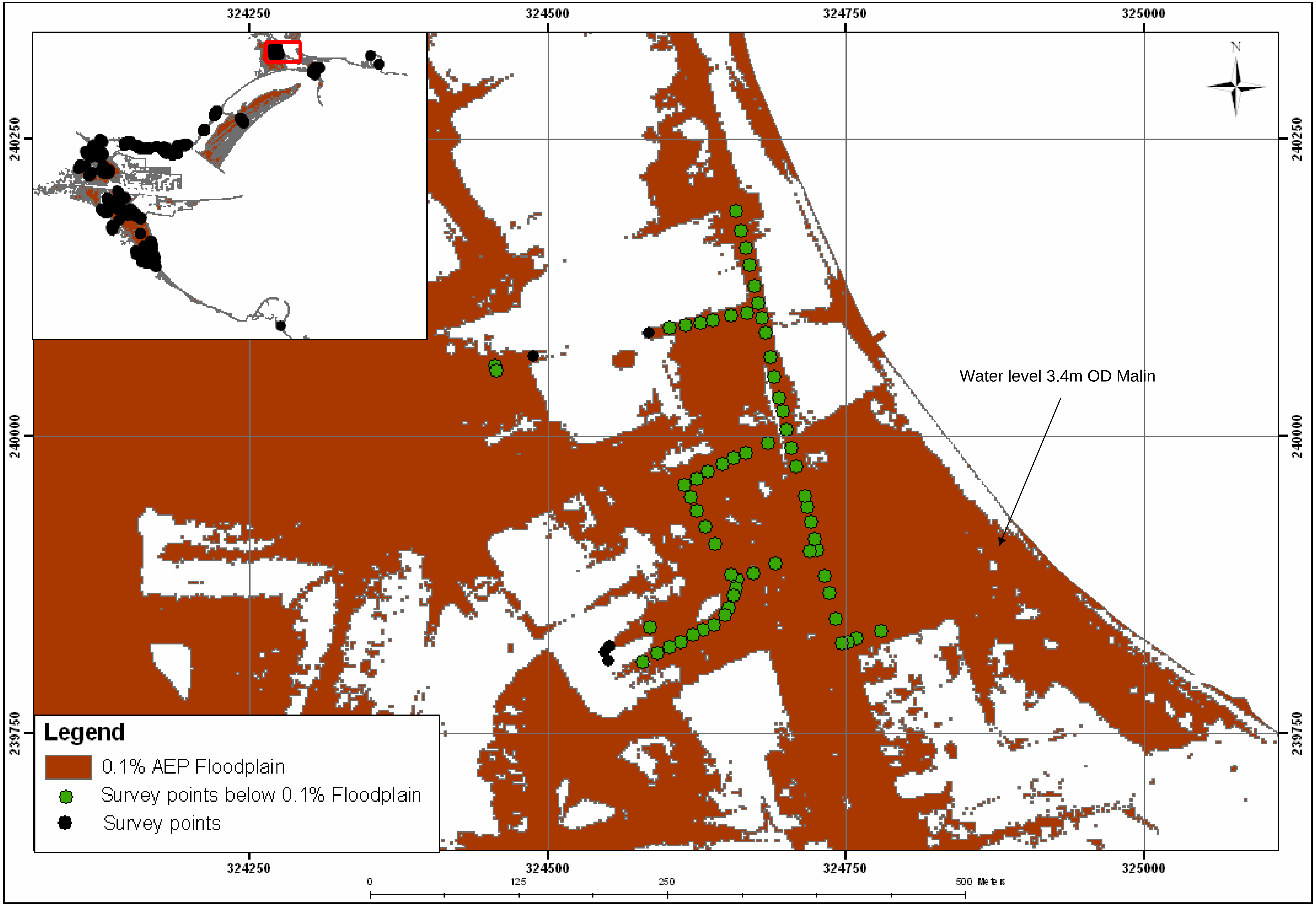


Figure 36: Comparison of 0.1% AEP Floodplain and Survey Data – Portmarnock (Dublin Survey Points)

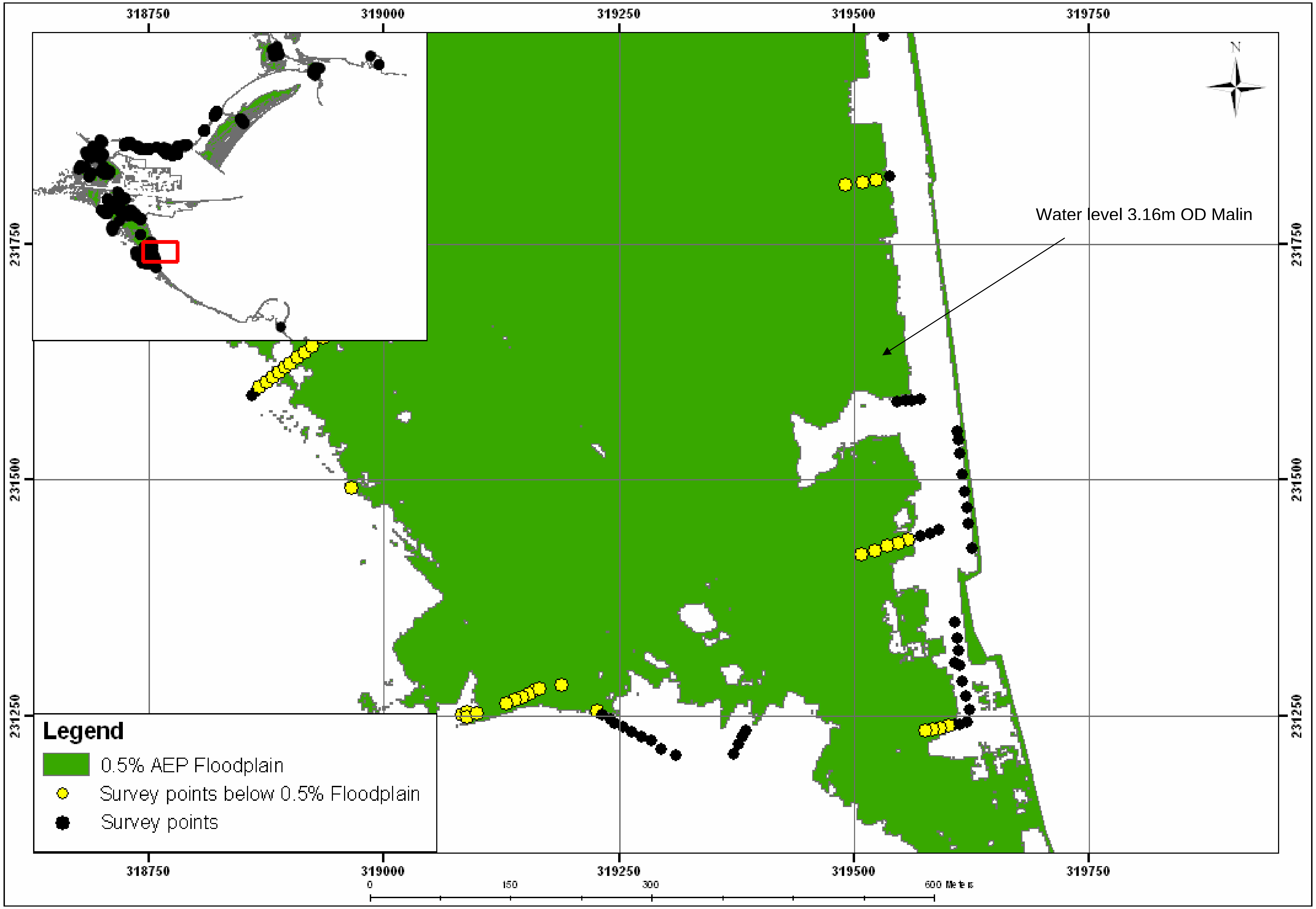


Figure 37: Comparison of 0.5% AEP Floodplain and Survey Data – Sydney Parade (Dublin Survey Points)

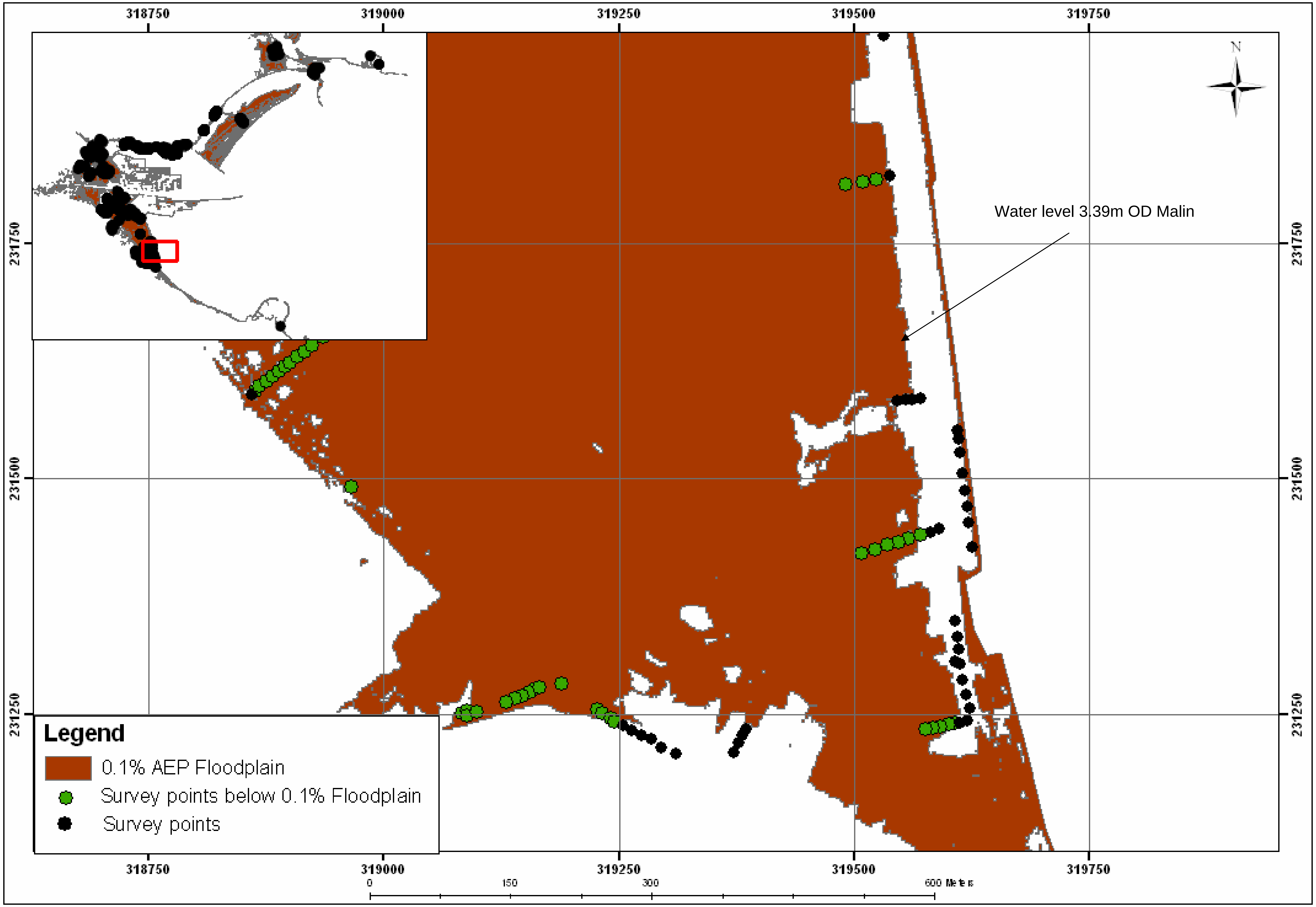


Figure 38: Comparison of 0.1% AEP Floodplain and Survey Data – Sydney Parade (Dublin Survey Points)

Appendix 7: Floodplain maps including flood extent maps for 0.1% and 0.5% AEP events, and flood depth maps for 0.5% AEP event (issued under separate cover)

Appendix 8: Erosion Maps for 2030 and 2050 (issued under separate cover)

Appendix 9: Confidence in Flood Extents and Erosion Lines

Appendix 9a: Confidence in Flood Extents

IRISH COASTAL PROTECTION STRATEGY STUDY – ANALYSIS OF CONFIDENCE IN FLOOD EXTENTS

1.0 Introduction

A fundamental issue in the delivery of the final flood extents as part of the Irish Coastal Protection Strategy Study was the level of confidence which they could be assigned. Data used in the production of any flood extents is rarely of consistent accuracy and may vary depending on location. Consequently a level of confidence was required to reflect the reliability of the input data, together with any discrepancies in the methodology of determining the flood extents. .

RPS therefore developed a quantitative methodology for determining the level of confidence in the flood extents, based on a scoring and weighting system, and the establishment of five confidence classifications based on various parameters in the flood extent determination.

This report describes the methodology used and the outcome for the north east coast study area.

2.0 General Methodology

The methodology adopted was based on the scoring and weighting of various parameters which influenced the position of the flood extents, and it established the level of confidence to be assigned to these flood extents; from very high, high or medium confidence to low or very low confidence. The parameters analysed are listed below.

- DTM Accuracy of the Digital Terrain Model (DTM)
- MALIN Accuracy of the conversion from Mean Sea Level (MSL) to Ordnance Datum (OD) Malin
- MODEL Accuracy and level of detail of the model
- MET Accuracy and quantity of meteorological data

A matrix was established using the above parameters, which were assigned a confidence rating, from 1 (complete confidence) to 10 (no confidence) at intervals along the study coastline. This range was large to allow a reasonable scale for future updates of these values. The values were then squared and multiplied by a weighting, related to the potential size of the resulting error in the flood extents, due to each parameter. To compute the final confidence rating, the root sum of the squares of the component confidence ratings times the weightings were calculated and expressed as a percentage of the potential score range. This was equivalent to applying the Gaussian equation generally used for error analysis. The matrix was then used to determine the overall confidence (very high, high, medium, low or very low) of the flood extents for the particular segment of coast.

The Confidence SumTotal was given by;

$$\sqrt{W_1 C_{DTM}^2 + W_2 C_{Malin}^2 + W_3 C_{Model}^2 + W_4 C_{Met}^2}$$

Where W_{1-4} represented the relevant weighting and the C values represented the confidence factors.

This simplified approach ignored interdependencies between the confidence components and the fact that these confidences may have related to over or under estimation of the flood levels, where the net effect was reduced or null. It also assumed that the confidence ratings were approximately normally distributed about the mean and it tended to highlight the least confident parameter.

It was noted that a feature of methods with multiple confidence sources is that the user tends to under-estimate the confidence, as there is a tendency to always assign some uncertainty to each category. For this reason, the default values were ascribed to give medium confidence (~50%) providing scope for movement in either direction.

2.1 Accuracy of the DTM

As the DTM was established for the purpose of a strategic study, the level of detail may have not been as high as that of a more localised or detailed study and this was considered when assigning confidence ratings. Unlike for the south east coast, the level of detail of the north east coast DTM was consistent along the coastline, as one DTM dataset was gathered for all areas.

The accuracy of the DTM was considered in terms of the mean height difference and the average of the 95% Confidence limits, where height difference referred to the difference between the DTM and the Quality Control Survey for each stretch of coastline.

2.2 Mean Sea Level to OD Malin Conversion

The Mean Sea Level (MSL) to OD Malin conversion model used in this study to help define the flood extents has been improved in recent years, but remained another factor affecting the level of confidence in the flood extents. Future modelling of the coastline may use an enhanced MSL to OD Malin conversion model, and so, as a necessity, the methodology and scale was developed to take account of this and allowed room for improvement.

2.3 Accuracy and Level of Detail of the Model

Model accuracy and detail depended on factors such as cell size, time step and the internal stability of the model. Ideally, all these factors would have been represented in the confidence analysis; however cell size and time step should actually vary depending on the requirements of the model and on the features within it. For example, model output from an open coastline with a cell size of 20-50 metres, would not yield any more accurate results compared to a grid size of 200 metres. However, the modelling of a tidal inlet quite often necessitates cell sizes of 20-50 metres for sufficient accuracy. Even with a highly detailed model, if the bathymetry data is not available at sufficient resolution to compliment the cell size, no more accurate results can be obtained, compared to a model of less detail. Determination of cell size therefore depended upon judgement of the modeller setting up the simulations and was difficult to quantify.

For this strategic study, the correlation of model data with relevant tide gauge data was considered to represent the accuracy of the model outcome.

The confidence in the model was taken from four factors;

- the distance between the water level points extracted from the model and the location under analysis,
- the general type of coastline under consideration, for example, open coastline or narrow sea loughs
- the confidence limits of the statistical analysis achieved on output of the model results and
- the correlation of the model results with tide gauge data.

While the first three factors were considered independent, model calibration and hence 'tuning' of the model depended on the level of accuracy of the gauging data used for comparison. The gauges used were located at different sites, where shallow water effects may have been dominant, which might not have been picked up by the methodology used for calibration. Furthermore, tide gauges on tidal river sections may have been influenced by river flow, thus affecting the harmonic analysis and the resulting astronomic tide. These influences along with factors such as damaged gauges, systematic errors and length of gauge data available were taken into account for the model calibration parameter.

2.4 Accuracy of Meteorological Data

The computational modelling of water levels required both meteorological and tidal records over as long a time period as possible. The simulations for this study were run on a hindcasting basis, using historical recorded atmospheric pressure and wind data generated from the European Centre for Medium-Range Weather Forecasts (ECMWF). The meteorological records used dated from the 1950's to present and have increased in accuracy over time as the meteorological models have been improved. The grid spacing of the ECMWF models has improved, with a resolution of 1.125° used between 1957 and 1991, 0.5° between 1991 and 2007, and 0.25° post 2007. The ECMWF models are also modified and improved frequently. Therefore the more events used in recent years, the more confidence can be attributed to the meteorological data, meaning that future modelling of the coastline has more potential for confidence, with an increase in the number of recent events used. However, it should be noted that this can only apply when a reasonable spread of data has been taken, over a significant number of years. For example, a dataset hosting only results from recent years would not give a true representation of extreme storm surge events over a 50 year period. From a statistical point of view, it is better to have as many events as possible, spread over the analysis period. Otherwise, it would have to be assumed that a trend exists, which would limit the validity of the statistical analysis.

In the initial stages of producing the confidence methodology for the flood extents, a factor named 'Event Dependency' was used, referring to the proportion of events used in more recent years gaining higher confidence. However, upon further consideration a decision was made to remove this factor, as it was a misleading and inaccurate representation of MET confidence. Although the events from recent years may have had a higher accuracy of meteorological data, in order for the statistical analysis to be reliable, a reasonable spread of events was mandatory. Therefore the proportion of recent events should be similar for all coastlines.

The selection of the storm surge events which were used to produce the water levels for the flood extents, was directly related to the reliability of historic tide gauge data. While the quality of the recorded data was of lesser importance, it was vital that the records did not omit any significant events. Even if the records had gaps and thus a large event had not been recorded or archived for a particular tide gauge location, then provided there were sufficient other tide gauges covering the section of coast, it should have been possible to identify the event. Therefore, the accuracy of the water level predictions from the tide gauges depended more on the number of storm surge events used to compute the water levels. Accuracy was also increased by having more historic records of storm surges available for assessing which periods to simulate for each stretch of coastline.

Two factors therefore were used to establish the overall confidence in the meteorological data; the number of years of tide gauge data available and the number of events used.

3.0 Confidence Analysis Results

To present the results of the confidence analysis it was necessary to create a raster grid of confidence ratings for the entire north east coast. This grid used a 500m x 500m spacing, and showed the high water mark and a 2000m buffer for geographical reference. Confidence ratings for DTM, MALIN, MODEL and MET were established using various computations on Microsoft Excel, as described in this Section. The confidence ratings were represented in the grid both manually and through computational interpolation. Each of the parameters are described in the following sub-sections.

3.1 Accuracy of the DTM

The confidence analysis of the DTM was based on the accuracy assessment of the DTM undertaken as part of this study (refer Quality Control Survey Report, Appendix 6).

The accuracy of the DTM was considered in terms of the mean height difference and the average of the 95% confidence limits, where height difference referred to the difference between the DTM and the Quality Control Survey points for each stretch of coastline. The average of the 95% confidence limits was derived by ignoring the negative value for the lower limit, and assuming both limits to be positive. It was further assumed that the number of Quality Control Survey points was chosen, to provide a representative sample in the context of statistics and that the survey itself was of the highest possible accuracy, as otherwise this comparison would have become meaningless.

The accuracy statistics for all surveyed areas are shown in Table 1. Quality control points were collected for Dundalk in 2006 and again in 2008, which yielded two sets of accuracy statistics for this location. The Dundalk statistics were combined proportionally, based on the number of control points for each exercise. The mean height differences for all areas ranged from -0.040m at Dundalk in 2008 to 0.104m at Drogheda. Balbriggan had the lowest average 95% confidence limit of 0.115m, with Dundalk 2006 having had the highest at 0.423m.

Table 1: Accuracy Statistics for Areas on North East Coast

North East Locations	Mean Height Difference (m)	Lower 95% Confidence Limits (m)	Upper 95% Confidence Limits (m)	Average 95% Confidence Limits (m)
Port Oriel	0.020	-0.267	0.283	0.275
Balbriggan	0.017	-0.112	0.117	0.115
Malahide	-0.013	-0.175	0.228	0.202
Drogheda	0.104	-0.057	0.283	0.170
Dundalk 2006	0.043	-0.376	0.469	0.423
Dundalk 2008	-0.040	-0.190	0.102	0.146
Dundalk Combined	0.041	-0.252	0.224	0.238
Dublin	0.091	-0.060	0.235	0.148

A rating system was established for both statistical parameters, as shown in Table 2. A rating of 1 was awarded for a mean height difference between 0 and 0.02m, with a rating of 10 for difference values over 0.25m. The average 95% confidence limit ranged from 0 to 0.1m for a rating of 1, to over 0.9m for a rating of 10. These ratings were assigned for mean height difference and average 95% confidence limits for the different areas listed in Table 1. Both parameters were considered to be of equal weighting, hence were averaged to produce the final rating for each area, as shown in Table 3. For example, Dublin had a mean height difference of 0.091m and an average 95% confidence limit of 0.148m, which corresponded to ratings of 5 and 2 respectively. The average of these two ratings was rounded to 4, which produced a final confidence rating of 4 for the Dublin DTM, as shown in Table 3. The values were added to the relevant areas on the raster grid.

Table 2: Ranges for each Rating for all Statistical Parameters

Rating	Mean Height Difference (+/-)	Average 95% Confidence Limit (+/-)
10	0.25+	0.9+
9	0.19 - 0.25	0.8 - 0.9
8	0.16 - 0.19	0.7 - 0.8
7	0.13 - 0.16	0.6 - 0.7
6	0.10 - 0.13	0.5 - 0.6
5	0.08 - 0.10	0.4 - 0.5
4	0.06 - 0.08	0.3 - 0.4
3	0.04 - 0.06	0.2 - 0.3
2	0.02 - 0.04	0.1 - 0.2
1	0.00 - 0.02	0.0 - 0.1

Table 3: Final Confidence Ratings for all North East Areas

North East Locations	
Port Oriel	2
Balbriggan	2
Malahide	2
Drogheda	4
Dundalk Combined	3
Dublin	4

3.2 Mean Sea Level to OD Malin Conversion

The Mean Sea Level to OD Malin conversion was originally based on individual points with conversions from UK Hydrographic Office tide tables. This was developed further and for the purpose of this study, the OD Malin Geoid was used for the conversion, as described in Section 6 of the main report. Thus, the Mean Sea Level to OD Malin conversion had improved compared to the initial methodology; however it had not been tested against a sufficient number of tide gauge locations, to get a measure of the accuracy of this conversion. Thus the confidence was considered medium and is expected to improve in the future with more data. Consequently as with the south east coast a confidence rating of 5 was applied to the extents of the north east coast on the raster grid. Table 4 shows the assigned confidence ratings for the NE and SE coastlines.

Table 4: Confidence Ratings awarded to the South East, and North East Coasts for MSL to OD Malin correction

SE	NE
5	5

3.3 Accuracy and Level of Detail of the Model

The confidence in the model was taken from four factors as outlined in Section 2.3 above.

Each of these factors were considered to have equal weighting and are discussed in detail in the following sections.

3.3.1 Distance of flood extent to water level point

The effect of distance between each water level extraction point along the coast on the accuracy of the model predictions was assessed in detail as part of the initial study for the south east coast model analysis. Water levels were extracted from the model and the Extreme Value Analysis (EVA) fitted at specific points to establish the optimum frequency of the water level points along the coast. It was found that there was very little variation in water level between the points along open sections of the coast, and thus the spacing was selected such that any error in the water levels was significantly lower than the uncertainty in the spatial distribution. Therefore it was assumed, with regard to water level, that the same confidence could be applied to the north east coast between the water level extraction points, when in open water.

As the water level was extrapolated inland the confidence in these water levels changed. It was decided to increment the confidence initially at 500m spacings, increasing thereafter as shown in Figure 1. High confidence was assigned to those cells around the water level extraction points and along the high water mark, denoted by a bold red line. With distance inland, confidence in the water levels decreased non-linearly, as shown in Figure 1. A non-linear manner was chosen in order to facilitate the spreading of confidences over the entire analysis area, with more focus on areas near to the high water mark.

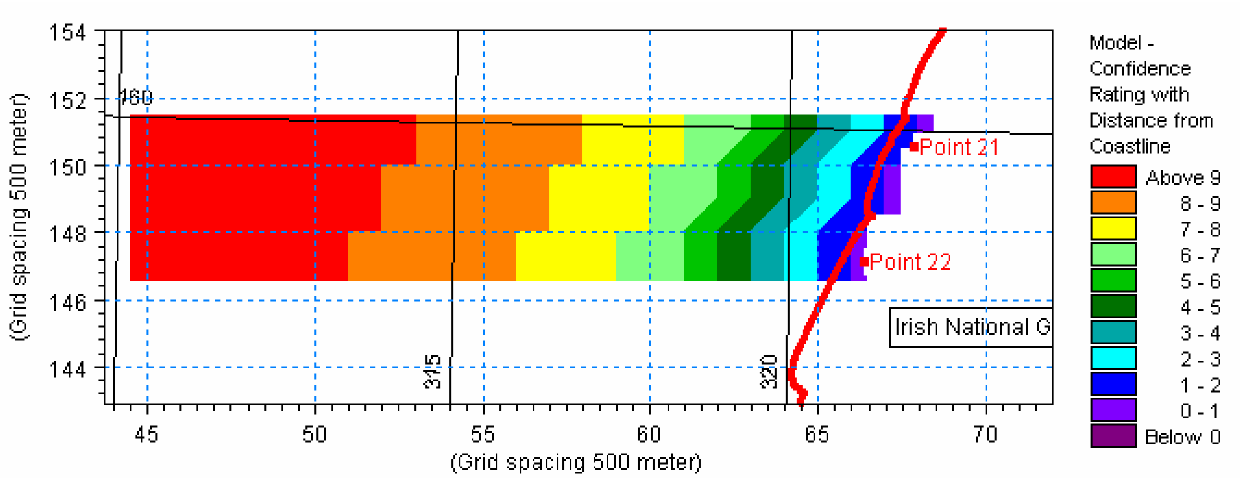


Figure 1: Confidence awarded to cells with distance inland

3.3.2 Type of coastline

A key consideration behind the assessment of the type of coastline for model confidence is that complex coastlines are more likely to be inaccurately represented in a model than simple coastlines, even if the same degree of calibration was used. Where a model features open coastline with a good correlation to a nearby tide gauge, then the water levels along that section of coastline are very likely to be accurate. In contrast, narrow sea loughs and fjords can produce complex resonance effects, which are more difficult to simulate correctly. Furthermore the bathymetry could change with time, thus changing the tidal response of the estuary. Tidal sections of rivers are largely influenced by fluvial flows, local wind effects and changes in bed level, making them one of the least confident stretches of coastline to simulate.

The ratings applied to different types of coastal segments ranged from a rating of 1 for very open coastline, to a rating of 10 for tidal sections of rivers. This is shown in Table 5. The coastline was reviewed and the ratings applied along the high water mark on the raster grid. In this case, the values ranged from 4 to 10, as higher confidence would only be awarded for more open coastlines, such as at the Atlantic Ocean. These ratings on the high water mark were interpolated to produce values for all inland cells.

Table 5: Confidence Ratings for Type of Coastline

Rating	General Type of Coastline
10	Tidal sections of rivers
9	
8	
7	Narrow Sea Loughs
6	
5	
4	Open
3	
2	
1	Very Open e.g. Atlantic

3.3.3 Statistical confidence limits of Extreme Value Analysis (EVA)

The Extreme Value Analysis (EVA) used the Jack-Knife re-sampling method to define statistical confidence limits, as described in Section 5 of the main report. It was decided to use the 1.0% AEP water level standard deviations in order to assess of the accuracy of the model output. In principal, it did not matter which AEP was chosen, as in the Jack-Knife method, the confidence limits are proportional for the various return periods. Confidence limits depended on the number of events taken, i.e. the number of storm surge events, which was also considered as part of the confidence in the meteorological conditions.

Values were extracted from the north east coast EVA, to represent the statistical confidence of the water levels for each of the 26 north east coast water level extraction points. Each of these 26 values were awarded a confidence rating between 1 and 10, where 10 coincided with a 200mm standard deviation or higher and a rating of 1 for 0 to 20mm, as shown in Table 6. These confidence ratings were transcribed to the raster grid, and interpolated to fill in the gaps.

Table 6: Confidence Ratings for Statistical Confidence

Rating	Confidence limits of Output - EVA _ Standard Deviation (1 in 100 year) (mm)
10	200+
9	150-200
8	120-150
7	90-120
6	70-90
5	60-70
4	50-60
3	40-50
2	20-40
1	0-20

3.3.4 Validation of the Model

The fourth parameter for model confidence related to the correlation of the tide gauge data with the model. This correlation was based on a comparison of the high water levels from the model and tidal predictions at a given location over a one month period (two full neap/spring tide cycles). As this method relied heavily on the accuracy of the tidal prediction itself, the gauge data was required to be assessed as well. The confidence in the gauge data was estimated using three factors with varying weightings; namely the location of the gauge, whether any problems had been encountered with the gauge and the length of gauge data used. Four gauges were used in the model calibration for the north east coast. The results for each gauge are shown in Table 7.

Table 7: Confidence Parameters for North East Coast Calibration Gauges

	Categories	North East Coast Gauges			
		Dublin	Port Oriel	Port Erin	Portpatrick
1	Location of Gauge	Port	Port	Port	Port
2	Severity of Gauge Problems	Seiching	No	Minor Fouling	No
3	Length of Gauge data (months)	36	8.5	144	480

Again, each gauge parameter needed to be scaled from 1 to 10. The confidence ranges corresponded to the scale of 1 to 10 for each of the three parameters shown in Table 8. For gauge location, a rating of 1 described perhaps a pelagic location, for example an open island, with a rating of 10 for a river location. A rating of 1 was awarded to a gauge with no recorded problems, whilst a rating of 10 was given to an extremely unreliable gauge. It should be noted that for the severity of gauge problems, gauges were rated according to the type of problems encountered. For example, a problem with a datum was considered not as severe as a siltation problem. Gaps in the dataset were also undesirable. For length of gauge data, 61 months or over was awarded a rating of 1, with a rating of 10 given to a gauge with only 0 to 1 month of data, or a gauge derived from information from the UK Tide Tables.

Table 8: Ratings for Gauge Parameters

Rating	Location of Gauge	Severity of problems with gauge	Length of Gauge Data (Months)
10	D – River	Extremely Unreliable	Tide Tables or 0-1 month
9		Unreliable	2-4 months
8		Poor	5-8 months
7	C - harbour/port - other influences	Below Satisfaction	9-12 months
6		Satisfactory	13-16 months
5		Good	17-20 months
4	B - open harbour/port	Very Good	21-30 months
3		Extremely Good	31-40 months
2		Excellent	41-60 months
1	A - Pelagic, open, e.g. Island	Perfect - No recorded problems	61+ months

A confidence rating was established for each of the four gauges individually, by applying the relevant weightings, as shown in Table 9. A weighting of 1 was used for gauge location and gauge problems, and a weighting of 2 for the length of available gauge data, as this was considered to potentially give rise to greater error in the flood extents. Table 9 also provides an example of how the final confidence rating was established for the Dublin gauge. Each of the confidence ratings were multiplied by their corresponding weighting. The sum total of these three numbers was divided by four (which represented the total of the three weightings), in order to produce one single value for confidence in the Dublin gauge. Similarly, the confidence ratings for the other three gauges were computed and are shown in

Table 10. The Port Erin and Portpatrick gauges were awarded the most confident rating of 2.00, with the Port Oriel gauge being noted as the least confident with a rating of 5.75.

Table 9: Weightings of Confidence Parameters for Validation of Model

	Dublin			
	Weighting	**Rating**	**Weighting*Rating**	**Confidence**
Number of Gauges	**1**	6	6	**4**
Severity of problems with gauges	**1**	4	4	
Length of Gauge Data (Months)	**2**	3	6	

Table 10: Confidence Ratings for Gauge Parameters

North East			
Dublin	**Port Oriel**	**Port Erin**	**Portpatrick**
4.00	5.75	2.00	2.00

On completion of the determination of the reliability of the tide gauge data, it was necessary to assess the correlation of this gauge data with the actual model data. This was achieved through the computation of a correlation coefficient for each gauge, established from the high waters of each data set. The correlation coefficients for each gauge on the north east coast are shown in Table 11.

Table 11: Correlation Coefficients for North East Coast

North East	Port Erin	Port Oriel	Portpatrick	Dublin
Correlation Coefficient	0.990	0.988	0.984	0.991

The ratings applied to each gauge for model correlation are shown in Table 12. These correlation coefficients only described the goodness of fit between the predicted and simulated data sets, but for the overall model calibration, the ratings needed to be taken in conjunction with the accuracy of the gauge data itself. Thus the two ratings for each gauge were multiplied, and the square root taken, in order to produce the final combined confidence ratings for model calibration, as shown in Table 13. For example, a gauge rating of 4.0 for Dublin was established as described above, and multiplied by a correlation rating of 1, from Table 12. The square root was taken to produce a value of 2, which is the overall confidence rating for model calibration in Table 13. The overall confidence ratings were then applied to the north east coast grid at the relevant locations.

Table 12: Confidence ratings for Model Correlation with Tide Gauge Data

Correlation between predicted and model high waters	Rating	Port Erin	Port Oriel	Portpatrick	Dublin
<0.9	10				
0.900-0.940	9				
0.940-0.960	8				
0.960-0.970	7				
0.970-0.976	6				
0.976-0.981	5				
0.981-0.985	4			4	
0.985-0.988	3				
0.988-0.990	2		2		
0.990+	1	1			1

Table 13: Overall Confidence Ratings for Model Calibration

Port Erin	Port Oriel	Portpatrick	Dublin
1	3	3	2

3.3.5 Overall Model Ratings

Each of the four overall model parameters was considered to be of equal weighting, and thus they were averaged, in order to compute a total model confidence for each cell.

3.4 Accuracy of the Meteorological Data

Two factors were used to establish the overall confidence in the meteorological data;

- the number of events simulated, and
- the number of years of tide gauge data available.

To gain an understanding of the number of events simulated, the north east coast was considered in conjunction with the south east and south coasts, for the purpose of this study. The number of events simulated for each coastline was recorded in Table 14. A total of 55 events were simulated for the south east coast, with 79 and 76 events being simulated for the north east and south coasts respectively.

Table 14: Number of Events used in Model Simulations

Number of events used	SE	NE	S
Total	55	79	76

A confidence rating was applied to the north east coast, according to the scale in Table 15, with a value of 3 representing the 79 events simulated.

Table 15: Confidence Ratings for Number of Events Simulated

Number of events used	Rating	NE
0-10	10	
10-20	9	
20-30	8	
30-40	7	
40-50	6	
50-60	5	
60-70	4	
70-80	3	3
80-110	2	
110-150	1	

This study was limited to 50 years of gauge data or less, due to limits on the available meteorological data. Ideally, 50 years of data from two separate tide gauges would have been used, or a combination of more tide gauges spread along the coast, in order to cover the required years of simulation and coastline. Therefore 100 years of tidal data would have been required from each coastline to achieve high confidence with respect to the gauge data. The available tide gauge data from Dublin, Quoile, Port Erin and Portpatrick, used for the north east coast is shown in Table 16. The maximum number of years required from one gauge, or a combination of gauges was fifty years, hence the final row in the table was produced (51 and 58 were capped to 50). The maximum total possible was 100 and hence the Port Erin and Portpatrick gauge data was not included in the final score. The values of 50 for Dublin and 50 for Quoile were added to give a final value of 100, which was used to establish a rating of 1 for the north east coast, as shown in Table 17.

Table 16: Gauge Data available for North East Coast

	North East				
Name of Gauge	Dublin	Quoile	Port Erin	Portpatrick	**Total**
Length of data (years)	51	58	11	37	
Length of data - max 50years	50	50	excess	excess	**100**

Table 17: Confidence Ratings for Number of Years of Gauge Data

Number of Years of Gauge Data	Rating	NE
<40	10	
40-50	9	
50-60	8	
60-70	7	
70-80	6	
80-85	5	
85-90	4	
90-95	3	
95-100	2	
100+	1	1

An overall individual confidence rating for the north east coast was established by averaging the ratings from the two MET factors; 3 for the number of events simulated and 1 for the available gauge data. This average value of 2 is shown in Table 18 and was applied to the raster grid, over the entire north east coast area.

Table 18: Weightings for Number of Events Used and Gauge Data, along with Final Ratings for Meteorological Data

	Weighting	SE	NE	S
Number of events	1	5	3	3
Gauge Data	1	3	1	4
Average		**4**	**2**	**4**

4.0 Results of Combined Confidence

With all four confidence parameter ratings transcribed to the raster grid, under individual items, the combined confidence for the entire north east coast was established. Weightings were assigned to each of the confidence parameters; 5 for DTM, 1 for Malin, 4 for Model and 3 for Met, as shown in Table 19. These weightings were assigned depending on the potential size of error the flood extents could be subject to, due to each parameter. Consideration was given to these weightings, and various analyses carried out to determine the optimum weightings, relative to each other and on a broad scale.

Table 19: Weightings assigned to individual confidence parameters

Confidence Divisions		Weighting
W1	**DTM**	**5**
W2	**Malin**	**1**
W3	**Model**	**4**
W4	**Met**	**3**

The final confidence value for each of the cells in the raster grid was calculated using the following formula:

$$\sqrt{W_1 C_{DTM}^2 + W_2 C_{Malin}^2 + W_3 C_{Model}^2 + W_4 C_{Met}^2}$$

Potential scores from the formula ranged from 3.606 (using all 1 ratings) to 36.056 (using all 10 ratings). These were shifted to produce high confidence for a value of 0 and low confidence for a value of 32.45. The uncertainty values for each cell were then expressed as a percentage of the range (32.45) and subtracted from 100 percent to produce the confidence score.

Confidence scores ranged for example from circa 62% to 74% in Dublin, 61% to 79% in Drogheda and 65% to 78% in Dundalk. Figure 2, Figure 3 and Figure 4 show a representation of the final confidence percentages for Dublin, Drogheda and Dundalk respectively.

It was decided to classify the final scores into five groups in terms of very high, high, medium, low and very low confidence. These confidence ratings are shown in Table 20. For example, flood extents in the Dublin, Drogheda and Dundalk areas were considered as having high or very high confidence. The final flood extents with assigned confidences for the entire north east coast are shown in Appendix 7 of this report. Most of the flood extents were classified as having high confidence, with a large number of areas also showing very high confidence. It should be noted that very low confidence was assigned to any flood extents which coincided with the landward limit or boundary of the DTM as it was not possible to identify the location of the flood extent in the absence a DTM.

Table 20: Overall Confidence Ratings

Confidence	Range
Very High	70%+
High	60-70%
Medium	50-60%
Low	40-50%
Very Low	<40%

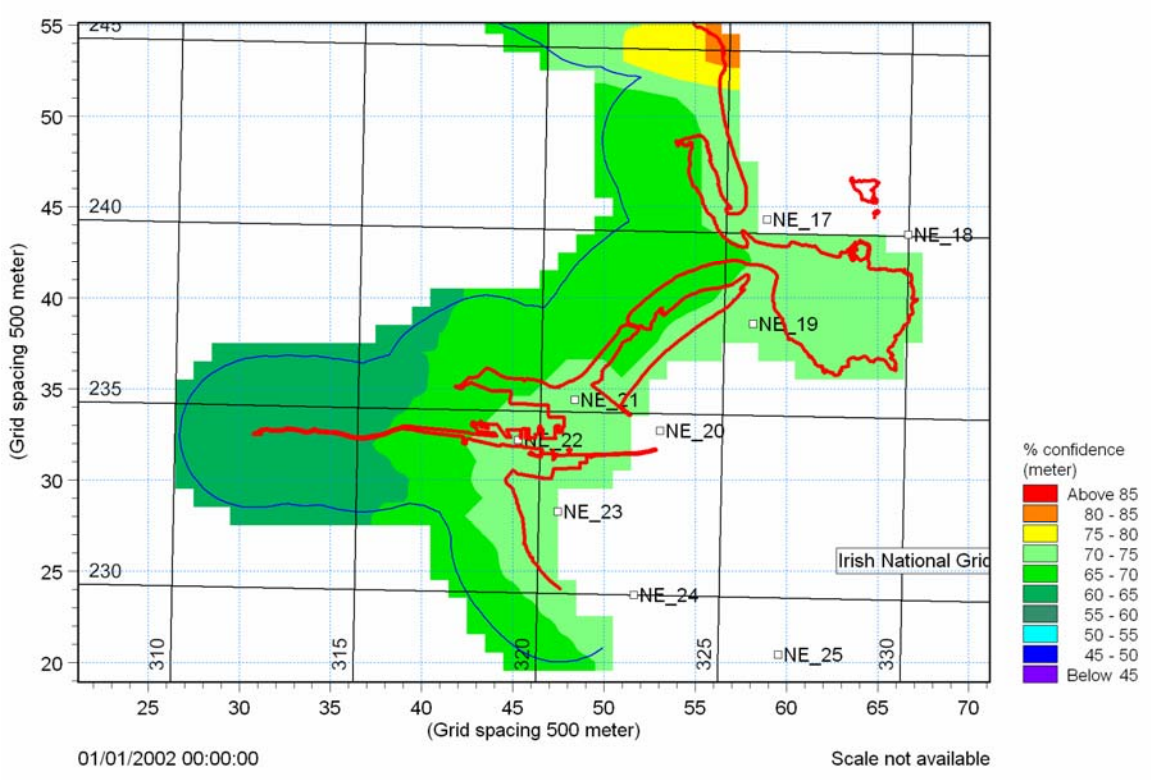


Figure 2: Final Confidence Results for Dublin (Blue line represents 2km buffer and Red line represents High Water Mark)

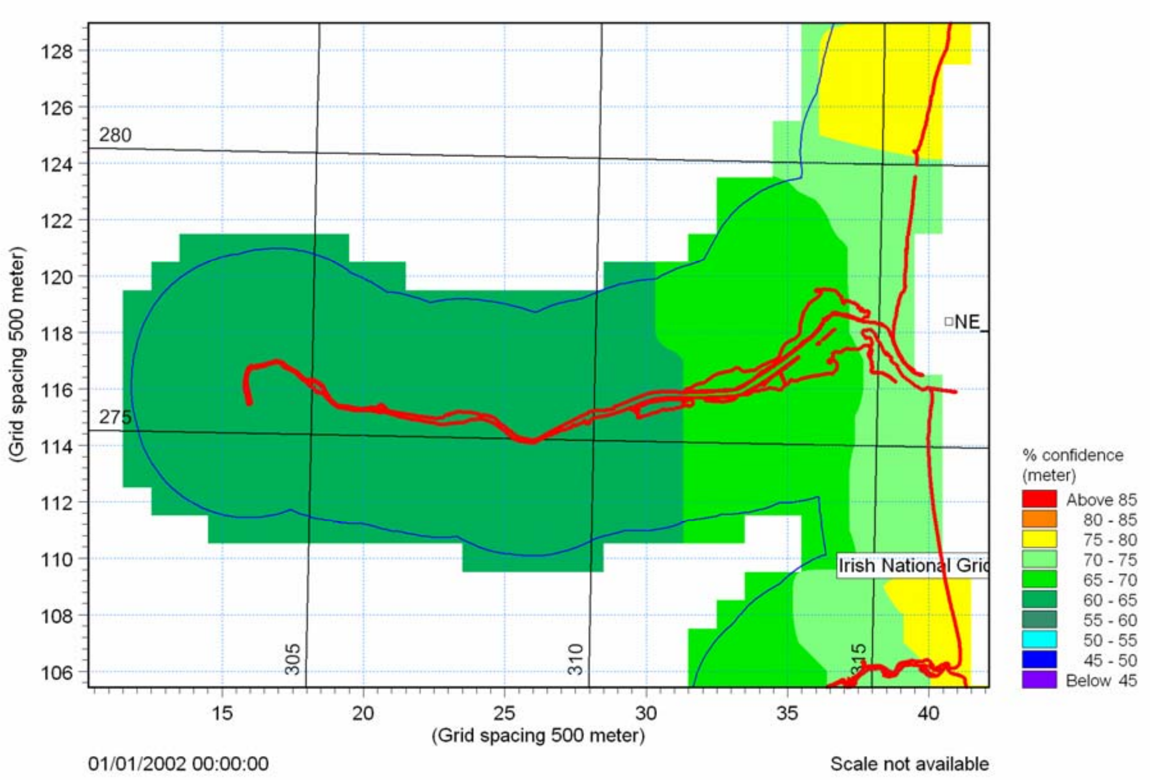


Figure 3: Final Confidence Results for Drogheda (Blue line represents 2km buffer and Red line represents High Water Mark)

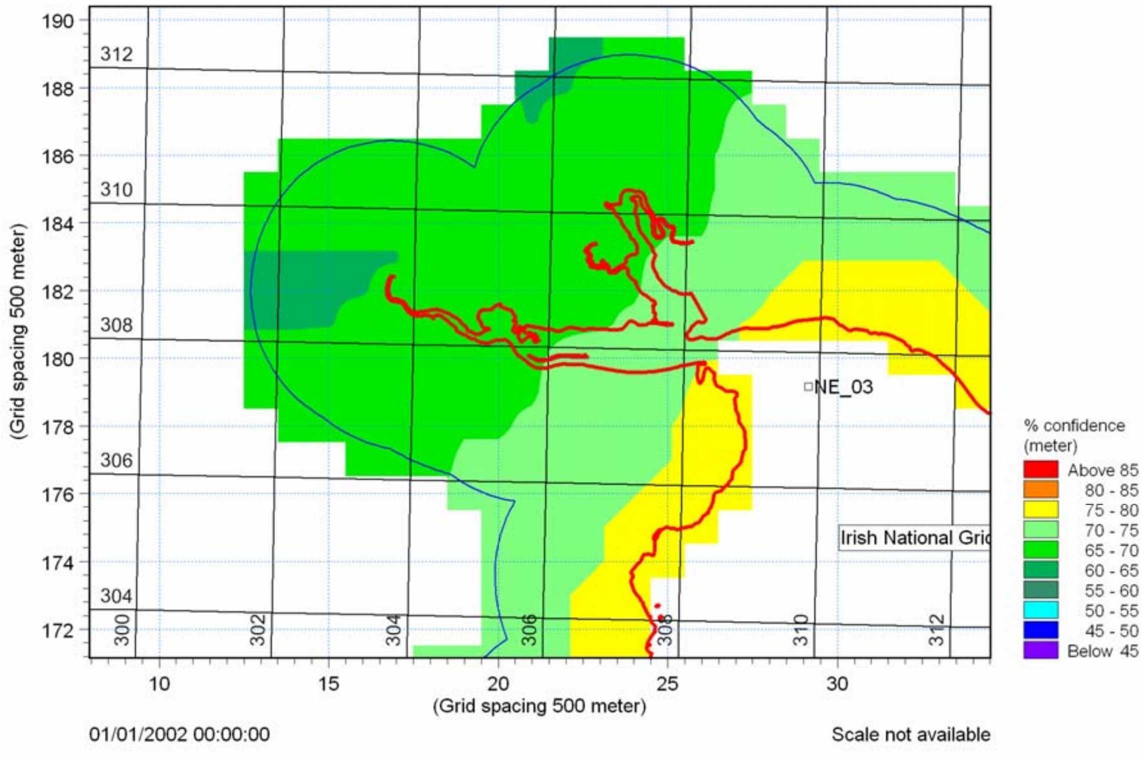


Figure 4: Final Confidence Results for Dundalk (Blue line represents 2km buffer and Red line represents High Water Mark)

5.0 Conclusions

The confidence analysis methodology used to assign confidence to the flood extents has been tested and modified to produce the optimum analysis for this strategic project. It involved the collaboration of qualitative and quantitative information into one overall quantitative database. The results were presented in the form of a raster grid, geographically showing the confidence of flood extents within the study area. The scoring and weighting system has established very high, high, medium, low or very low confidence for various parameters in the flood extent determination; i.e. DTM, MALIN, MODEL and MET. It should be noted that as this methodology required the translation of many qualitative values to quantitative, many assumptions have had to be made.

All cells in the raster confidence grid were expressed in terms of very high, high, medium, low or very low confidence. Very high confidence was represented by a score of over 70%, with high confidence between 60-70%, medium confidence between 50-60%, low confidence between 40-50% and very low confidence being represented by a result of less than 40%. For example, flood extents in the Dublin, Drogheda and Dundalk areas were considered as having high or very high confidence.

The final flood extents with assigned confidence for the entire north east coast are shown on the flood extent maps presented in Appendix 7 of the main report. Digital copies of these are also appended to the main report. Most of the flood extents were classified as having high confidence, with a large number of areas also showing very high confidence.

Appendix 9b: Confidence in Erosion Lines

IRISH COASTAL PROTECTION STRATEGY STUDY – ANALYSIS OF CONFIDENCE IN EROSION LINES

1.0 Introduction

A fundamental issue in the delivery of the final erosion lines is the level of confidence which can be assigned to the prediction of erosion along the coastline. The level of confidence should reflect the reliability of the input data, together with any discrepancies in the methodology used to determine the potential erosion risk. Data used in any erosion assessment is rarely of consistent accuracy and often shows significant spatial variation in accuracy.

RPS have therefore developed a quantitative methodology for determining the level of confidence in the erosion lines, which is based on a scoring and weighting system, establishing four confidence classifications based on various parameters in the erosion extent determination.

This report describes the methodology used and the outcome for the north east coast study area.

2.0 General Methodology

The methodology adopted is based on the scoring and weighting of various parameters which could influence the position of the final erosion lines, and establishes the level of confidence to be assigned to these erosion lines; from very high, high or medium confidence to low or very low confidence.

Four principal parameters were identified for inclusion within the analysis as listed below;

- **Geology** Accuracy and availability of underlying geology
- **Imagery** Geographical accuracy of historical/ recent aerial imagery
- **Resolution** Resolution of assessment
- **Protection** Presence of Coastal Protection Structures

A matrix was established using the above parameters, which were assigned a value of confidence ranging from 9 (complete confidence) to 1 (no confidence) at intervals along the study area coastline. The values were then squared and multiplied by a weighting, depending on the potential magnitude of the error in the position of the final erosion lines, which would result from inaccuracy in each parameter. To compute the final score, the root sum of the squares of the component confidences times the weightings was calculated and expressed as a percentage of the maximum allowable score.

The overall Confidence Sum Total is given by;

$$C_{OVERALL} = \sqrt{W_1 C^2_{IMAGERY} + W_2 C^2_{PROTECTION} + W_3 C^2_{GEOLOGY} + W_4 C^2_{RESOLUTION}}$$

Where $W_{1\text{-}4}$ represent the relevant weightings and the C values represent the confidence factors.

This was equivalent to applying the Gaussian equation generally used for error analysis. The matrix was then used to determine the overall confidence (very high, high, medium, low or very low) of the erosion lines for the particular segment of coast.

This simplified approach ignores any interdependencies between the component parts of the confidence analysis and the fact that these confidences may have resulted in over or under estimation of the erosion rates, where the net effect of combination would be reduced or null. It also assumes that the confidences were approximately normally distributed about the mean and tends to highlight the least confident source.

It should be noted that a feature of methods with multiple confidence sources is that the user tends to under-estimate the overall confidence, as there is a tendency to always assign some uncertainty to each category. For this reason, the default values were ascribed to give medium confidence (~50%) providing scope for movement in either direction.

2.1 Underlying Geology

In developing the predictive erosion lines for the years 2030 and 2050, it was assumed that the annual rate of coastal change would be similar to that observed over the past circa 30 years. This is a fair assumption where the period of projection is not overly long and where the underlying geology does not change significantly with distance from the coastline.

The potential for the underlying geology to introduce uncertainty into the fundamental assumption that erosion in the future is going to continue at a similar rate to that observed over the past circa 30 years was considered by reference to the GSi Quatenary sub-soils dataset. A confidence rating was assigned to each section of the coast based on the coverage and complexity of this information.

2.2 Accuracy of the Imagery

The derivation of an “annual” rate of erosion was fundamental to the methodology adopted by RPS in establishing the projected future coastline position in 25 and 50 years. This was established by comparing the position of the coastline, as defined by the visible vegetation line in aerial photography from 1973, 2000 and 2006. Both the 2000 and 2006 photographic series were supplied as geo-referenced digital images however the 1970 data while supplied digitally was not geo-referenced. Thus the accuracy of the subsequent geo-referencing of this data was an essential consideration in the determination of confidence in the resulting erosion lines.

In order to establish the accuracy of this process and the resulting level of confidence in the positioning of the coastline a comparison between physical features, buildings, roads, railway lines etc. as depicted on the 1970 aerial photographs and recent OSi mapping was undertaken. Confidence ratings were assigned to this parameter based on any observed shift in position of the reference features used.

2.3 Resolution of Assessment

The erosion assessment was generally undertaken at a resolution consistent with a strategic level assessment i.e. at circa 1km intervals along the coast, however the actual spacing of the assessment points varied depending on spatial variations in the observed rate of coastal change and variation in coastal form. In order to address the potential impact of the spacing of the analysis points on the final output, confidence ratings were assigned to this parameter based on the distance between adjacent assessment points.

2.4 Protection Status of the Coast

As previously stated the fundamental assumption of the adopted methodology was that coastal erosion would continue in the future at the same rate as was observed over the past circa 30 years. Thus in order to produce a predictive erosion line for a particular section of coast some change in the plan position of the coast had to have been observed during the analysis period.

The presence of coastal protection structures at the start of the analysis period, or the introduction of such structures at some time during the analysis period, would obviously have a significant impact on the prediction of future erosion lines for a particular segment of coast which would reduce the level of confidence in that prediction. Conversely there are some areas of coast that are naturally resistant to erosion e.g. where the coastline comprises outcrops of hard rock, thus giving a high degree of confidence in the prediction of no potential erosion risk in these areas.

The presence of coastal protection structures or naturally resistant coastlines was established by reference to plan aerial photography, both historic and recent, and also by reference to the Coast of Ireland, Oblique Imagery Survey of 2003.

3.0 Confidence Analysis Results

To present the results of the confidence analysis it was necessary to create four GIS shapefiles for the entire length of the north east coastline. Confidence ratings for each of the individual parameters were manually assigned to the appropriate sections of these lines to produce individual confidence lines for the effects of underlying 'geology', 'accuracy of imagery', coastal 'protection' and 'resolution' of the erosion analysis. These were then combined to form one line representing overall erosion confidence on the north east coast, which was displayed on the baseline used for the erosion analysis, the vegetation line as derived from the 2000 aerial photographic series.

3.1 Underlying Geology

Due to the extensive spatial extent of the study area the confidence analysis for the effect of underlying geology was based on the use of spatial datasets rather than specific site inspections. For the north east coast the GSi Quatenary sub-soils dataset was used to determine the complexity of the underlying geology along and behind the present coastline.

The level of detail provided within this dataset varied spatially along the coast both as a result of variations in the complexity of the underlying geology and also due to data availability. Thus a confidence rating was assigned to each section of the coast based on the coverage and complexity of the information contained within the GSi sub-soils dataset.

In areas where there was no information on the underlying geology a low confidence rating (1) was assigned. Where the underlying geology was shown as extensive occurrences of the same or similar material a high confidence rating was awarded (8). All other areas were assigned a confidence rating somewhere between these two extreme values (2-7), the actual rating being dependent on the complexity of the sub-surface geology indicated by the GSi dataset. Figure 1 shows an example of the GSi data and resulting geological confidence rating in the Laytown area while Figure 2 shows the same information for the coastline between Dunany Point and Annagassan.

Approximately 12% of the north east coast has a very low geological confidence (<2) with the most extensive area occurring around Dublin Bay where there is a significant stretch of the coast for which no geological information was available. Conversely over 56% of the north east coast achieved a high geological confidence rating (>7). Overall the mean geological confidence rating for the north east coast is 5.8 which equates to medium/high confidence.

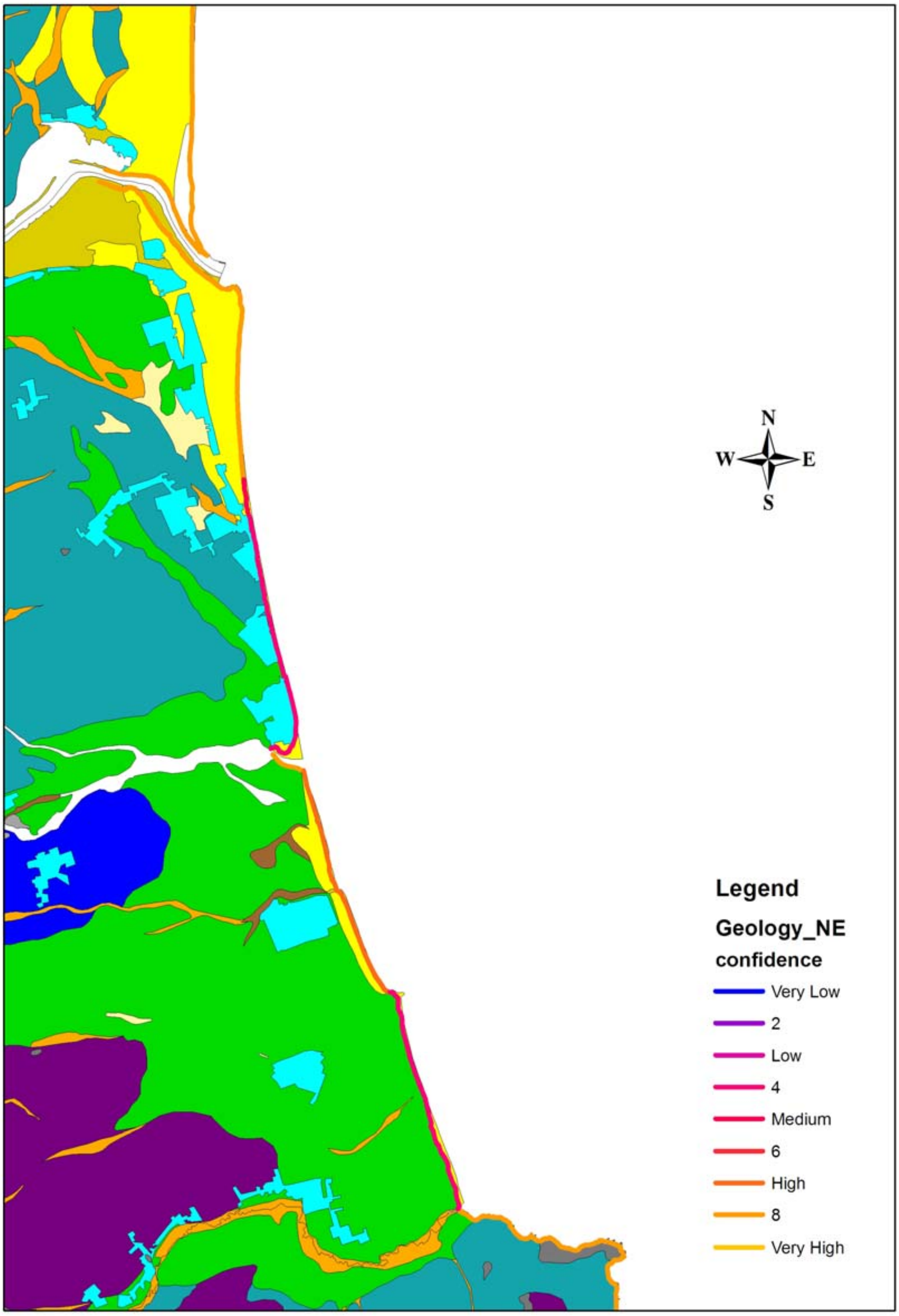


Figure 1 Geological Confidence Line – Laytown Area

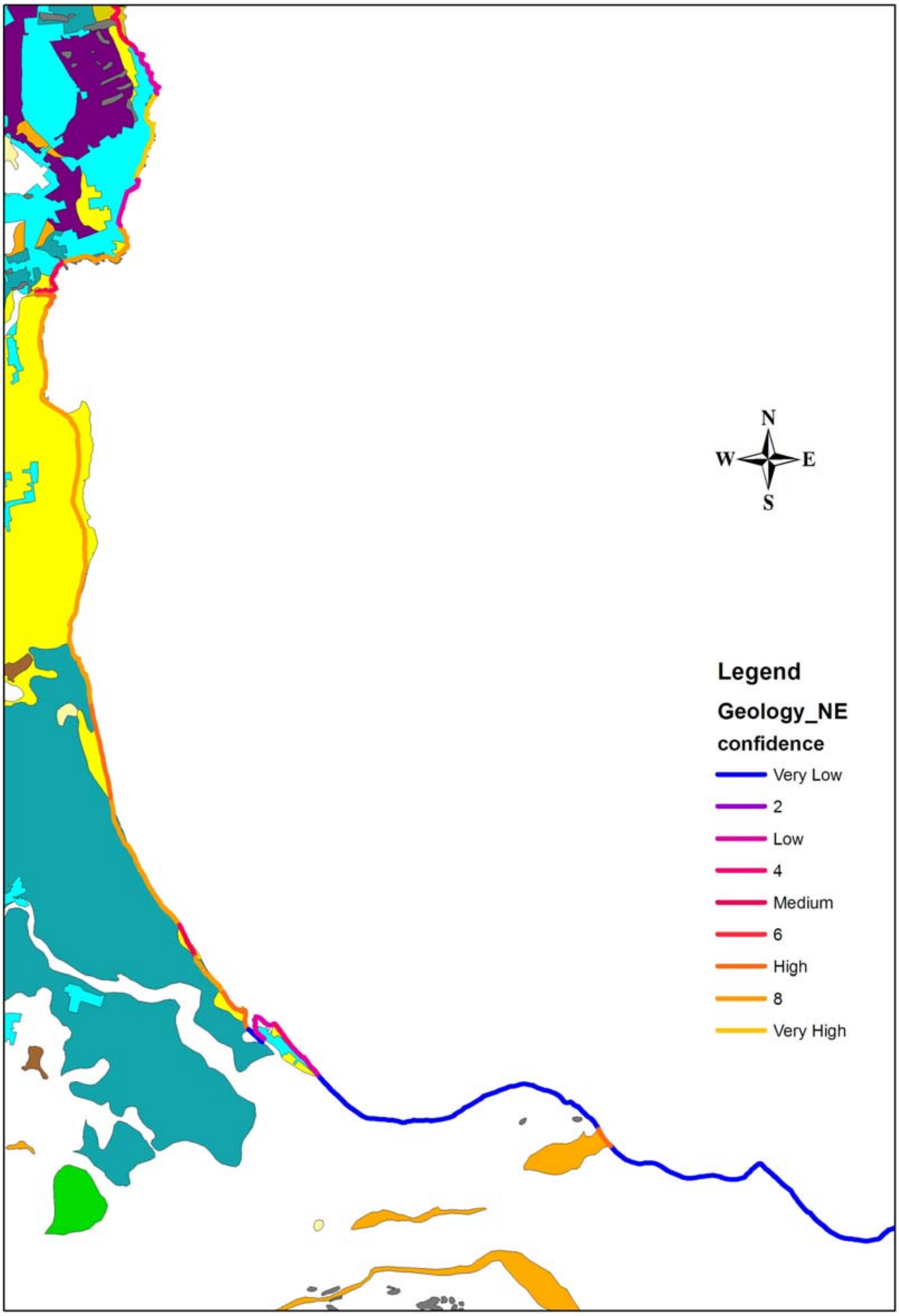


Figure 2 Geological Confidence Line – Annagassan Area

3.2 Accuracy of Imagery

The potential error in the derived annual erosion rates arising from inconsistencies in the geo-referencing of the historic aerial imagery was established by comparing the locations of notable physical features, buildings, roads, railway lines etc. as depicted on the 1970 aerial photographs and recent OSi mapping. GIS techniques were used to compare the positions of key features at intervals along the coast as shown on the most recent OSi large scale digital mapping with the corresponding feature as depicted on the historic aerial photography.

Confidence ratings were assigned to this parameter based on any observed shift in position of the reference features used with a score of 9 representing an error of less than 1m and lower score being assigned for increasing positional error. Imagery confidence ratings of greater than 6 were assigned to approximately 89% of the north east coastline using this procedure, with the mean score being 7 indicating a high degree of confidence in the geo-referencing overall. The areas of poorest geo-referencing accuracy (<4) are located within Dundalk Harbour, as shown in Figure 3 and in the area of Balleally landfill where there was little or no overlap in the coverage of the aerial photography and hence edge distortion was significant.

Figure 3 **Imagery Confidence Line – Dundalk**

3.3 Resolution of Assessment

Whilst generally being undertaken at a resolution consistent with that of a strategic level assessment (circa 1 km intervals) the actual spacing of the assessment points varied depending on the spatial variation in the observed rate of coastal change and coastal form. GIS spatial analysis tools were used to calculate the length of each coastline segment used in the original erosion analysis and to assign an appropriate confidence rating.

Where assessment points were less than 100m apart, a high confidence rating (9) was assigned, whilst in areas where the assessment points were greater than 3,000m apart a low confidence rating (1) was assigned. All other areas were awarded confidence ratings between 8 and 2 depending on the actual spacing of the analysis points as shown in Table 1.

Table 1: Resolution Confidence Ratings

Confidence Score	Spacing
9	<100
8	100-250m
7	250-500m
6	500-750m
5	750-1,250m
4	1,250-1,500m
3	1,500-2,000m
2	2,000-5,000m
1	>5000m

An example of the contents of the resulting GIS attribute table for the section of coastline between Balbriggan and Mornington, Co Meath is shown as Figure 4 below with the corresponding Resolution Confidence Line shown graphically in Figure 5.

Selected Attributes of Resolution_NE

FID	Shape *	LENGTH	certainty
104	Polyline	2867.437522	2
105	Polyline	399.823476	7
106	Polyline	2117.077057	2
107	Polyline	662.94614	6
108	Polyline	528.697041	6
109	Polyline	521.354852	6
110	Polyline	509.121938	6
185	Polyline	39.211971	9
186	Polyline	55.959818	9
248	Polyline	1495.720597	4
271	Polyline	177.010423	8
272	Polyline	210.241118	8
273	Polyline	280.278455	7
274	Polyline	617.069878	6
275	Polyline	920.670115	5
276	Polyline	824.107635	5
277	Polyline	441.821122	7
278	Polyline	234.072605	8
279	Polyline	958.0951	5
280	Polyline	716.155774	6
281	Polyline	112.15078	8
282	Polyline	1706.817619	3
283	Polyline	563.884586	6
284	Polyline	188.778099	8
368	Polyline	224.721783	8
369	Polyline	109.700753	8
370	Polyline	375.91827	7
371	Polyline	276.106866	7
372	Polyline	449.215633	7
373	Polyline	240.571892	8
374	Polyline	112.36024	8
375	Polyline	211.651713	8
376	Polyline	196.282634	8
377	Polyline	354.114391	7
378	Polyline	73.072212	9
379	Polyline	131.75382	8
380	Polyline	320.232319	7
381	Polyline	195.2052	8
382	Polyline	224.935232	8
383	Polyline	337.76343	7
384	Polyline	171.652168	8
385	Polyline	198.856553	8
386	Polyline	653.959561	6

Record: 1 Show: All Selected Records (43 out of 413 Selected) Options

Figure 4 Resolution Confidence Values – Co Meath

Figure 5 Resolution Confidence Line – Laytown Co Meath

Approximately 57% of the north east coast was assessed using line segments of greater than 1km in length and was therefore assigned a low resolution confidence rating. However the areas containing the longer sections of coastline are generally located within sheltered inlets and harbours where erosion is not a significant issue.

The overall mean assessment interval for the north east coast was 663m which is in line with the target resolution for a strategic study. The mean resolution confidence rating for the north east coast was 6.55 which equates to a medium/high confidence.

3.4 Protection Status of the Coast

The potential impact of the natural coastal form and coastal protection structures on the results of the erosion confidence analysis was assessed by reference to the plan aerial photography, both historic and recent, and also by reference to the Coast of Ireland, Oblique Imagery Survey of 2003

For areas of the coast that were shown to be protected in any of these aerial photography surveys, a low confidence rating (2) was assigned. (Refer Figure 6 and Figure 7).

Figure 6 Typical Protected Area of Coast from 2003 Oblique Imagery Survey (Annagassan)

Figure 7 **Protection Confidence Ratings (Annagassan)**

Conversely where examination of these aerial photography surveys indicated a predominately rocky coastline, (Refer Figure 8 and Figure 9), a high confidence rating (8) was assigned.

Figure 8 Typical Area of Rocky Coastline from 2003 Oblique Imagery Survey (Clogher Head)

Figure 9 **Protection Confidence Ratings (Clogher Head)**

All other areas of the coast (un-protected soft coastline) were assigned a medium confidence rating (5). Classification of the coastline in terms of the potential for erosion resistance resulted in 45% of the coast being assigned a low confidence rating due to the presence of extensive coastal protection works or other structures while 13% was given a high confidence rating due to the fact that the coast comprised erosion resistant rock. Thus some 55% of the north east coastline was deemed to be unprotected and therefore the methodology adopted to establish the erosion potential could be considered to have reasonable accuracy.

4.0 Results of Combined Confidence

With all four confidence parameter ratings transcribed to individual lines, the combined confidence for the entire north east coast could be established. Weightings were assigned to each of the confidence parameters; 1 for Underlying 'Geology', 1 for 'Resolution' of Assessment, 1 for geo-referencing of the historic images and 2 for the 'Protection Status of the Coastline'. These weightings were assigned on the basis of the perceived potential size of the error likely to be produced in the predicted erosion lines due to inaccuracies in each parameter.

The four separate confidence lines ('Geology', 'Imagery', 'Resolution', 'Protection') whilst based on the same initial GIS baseline were divided into different numbers of segments following the individual confidence assessments. This anomaly in the make up of the individual confidence lines resulted from the insertion of break points as required along the coast where the confidence rating of the parameter under consideration changed. In order to combine the three individual confidence lines into one overall confidence line, each individual confidence line had to contain the same number and distribution of segments.

Thus the 'Protection' confidence line, was first sub-divided into 5m length segments with further breaks created at all direction change nodes and line end nodes. Each 5m segment was assigned the appropriate confidence rating from the original 'Protection' confidence line to form the basis of the overall Erosion Confidence line. Spatial joins were then carried out within GIS between the 'Geology' 'Imagery' and 'Resolution' confidence lines and the sub-divided 'Protection' confidence line using proximity based techniques to transfer the appropriate 'Geology' 'Imagery' and 'Resolution' confidence rating to a new attribute for each section of the Erosion Confidence line. This technique effectively transferred the closest confidence rating from each of the individual confidence lines to each segment of the overall erosion confidence line.

To ensure that the spatial joins had worked correctly the relevant attribute of the overall line was plotted against the original confidence line using GIS and the ratings compared along the entire length of the coast. The attribute table of the overall erosion confidence line was therefore populated with confidence ratings from all three parameters at approximately 5m intervals along the entire north east coast. A random sample from the overall erosion confidence shapefile is presented in Figure 10 where the columns headed RES_CONF, GEO_CONF, IMG_CONF and PRO_CONF contain the individual confidence ratings assigned to the 'Resolution', 'Geology', 'Imagery' and 'Protection' parameters respectively.

Attributes of Confidence_NE

FID	Shape *	RES_CONF	GEO_CONF	PRO_CONF	IMG_CONF	LENGTH	Confidence	Percentage	CONF_LEVEL
0	Polyline	3	8	8	8	5	14.56	81	High
1	Polyline	2	6	8	8	5	13.62	76	High
2	Polyline	7	1	8	8	5	13.91	77	High
3	Polyline	7	1	2	8	5	9.88	55	Medium
4	Polyline	7	1	2	8	5	9.88	55	Medium
5	Polyline	7	1	2	8	5	9.88	55	Medium
6	Polyline	7	1	2	8	5	9.88	55	Medium
7	Polyline	7	1	2	8	5	9.88	55	Medium
8	Polyline	7	1	2	8	5	9.88	55	Medium
9	Polyline	7	1	2	8	5	9.88	55	Medium
10	Polyline	7	1	2	8	5	9.88	55	Medium
11	Polyline	7	1	2	8	5	9.88	55	Medium
12	Polyline	7	1	2	8	5	9.88	55	Medium
13	Polyline	7	1	2	8	5	9.88	55	Medium
14	Polyline	7	1	2	8	5	9.88	55	Medium
15	Polyline	7	1	2	8	5	9.88	55	Medium
16	Polyline	7	1	2	8	5	9.88	55	Medium
17	Polyline	7	1	2	8	5	9.88	55	Medium
18	Polyline	7	1	2	8	5	9.88	55	Medium
19	Polyline	7	1	2	8	5	9.88	55	Medium
20	Polyline	7	1	2	8	5	9.88	55	Medium
21	Polyline	7	1	2	8	5	9.88	55	Medium
22	Polyline	7	1	2	8	5	9.88	55	Medium
23	Polyline	7	1	2	8	5	9.88	55	Medium
24	Polyline	7	1	2	8	5	9.88	55	Medium
25	Polyline	7	1	2	8	5	9.88	55	Medium
26	Polyline	7	1	2	8	5	9.88	55	Medium
27	Polyline	7	1	2	8	5	9.88	55	Medium
28	Polyline	7	1	2	8	5	9.88	55	Medium
29	Polyline	7	1	2	8	5	9.88	55	Medium
30	Polyline	7	1	2	8	5	9.88	55	Medium
31	Polyline	7	1	2	8	5	9.88	55	Medium
32	Polyline	7	1	2	8	5	9.88	55	Medium
33	Polyline	7	1	2	8	5	9.88	55	Medium
34	Polyline	7	1	2	8	5	9.88	55	Medium
35	Polyline	7	1	2	8	5	9.88	55	Medium
36	Polyline	7	1	2	8	5	9.88	55	Medium
37	Polyline	7	1	2	8	5	9.88	55	Medium
38	Polyline	7	1	2	8	5	9.88	55	Medium
39	Polyline	7	1	2	8	5	9.88	55	Medium
40	Polyline	7	1	2	8	5	9.88	55	Medium
41	Polyline	7	1	2	8	5	9.88	55	Medium
42	Polyline	7	1	2	8	5	9.88	55	Medium
43	Polyline	7	1	2	8	5	9.88	55	Medium
44	Polyline	7	1	2	8	5	9.88	55	Medium
45	Polyline	7	1	2	8	5	9.88	55	Medium
46	Polyline	7	1	2	8	5	9.88	55	Medium
47	Polyline	7	1	2	8	5	9.88	55	Medium
48	Polyline	7	1	2	8	5	9.88	55	Medium
49	Polyline	2	1	2	6	5	6.26	35	Very Low
50	Polyline	2	1	2	8	5	7.85	44	Low
51	Polyline	2	1	2	8	5	7.85	44	Low
52	Polyline	2	1	2	8	5	7.85	44	Low
53	Polyline	2	1	2	8	5	7.85	44	Low

Record: 1 Show: All Selected Records (0 out of 54792 Selected) Options

Figure 10 Sample of Overall Confidence Rating Attribute Table

The confidence ratings at each point were subsequently weighted and combined to give a final overall confidence Sum Total value for each line segment. The formula used to weight and combine the individual confidence ratings was as follows;

$$C_{OVERALL} = \sqrt{C^2_{IMAGERY} + 2C^2_{PROTECTION} + C^2_{GEOLOGY} + C^2_{RESOLUTION}}$$

The resulting potential combined confidence ratings after scaling lay in the range 2 (all individual confidences scores 1) to 18 (all individual confidence scores 9). The combined confidence ratings for each line segment were then converted to a percentage of the possible maximum score before being classified into one of 5 groupings, Very High, High, Medium, Low or Very Low as shown in Table 2**.**

Table 2: Overall Confidence Ratings

Confidence	Range
Very High	>85%
High	70-85%
Medium	55-70%
Low	40-55%
Very Low	<40%

The percentage bands listed above are different from those used for the flooding confidence analysis however this is a function of different parameter scorings and weighting used in the two analyses. The actual percentage bands were selected to give what was considered a realistic distribution of confidence class along the north east coast and for consistency with the results of the erosion confidence analysis for the SE coast.

The overall confidence rating for each segment of the coast calculated using the equation outlined above is contained in the column headed "Confidence" in Figure 10, while the resulting overall percentage score and confidence class are in the columns headed "Percentage" and "CONF_LEVEL" respectively.

Statistical analysis of the distribution of overall confidence ratings along the north east coast indicates that the mean confidence rating for the erosion assessment of the north east coastline between Omeath and Dalkey was 61% i.e. Medium Confidence. Approximately 2% of the coastline was assigned a very high overall confidence rating while 6% was assigned a very low overall confidence rating. Inspection of the distribution of sections of the coastline with very low overall confidence ratings indicates that the majority of these are located in areas where coastal protection structures were observed to be present or where there was no information on geology available.

5.0 Conclusions

The confidence analysis methodology used to assign confidence to the erosion lines has been tested and modified to produce the optimum analysis for this strategic project. It involves the combination of qualitative and quantitative information into one overall quantitative database. The results are presented in the form of an overall confidence rating for the erosion analysis of the north east coast at approximately 5m resolution. The methodology which is based on scoring and weighting confidence in individual parameters likely to impact on the accuracy of the erosion assessment has established whether confidence in the erosion extent determination is very high, high, medium, low or very low based on four principal parameters; i.e. Underlying 'Geology', 'Accuracy' of the historic imagery, 'Resolution' of the Assessment and 'Protection' status of the coast.

All sectors of the overall erosion confidence line have been assigned a confidence rating. Very high confidence was represented by a score of over 85%, with high confidence between 70-85%, medium confidence between 55-70%, low confidence between 40-55% and very low confidence being represented by a result of less than 40%. Overall the analysis indicates that there is generally a medium level of confidence in the position of the erosion lines identified for the north east coast. There are however some localised areas where the analysis has identified a very low confidence generally as a result of the presence of coastal protection works or lack of information on underlying geology. The principal areas of very low confidence in the erosion assessment are; Dundalk Harbour, Balleally Landfill, Howth Harbour, Clontarf, and Dun Laoghaire Harbour.

The final erosion lines with assigned confidence for the entire north east coast are shown on the erosion maps presented in Appendix 9 of the main report. Digital copies of these are also appended to the main report.

As this methodology requires assigning quantitative values to what is in many cases essentially qualitative data, the results may be subject to variations in user's interpretation. It is difficult to fully assess the impact of variations in interpretation on the reliability of the current methodology, however any such impact has been at least partially mitigated by ensuring that the same personnel have undertaken the assessment for all areas of the coast.