Bathing Water Pollution Risk Forecasting

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Contents

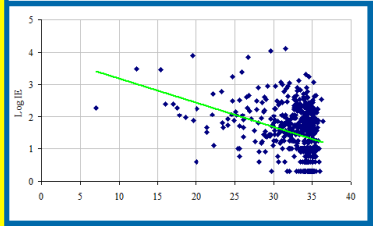
- Pollution risk forecasting (PRF) system
- Factors affecting water quality
- Forecasting method development 2016/17
- Further development 2018
- Forward look

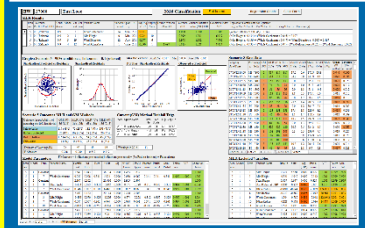
Introduction

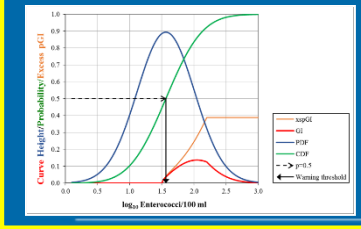
- We use Pollution Risk Forecasting to provide information to the public on where and when to bathe.
- Our current method uses the relationship between rainfall and water quality to give daily forecasts, and is currently used at 38% of bathing waters (155).
- We have developed a new method which is ~30% more accurate than our current method and applicable to ~80% of our bathing waters.

EA Pollution Risk Forecasting System

MODELLING
Data management
Model build and validation
Model export
In season tracking

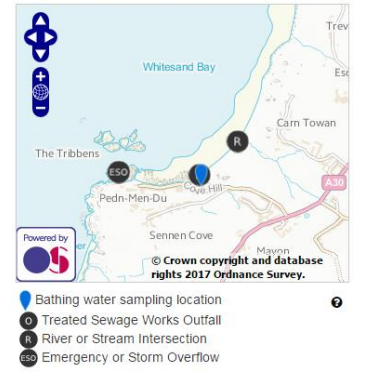




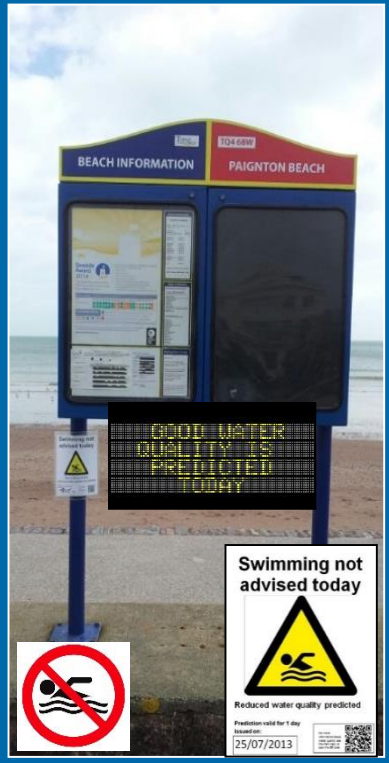


FEWS SYSTEM
Real-time automated daily forecast
Data capture
Data visualisation and export

FORECAST DISSEMINATION
Environment Agency
Data Explorer
Text messages
Email notifications



BEACH MANAGEMENT
Beach signage
Electronic signs



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http://environment.data.gov.uk/bwq/profiles/

PORTH'S COASTAL CATCHMENT

The Coastal Catchment is the area of land that can influence the water quality at Porth.
This includes far reaching urban and rural areas linked to the coast by networks of sewers, streams and rivers.

DIFFUSE POLLUTION

Pollutants running off farmland and roads are one of the major issues in this Catchment. Improved land management can protect bathing water quality.

RAIN WIND SUNLIGHT

PROTECTING SEWERS, IMPROVING WATER QUALITY

Sewers are designed to take the 4 P's from homes and businesses to sewage plants (poo, pee, paper and puke). Sanitary products and fats, oils and greases block sewers, resulting in sewage spills.

PAVEMENTS TO PEBBLES

Keep pollutants out of road drains as they are often linked back to beach drains.

Install a Water Butt in your garden.

Turn the tap off when brushing your teeth.

TIDE AND WAVE ACTION

Fit a Hippo in your loo.

MISCONNECTIONS

Properties mistakenly connected to the surface drains rather than sewers can pollute the seas with untreated sewage.

DIVERTING WATER AWAY FROM SEWERS

Excess water in the sewers overpowers the system, resulting in sewage spills.

BATHING WATER QUALITY

Bathing water quality is tested weekly during the bathing season (May - Sept.) by the Environment Agency. The results are posted on the Cleaner Coastal Catchments website.

NFC TAP HERE
tapplo

CLEANER COASTAL CATCHMENTS

SURFERS AGAINST SEWAGE
www.sas.org.uk

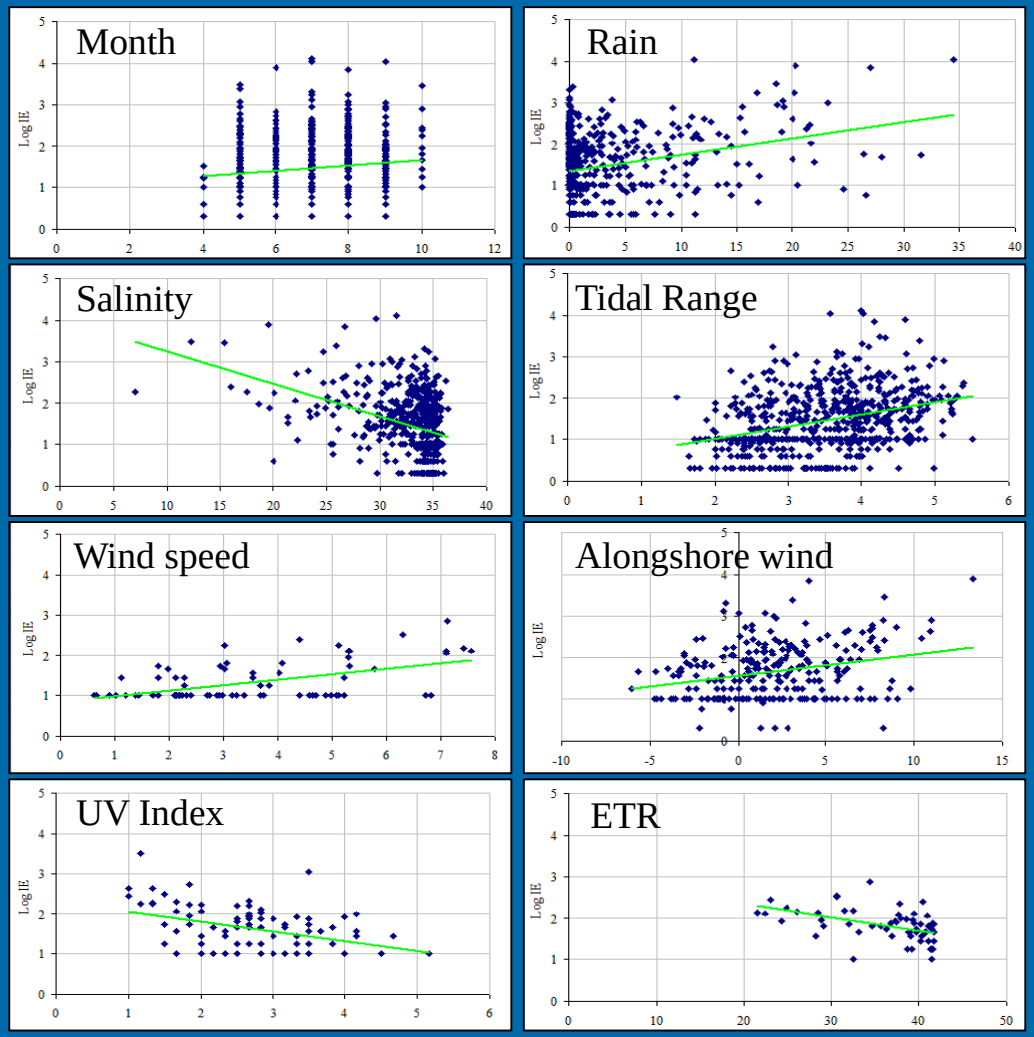
Environment Agency

www.CleanerCoastalCatchments.org.uk

For more information on all these issues please visit the Cleaner Coastal Catchments website

Water Quality Variables

- Time - month, day of bathing season, time;
- Rain - gauge, radar;
- Flow – salinity (freshwater proxy);
- Tide - range, height (min on day, max on day, at sample time), HW relative at sample time;
- Wind – speed, direction, onshore and alongshore components;
- Solar Radiation - UV Index, extraterrestrial radiation (ETR)



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Results – bivariate regression

BW	25700	Bantham	View Raw Data	MLR	Close

Single Regression | TBR | DAVEY PARK FARM (TBR) | Profile | http://environ | Catchment Map | O:\Bathing

Ranked | All

Rank	Variable Type	Variable Name (yellow = excluded from MLR) Variable List	In MLR Mod	Exclude Var	Quantity	Time Scale hrs	Ant or Hyd	n	P-value (<0.1)	RSq (<0.1)	Intercept	Slope	Mean	SDev	Range
1	Salinity	Salinity	☐	☑	Value	0	Ant	359	0.000	0.195	4.043	-0.090	33.3	2.7	21.1
2	Rain Gauge	TBR	☑	☐	Sum	48	Hyd	365	0.000	0.168	0.944	0.028	4.3	8.2	60.8
3	Rain Radar	Whole Catchment	☐	☐	Sum	72	Ant	285	0.000	0.165	0.853	0.020	8.7	12.4	67.9
4	Rain Radar	Whole Catchment	☐	☐	Sum	72	Ant	285	0.000	0.165	0.853	0.020	8.7	12.4	67.9
5	Rain Radar	10km Radius	☐	☐	Sum	72	Ant	285	0.000	0.159	0.863	0.022	7.2	10.7	67.5
6	Rain Radar	Whole Catchment	☐	☐	Sum	48	Hyd	285	0.000	0.158	0.889	0.022	6.0	10.6	65.9
7	Rain Radar	Whole Catchment	☐	☐	Sum	24	Hyd	285	0.000	0.158	0.914	0.035	3.1	6.9	51.8
8	Rain Radar	Whole Catchment	☐	☐	Sum	48	Hyd	285	0.000	0.158	0.890	0.022	6.0	10.6	66.0
9	Rain Radar	Whole Catchment	☐	☐	Sum	48	Ant	285	0.000	0.157	0.889	0.022	6.0	10.6	66.0
10	Rain Radar	Whole Catchment	☐	☐	Sum	48	Ant	285	0.000	0.157	0.889	0.022	6.0	10.6	65.9
11	Wind	Wind Speed	☐	☐	Ave	15	Ant	120	0.000	0.150	0.918	0.071	4.7	2.6	13.3
12	Wind	Wind Speed	☐	☐	Ave	12	Ant	120	0.000	0.149	0.924	0.068	4.8	2.7	13.9
13	Wind	Wind Speed	☐	☐	Ave	6	Ant	119	0.000	0.142	0.943	0.064	4.9	2.9	14.3
14	Wind	Wind Speed	☐	☐	Ave	9	Ant	119	0.000	0.142	0.944	0.064	4.9	2.8	14.7
15	Wind	Wind Speed	☐	☐	Ave	3	Ant	119	0.000	0.136	0.930	0.063	5.2	2.8	13.8
16	Wind	Wind Speed	☐	☐	Value	1	Ant	119	0.000	0.130	0.899	0.066	5.4	2.6	12.8
17	Wind	Wind Alongshore	☑	☐	Ave	15	Ant	120	0.000	0.109	1.249	-0.057	-0.1	2.8	12.9
18	Tide	Abs Hrs Relative to HV	☐	☑	Value	0	Ant	365	0.000	0.102	0.760	0.102	3.0	1.8	6.2
19	Tide	Height Relative to Samp	☐	☑	Value	0	Ant	365	0.000	0.094	1.514	-0.140	3.2	1.2	4.7
20	Wind	Wind Alongshore	☐	☐	Ave	12	Ant	120	0.000	0.092	1.249	-0.051	-0.1	2.9	13.5
21	Wind	Wind Onshore	☐	☐	Ave	9	Ant	119	0.002	0.072	1.191	0.031	2.1	4.3	21.8
22	Wind	Wind Onshore	☐	☐	Ave	6	Ant	119	0.002	0.072	1.196	0.030	2.0	4.3	21.9
23	Wind	Wind Alongshore	☐	☐	Ave	9	Ant	119	0.002	0.069	1.248	-0.044	-0.2	3.0	14.7
24	Wind	Wind Onshore	☐	☐	Ave	12	Ant	120	0.003	0.067	1.184	0.031	2.3	4.2	20.9
25	Wind	Wind Onshore	☐	☐	Ave	3	Ant	119	0.003	0.066	1.201	0.028	2.0	4.5	22.7

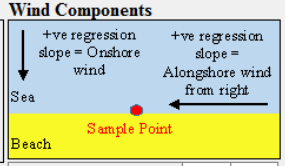
Record: 15 of 40 | Filtered | Search

Accept Model ☑ | Notes

Pollution Sources from BW Profile

Category	Feature name	Dist to BW m	Onshore Dim	BW Dim	Feature to Spt
Treated Sewage V	Bigbury & Challaborough S	1540	270	180	Right
River or Stream	Buckland Stream	215	270	180	Left

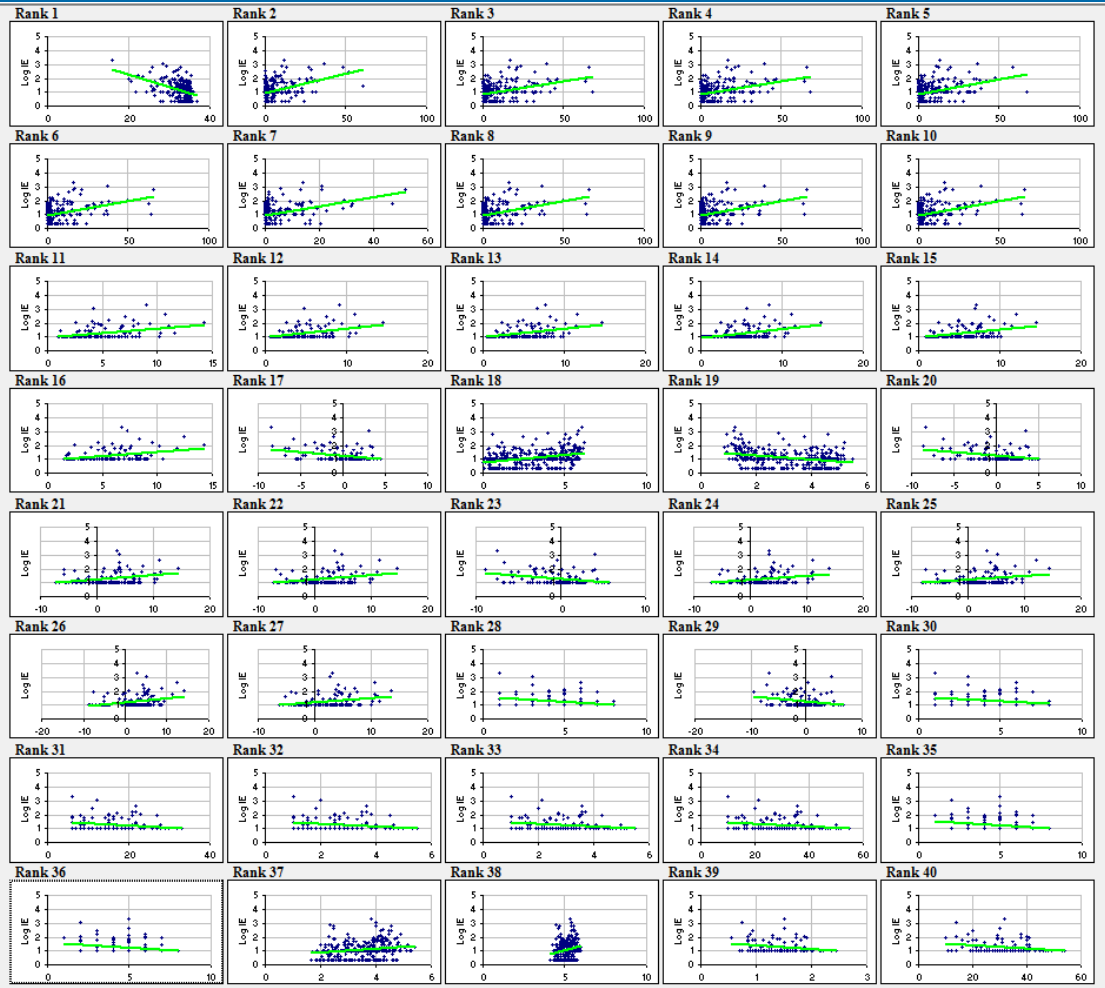
Wind Components



Warnings/BS (GM:MLR)	5	9
F Measure (GM:MLR)	0.171	0.418

MLR Results - Scenario 5

Model	Var ent	Var rem	Variable Name	Period	AdjRSq	Tol	Cond inc
1	2		TBR	48	0.280	1.000	1.749
2	38		Max Height	0	0.334	1.000	28.248
3	17		Wind Alongshore	15	0.390	0.962	28.337
4	13		Wind Speed	6	0.400	0.748	33.148



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Results – multiple linear regression

BW	27000	East Looe	2017 Classification	Sufficient	Regression Graphs	Close Form

DEFRA	BW	2017	GM	Fall back	Data Start	n	n>0.7 Prob	n%>0.7 Prob	Tolerance	VIF	n Mod All	n Mod Fin	AdjRSq <0.1 red	Std Err Est.	Condition Index >15 amber	PPMin10 % >0.1 amber	PPMax >0.1 amber	PPMax10 % >0.1 amber	FMeas (70%)	Score	Model check	Regression Coefficients for Equation IE(y) = Var1*Coeff1 + Var2*Coeff2 + ... + Varp*Coeffp + Constant(a)
27000	East Looe	Sufficient	☑	☐	2011	271	113	42	0.966	1.035	5	5	0.278	0.555	8.286	0.036	0.059	0.022	0.526	0	Model OK	(Min Height x -0.428) + (Whole Catchment (24hr Sum) x 0.039) + (Wind Alongshore (1hr Value) x 0.02) + (Wind Onshc

Record: 1 of 1 Unfiltered Search

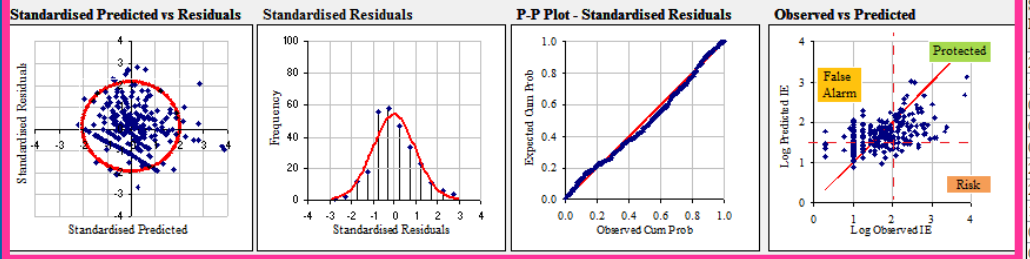
MLR Results

MLR Equation (Min Height x -0.428) + (Whole Catchment (24hr Sum) x 0.039) + (Wind Alongshore (1hr Value) x 0.02) + (Wind Onshore (6hr Ave) x 0.045) + (UV Index (12hr Sum) x -0.008) + 2.225

Scenario	Tolerance Pin:0.1 Pout: 0.11	dence		ent	rem		Period	tity		<0.25	%inc	Est.	<1 or >3	<0.1	factor (VIF) >10	>30 (red)	IE(y) = Var1*Coeff1 + Var2*Coeff2 + ... + Varp*Coeffp + Constant(a)
5	0.1 (Relaxed)	0.9	1	7		Whole Catchment	24	Sum	271	0.113		0.614		1.000	1.000	1.703	
5	0.1 (Relaxed)	0.9	2	3		Min Height	0	Min	271	0.214	10	0.579		0.999	1.001	6.059	
5	0.1 (Relaxed)	0.9	3	17		Wind Onshore	6	Ave	271	0.266	5	0.559		1.000	1.000	6.150	
5	0.1 (Relaxed)	0.9	4	12		Wind Alongshore	1	Value	271	0.273	1	0.556		0.809	1.236	6.727	
5	0.1 (Relaxed)	0.9	5	34		UV Index	12	Sum	271	0.278	0	0.555	1.687	0.966	1.035	8.286	(Min Height x -0.428) + (Whole Catchment (24hr Sum) x 0.039) + (Wind Alongshore (1hr Value) x 0.02) + (Wind Onshore (6hr Ave)

Graphs: Scenario 5 - 90% confidence, Tolerance = 0.1 (relaxed)

Max P-P errors: Min10% 0.036 Max 0.059 Max10% 0.022 Fall Back



Scenario 5 Raw Data

Sampling Date/Time	Pur p	Sample IE	GM Out	MLR 50%	MLR Raw 70%	MLR 70%	MLR 90%	Model 1 Var	Model 2 Var	Model 3 Var	Model 4 Var	Model 5 Var	Model 6 Var	Model 7 Var	Model 8 Var	Model 9 Var	Cooks (IE outlier)	Leverage (Var extreme)
20/09/17 12:22	MS	118	3	114	114	114	114	0.5	0.8	1.3	6.8	7.0					0.000	0.022
11/09/17 11:45	MS	220	3	35	35	35	35	4.6	1.0	-8.6	2.3	9.0					0.010	0.023
06/09/17 13:30	MS	109	3	28	28	28	28	0.1	1.0	-4.8	1.0	17.0					0.002	0.008
06/09/17 13:29	MI	250	3	28	28	28	28	0.1	1.0	-4.8	1.0	17.0					0.006	0.008
01/09/17 11:44	MS	10	4	17	17	17	17	7.3	2.3	-2.2	-4.2	11.0					0.001	0.042
24/08/17 12:56	MS	230	3	77	77	77	77	0.0	0.5	-1.3	4.0	16.0					0.002	0.014
24/08/17 12:55	MI	310	3	77	77	77	77	0.0	0.5	-1.3	4.0	16.0					0.004	0.014
17/08/17 11:32	MS	10	4	45	45	45	45	8.9	1.9	-2.3	5.8	11.0					0.004	0.015
08/08/17 11:40	MS	55	3	71	71	71	71	7.6	1.1	-2.3	0.3	10.0					0.000	0.009
06/08/17 10:29	MS	64	3	38	38	38	38	0.2	1.3	-2.1	3.9	9.0					0.000	0.007
27/07/17 12:10	MS	100	3	57	57	57	57	0.5	0.7	-3.6	4.9	17.0					0.001	0.016
27/07/17 12:09	MI	136	3	57	57	57	57	0.5	0.7	-3.6	4.9	17.0					0.002	0.016
21/07/17 11:58	MS	360	2	991	991	991	991	23.3	1.2	3.9	13.1	7.0					0.010	0.080
14/07/17 12:30	MS	173	3	19	19	19	19	0.1	1.2	-4.5	-1.8	22.0					0.009	0.014
06/07/17 12:17	MS	10	1	16	16	16	16	0.0	1.6	-1.9	-1.2	26.0					0.000	0.016
30/06/17 13:20	MS	10	1	19	19	19	19	2.2	1.3	-5.9	-4.2	12.0					0.001	0.022
23/06/17 12:25	MS	36	1	47	47	47	47	0.0	0.7	-3.5	5.3	22.0					0.000	0.021
12/06/17 12:48	MS	18	1	26	26	26	26	1.5	1.2	-5.2	2.1	20.0					0.000	0.011
12/06/17 12:47	MI	10	1	26	26	26	26	1.5	1.2	-5.2	2.1	20.0					0.001	0.011

Record: 1 of 271 No Filter Search

Scenario 5 Outcomes MLR and GM Methods

Outcome for probability of exceeding the 10% health risk	GM 50% 37 (1.56)	MLR 50% 37 (1.56)	MLRRaw 70% 63 (1.80)	**MLR 70% 63 (1.80)**	MLR 90% 136 (2.13)
Safe to bathe	118 (44%)	80 (30%)	127 (47%)	**127 (47%)**	200 (74%)
Bathers protected	28 (10%)	106 (39%)	56 (21%)	**56 (21%)**	20 (7%)
Risk to bathers	112 (41%)	34 (13%)	57 (21%)	**57 (21%)**	45 (17%)
False alarm	13 (5%)	51 (19%)	31 (11%)	**31 (11%)**	6 (2%)
Estimate of Warnings/BS	23	89	49	**49**	15
F Measure	0.243	0.735	0.526	**0.526**	0.362

Current (GM) Method Rainfall Triggers and Warnings

Year	Space Scale	Time Rel	Time Scale	Trig	AdjRSq	Warns 2016	Warns 2017
2016	5km from coast	Hyd	24	6.1	0.647	13	22
2017	10km Radius	Hyd	24	6.6	0.626	13	22
2018	10km Radius	Hyd	24	6.5	0.640	13	22

F Measure = 4 x Bathers protected/((4 x Bathers protected)+ (3 x Risk to bathers) + False alarm)

Model Parameters

Scenario	Model	Term	Variable Name	Coefficient	Std Error	Beta	t stat	Sig	95%CI Lower	95%CI Upper	Pearson correl	Partial correl	Semi Partial	Tolerance	VIF	Condition Index
5	1	Constant		1.547	0.043		36.134	0.000	1.463	1.632						1.000
5	1	7	Whole Catchment	0.045	0.008	0.341	5.934	0.000	0.030	0.060	0.341	0.341	0.341	1.000	1.000	1.703
5	2	Constant		2.107	0.102		20.566	0.000	1.905	2.309						1.000
5	2	3	Min Height	-0.434	0.073	-0.321	-5.942	0.000	-0.577	-0.290	-0.312	-0.342	-0.321	0.999	1.001	6.059
5	2	7	Whole Catchment	0.046	0.007	0.350	6.463	0.000	0.032	0.060	0.341	0.368	0.349	0.999	1.001	1.879
5	3	Constant		2.137	0.099		21.550	0.000	1.942	2.332						1.000

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MLR Excluded Variables

Scenario	Model	Term	Variable Name	Beta In	t stat	Sig (0.05)	Partial correl	VIF	Tolerance	Min Tol
5	1	1	Max Height	0.303	5.560	0.000	0.322	1.001	0.999	0.999
5	1	3	Min Height	-0.321	-5.942	0.000	-0.342	1.001	0.999	0.999
5	1	4	Tidal Range	0.307	5.647	0.000	0.327	1.001	0.999	0.999
5	1	5	3km Radius at TBR	-0.138	-0.834	0.405	-0.051	8.314	0.120	0.120
5	1	6	10km Radius	-0.490	-0.644	0.520	-0.039	174.878	0.006	0.006
5	1	8	5km Radius	-0.217	-0.682	0.496	-0.042	30.661	0.033	0.033

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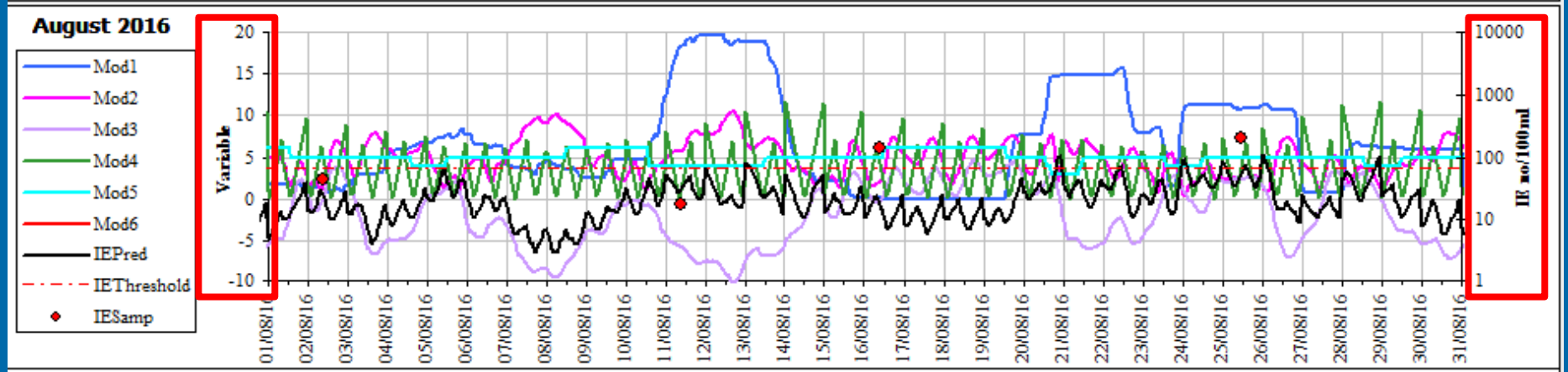
2018 Within day bacti variation

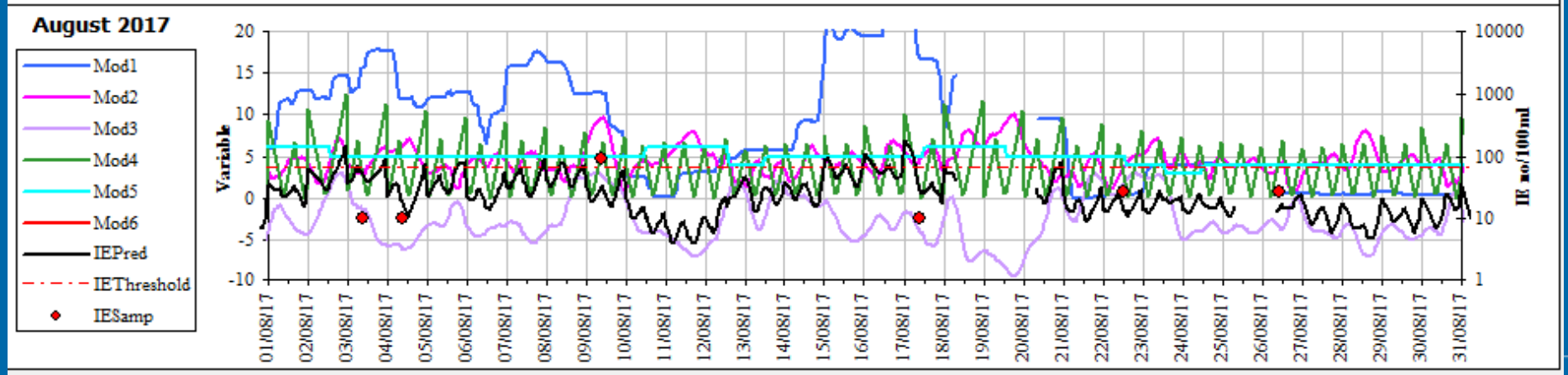
- Sub-daily variables were added to the bivariate regression and the MLR analysis repeated. Results showed in day variation evident in 156 of the 414 bathing waters.
- Hourly data were compiled for all variables (monster amount of data processing), and the MLR equations were used to calculate hourly levels of IE throughout the 2016 (dry) and 2017 (wet) bathing seasons;
- Tools built to post process and visualise results.

BW	03600	Spittal	2017 Classification	Sufficient

MLR Equation (Tweed C021005 (72hr Sum) x 0.04) + (Abs Hrs Relative to HW x 0.055) + (Wind Onshore (9hr Ave) x 0.031) + (UV Index (50hr Max) x -0.057) + (Wind Speed (6h

Scenario	Tolerance Pin:0.1 Pout: 0.11	Confidence	Model	Varent	Varrem	Variable Name	Variable Period	Quantity	n	AdjRSq <0.25	AdjRSq %inc	StdErr Est.	Durbin Watson <1 or >3	Tolerance <0.1	Variance Inflation factor (VIF) >10	Condition Ind >30 (red)
5	0.1 (Relaxed)	0.9	1	6		Tweed C021005	72	Sum	125	0.215		0.459		1.000	1.000	2.571
5	0.1 (Relaxed)	0.9	2	29		Wind Speed	6	Ave	125	0.293	8	0.436		0.936	1.068	5.187
5	0.1 (Relaxed)	0.9	3	25		Wind Onshore	9	Ave	125	0.324	3	0.426		0.960	1.042	5.540
5	0.1 (Relaxed)	0.9	4	12		Abs Hrs Relative to HW	0	Value	125	0.353	3	0.417		0.988	1.013	7.474
5	0.1 (Relaxed)	0.9	5	27		UV Index	50	Max	125	0.366	1	0.413	1.629	0.966	1.035	12.065





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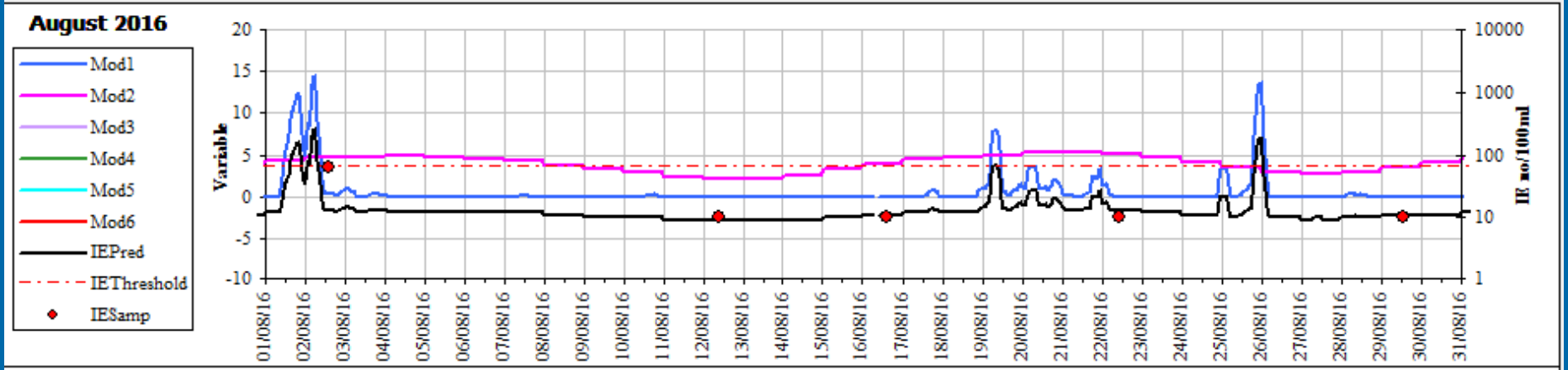
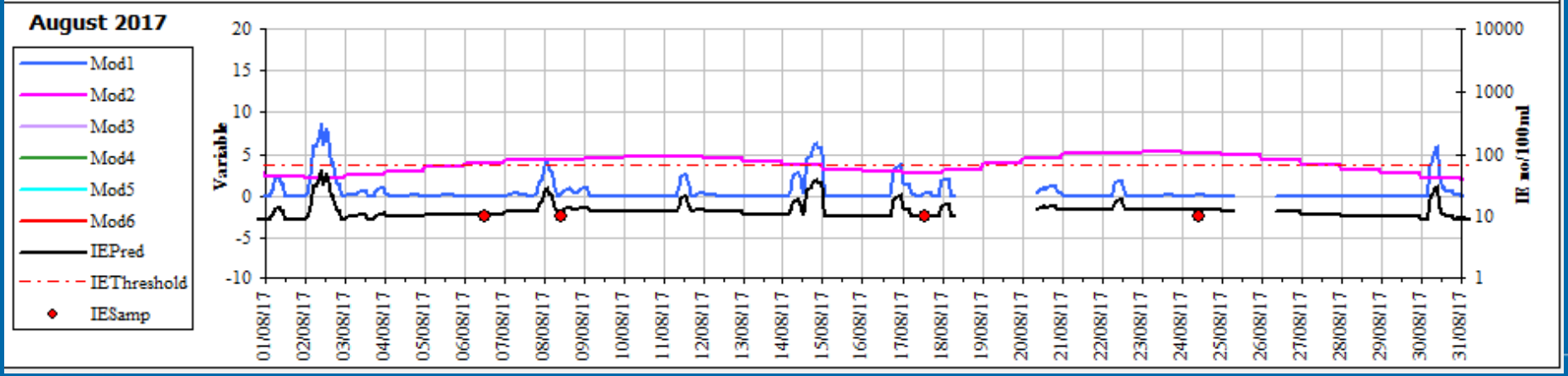
BW	26530	Cawsand	2017 Classification	Excellent

MLR Equation (Whole Catchment (6hr Sum) x 0.092) + (Tidal Range x 0.054) + 0.835

Scenario	Tolerance Pin:0.1 Pout: 0.11	Confidence	Model	Varent	Varrem	Variable Name	Variable Period	Quantity	n	AdjRSq <0.25	AdjRSq %inc	StdErr Est.	Durbin Watson <1 or >3	Tolerance <0.1	Variance Inflation factor (VIF) >10	Condition Index >30 (red)
5	0.1 (Relaxed)	0.9	1	1		Whole Catchment	6	Sum	279	0.483		0.200		1.000	1.000	1.323
5	0.1 (Relaxed)	0.9	2	19		Tidal Range	0	Value	279	0.506	2	0.195	1.203	1.000	1.000	9.221



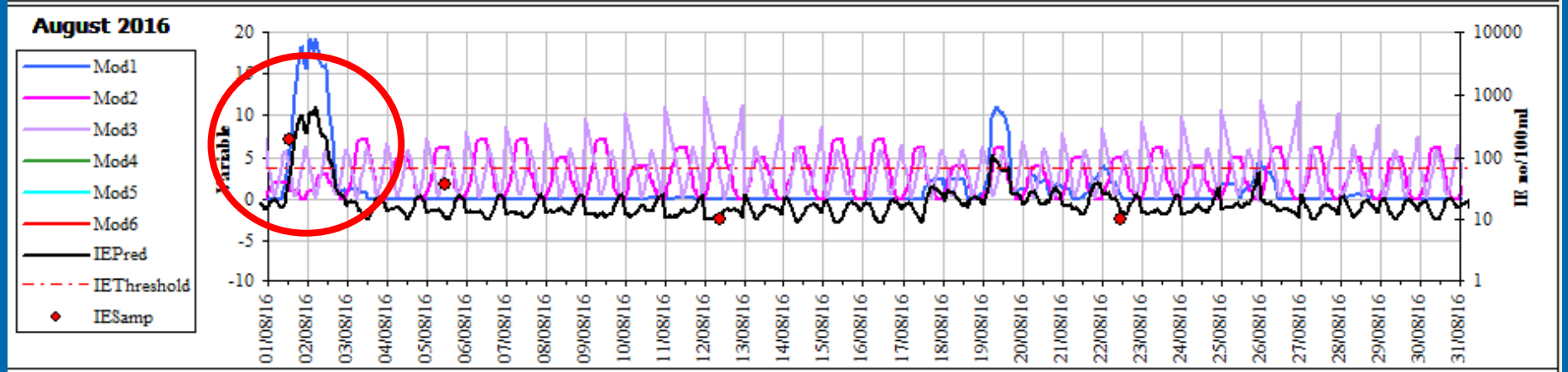


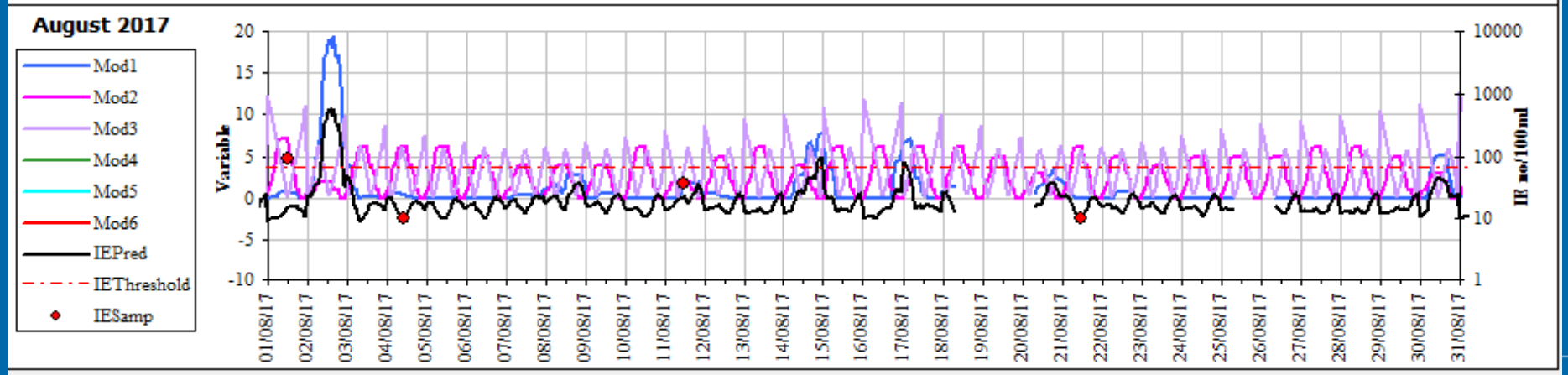
Environment Agency

BW	26000	Challaborough	2017 Classification	Excellent

MLR Equation (1km Radius (12hr Sum) x 0.076) + (UV Index (5hr Max) x -0.038) + (Abs Hrs Relative to HW x -0.034) + 1.41

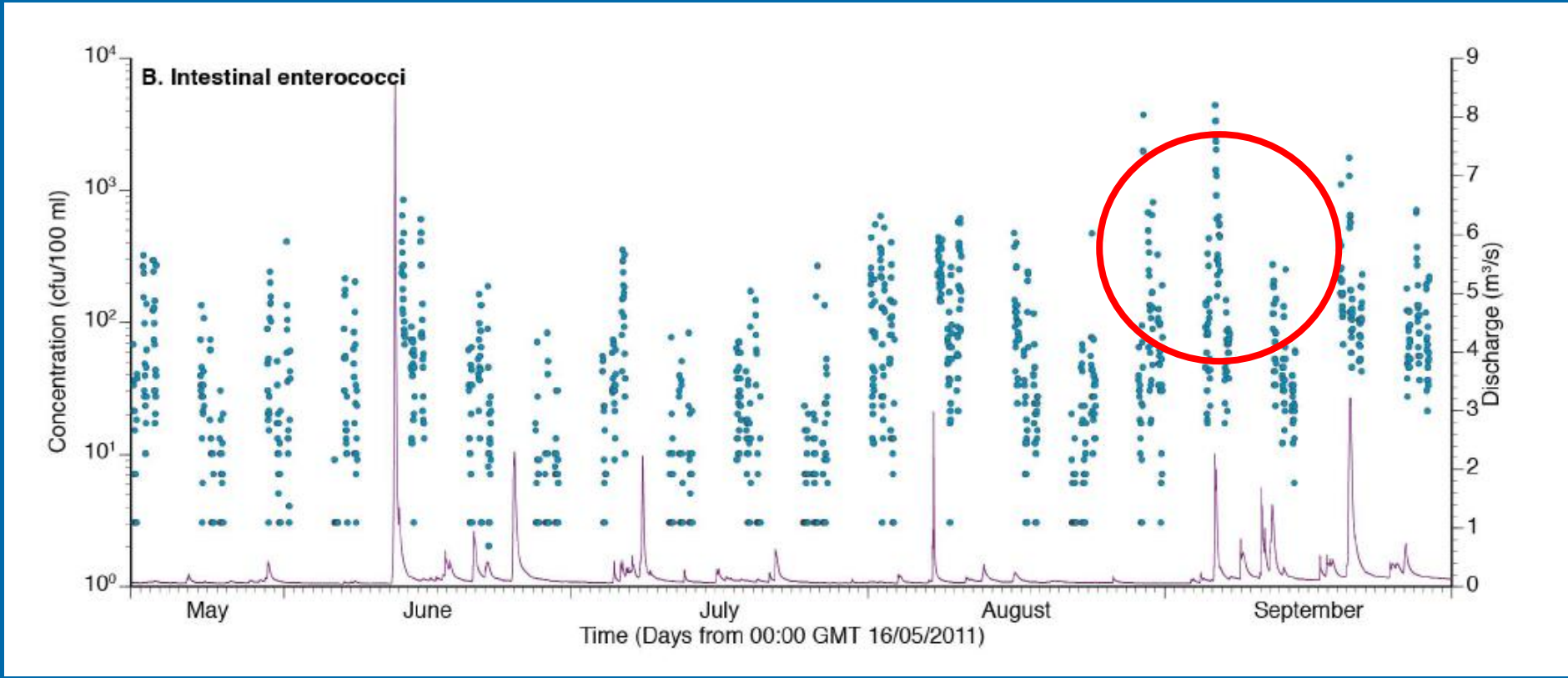
Scenario	Tolerance Pin:0.1 Pout: 0.11	Confidence	Model	Varent	Varrem	Variable Name	Variable Period	Quantity	n	AdjRSq <0.25	AdjRSq %inc	StdErr Est.	Durbin Watson <1 or >3	Tolerance <0.1	Variance Inflation factor (VIF) >10	Condition Index >30 (red)
5	0.1 (Relaxed)	0.9	1	3		1km Radius	12	Sum	138	0.303		0.355		1.000	1.000	1.533
5	0.1 (Relaxed)	0.9	2	11		UV Index	5	Max	138	0.320	2	0.351		0.896	1.116	5.812
5	0.1 (Relaxed)	0.9	3	22		Abs Hrs Relative to HW	0	Value	138	0.337	2	0.347	1.845	0.984	1.016	7.263





Environment Agency

Diurnal variation in bacti levels - Swansea



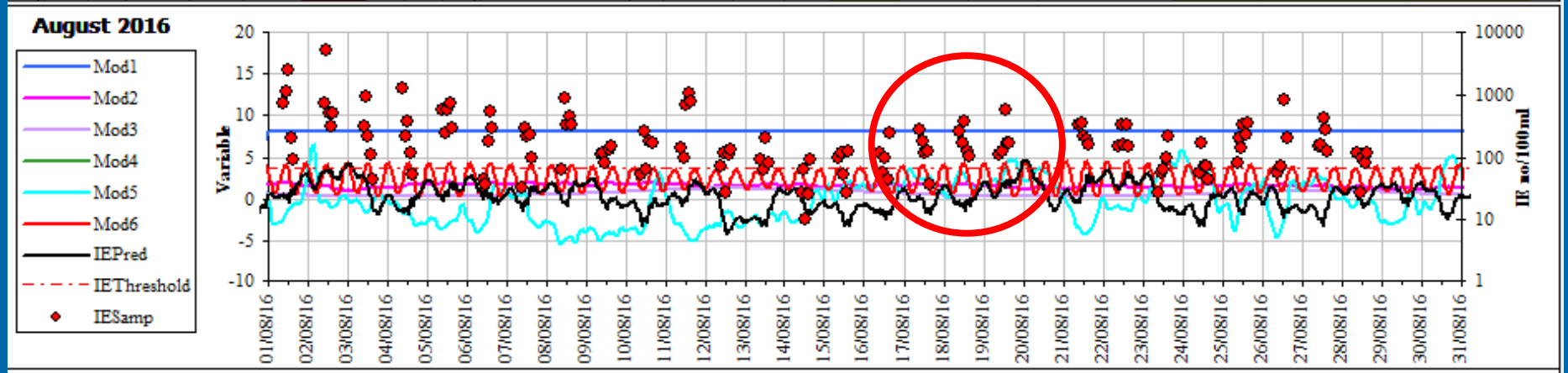
Wyer M, *et al.*, 2013

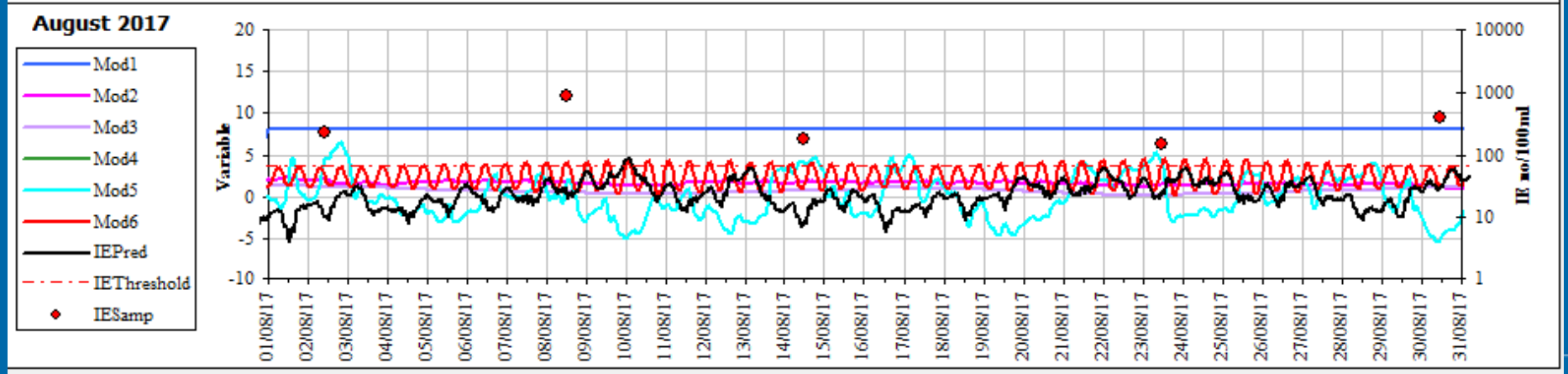
Environment Agency

BW	11550	Clacton (Groyne 41)	2017 Classification	Poor

MLR Equation (Month x 0.183) + (Wind Onshore (3hr Ave) x -0.03) + (UV Index (50hr Ave) x 0.59) + (UV Index (26hr Sum) x -0.016) + (Min Height x -0.388) + (Height Relative t

Scenario	Tolerance Pin:0.1 Pout: 0.11	Confidence	Model	Var ent	Var rem	Variable Name	Variable Period	Quantity	n	AdjRSq <0.25	AdjRSq %inc	StdErr Est.	Durbin Watson <1 or >3	Tolerance <0.1	Variance Inflation factor (VIF) >10	Condition Ind >30 (red)
5	0.1 (Relaxed)	0.9	1	1		Month	0	Value	293	0.110		0.513		1.000	1.000	13.830
5	0.1 (Relaxed)	0.9	2	15		UV Index	50	Ave	293	0.155	5	0.500		0.983	1.017	19.027
5	0.1 (Relaxed)	0.9	3	28		Min Height	0	Min	293	0.195	4	0.488		0.989	1.011	21.698
5	0.1 (Relaxed)	0.9	4	25		UV Index	26	Sum	293	0.233	4	0.476		0.669	1.494	24.213
5	0.1 (Relaxed)	0.9	5	8		Wind Onshore	3	Ave	293	0.256	2	0.469		0.934	1.071	24.754
5	0.1 (Relaxed)	0.9	6	32		Height Relative to Sample	0	Value	293	0.261	1	0.468		0.733	1.364	28.250



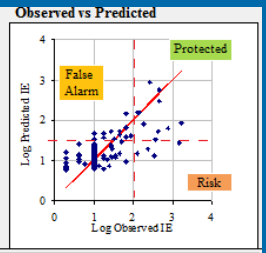


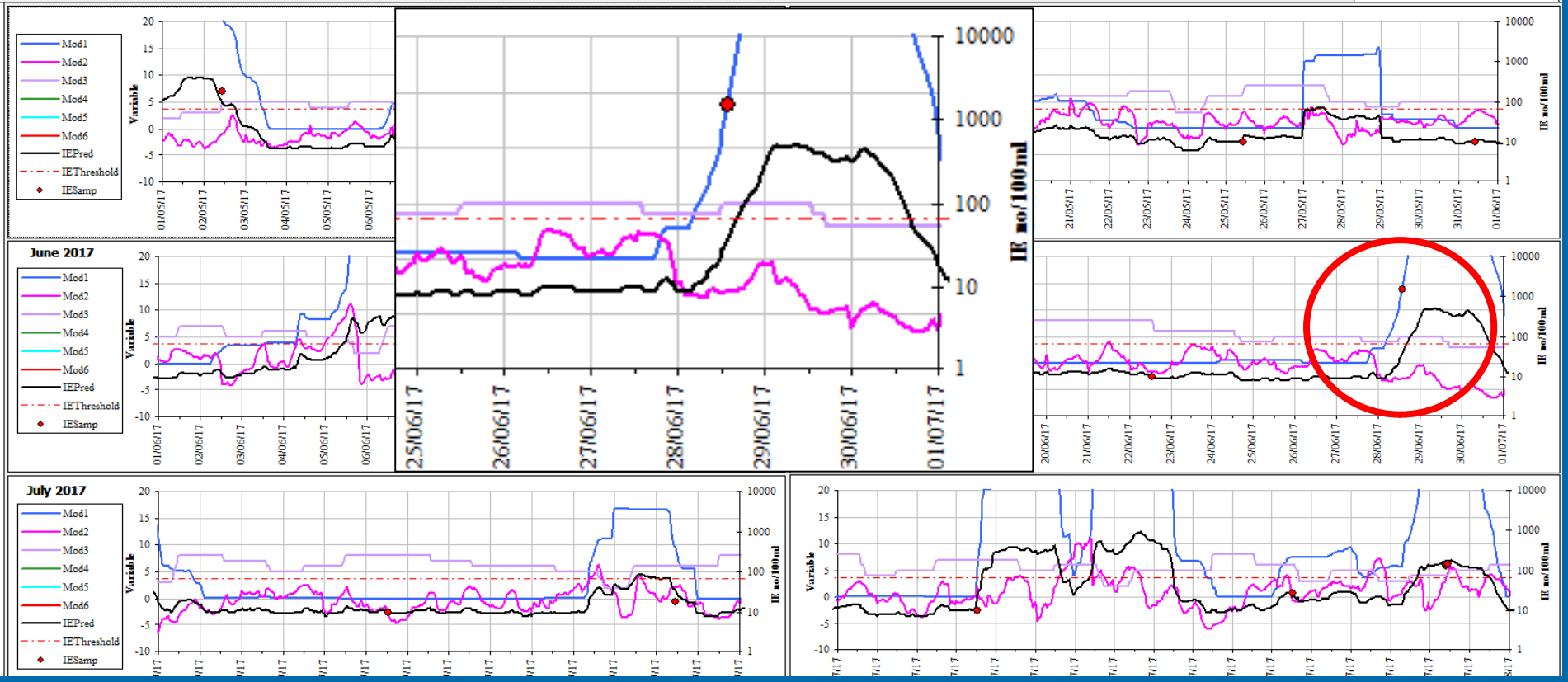
Environment Agency

BW	26400	Plymouth Hoe East	2017 Classification	Excellent	Regression Graphs	Close Form

MLR Results | **MLR Equation** (10km Radius (48hr Sum) x 0.051) + (Wind Onshore (1hr Value) x 0.027) + (UV Index (26hr Max) x 0.046) + 0.709

Scenario	Tolerance Pin:0.1 Pout: 0.11	Confidence	Model	Variant	Variarem	Variable Name	Variable Period	Quantity	n	AdjRSq <0.25	AdjRSq %inc	StdErr Est.	Durbin Watson <1 or >3	Tolerance <0.1	Variance Inflation factor (VIF) >10	Condition Index >30 (red)	Re IE
5	0.1 (Relaxed)	0.9	1	7		10km Radius	48	Sum	149	0.418		0.409		1.000	1.000	1.898	
5	0.1 (Relaxed)	0.9	2	13		Wind Onshore	1	Value	149	0.435	2	0.403		0.966	1.035	2.035	
5	0.1 (Relaxed)	0.9	3	22		UV Index	26	Max	149	0.451	2	0.398	1.800	0.848	1.180	6.790	(10





Environment Agency

Issues we have when assessing our results

- Low values of r^2 (typically 0.2 – 0.4).
- Low numbers of "dirty" samples to build models, and no validation data.
- Bias in sampling time and/or tidal time.
- Variability in samples taken close together in time and space.
- Accuracy of weather forecast.

Forward look

- Further data analysis looking at non-linear relationships, data transformations, significant outliers, high leverage points, and highly influential points, censored results, diagnostics.
- Further acquisition of river flow and met data.
- Produce scientific papers for Water Research journal.
- Apply the methodology to a shellfish water (e.g. the Fal) to test the feasibility for a wider project.

Questions