EA - Anglian BOX 11

Monitoring of the River Burn upstream and downstream of Burnham Market sewage treatment works 1999

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1 Introduction

An investigation into the impact of effluent from Burnham Market sewage treatment works on water quality in the River Burn was undertaken during May and August 1999. This was instigated following concerns that were raised with the Agency. Continuous monitoring of the River Burn was undertaken during May and August at two sites on the River Burn, upstream and downstream of Burnham Market sewage treatment works. Routine Environment Agency monitoring of the river has not indicated any problems but it was felt worthwhile to carry out a programme of intensive continuous monitoring during May and August to confirm this.

2 Background

The River Burn, located in North Norfolk, rises at Leicester Square Farm (South Creake parish) and flows northwards where it enters the sea near Burnham Overy. The river's flow principally consists of ground water baseflow from the Norfolk chalk. Water quality in the Burn from the upper reaches to Roys Mill is good and was graded as GQA B in 1998. The water quality target for the river is RE2 from Long Plantation to North Creak and RE1 from North Creake to Burnham Overy Mill.

Burnham Market sewage treatment works, owned and operated by Anglian Water Services Limited, is the only significant (greater than 5 cubic metres per day) consented discharge to the river. It discharges into the lower reaches of the river, upstream of Roys Mill. The STW has a Consent to Discharge with limits, which are designed to protect the receiving watercourse. The consent limits are summarised in the below table.

Table 2.1 Consent limits of Burnham Market sewage treatment works

Parameter	Limit	units
Dry Weather flow	780	m^3/day
Suspended solids	40	mg/l SS
Biochemical oxygen demand	25	mg/l O
Ammonia	10	mg/l N

The sewage treatment works has been fully compliant with these standards for 7.5 years. The Consent to Discharge also permits the discharge of settled storm sewage to be made. However, this can only be made when the storm tanks are full and flow can only be diverted to these tanks when the flow into the treatment works is greater than three times the dry weather flow. A maximum limit for suspended solids of 200 mg/l applies to this discharge. The Environment Agency samples the final effluent from the sewage treatment works on a regular basis.

During 1995 and early in 1999 there were problems with infiltration of the sewerage system in South Creake, in the upper Burn, which caused flooding of properties and some sewage overflows into the river. During the 1999 incident Anglian Water Services undertook tankering to resolve the immediate problem and it is believed that there were no overflows to the river. Anglian Water Services are now investigating and implementing a long-term solution.

3. Monitoring programme

YSI multiparameter water quality monitors (sondes) (model type 6920) were deployed at two sites, detailed below. Measurements were taken every 15 minutes for ammonium (NH_4^+) dissolved oxygen, pH, Conductivity (mS), and Nitrate (NO_3). The monitors were deployed from 6th May until 3rd June and again from 4th August to the 2nd September. The monitors were calibrated every 14 days or so. Spot water samples were also taken when the sondes were deployed which were then analysed at the Environment Agency's laboratory for comparison with the sonde readings.

The monitors were deployed at the following two locations

Monitoring Point 1
Burnham Thorpe Bridge **Grid Ref: TF 8510 4175**

The YSI water quality monitor was suspended off the bridge into the river. At this site the river is approximately 1.5 metres wide and has a medium to fast flow and is less than 50cm in depth.

This point is approximately 750 metres upstream of Burnham Market Sewage treatment works outfall and was the closest location to the outfall where a water quality monitor could be deployed securely.

Monitoring Point 2
Mill Farm Bridge, Burnham Overy **Grid Ref: TF 8430 4170**

The water quality monitor was suspended off a small metal bridge in to the river. The river is approximately 3.5 metres wide with a medium flow at this point. The depth is approximately 1 metre. This point is about 100 metres downstream of Burnham Market Sewage treatment works outfall.

4 Results

The calibration records (Appendix 1) show that for all parameters there was minimal drift from calibration standards and that the probes calibrated successfully. Good correlation between the spot water samples and the sonde readings (Appendix 1) were also obtained with the percentage difference substantially less than 10% for the majority of samples. There was a large difference on the 4/8/99 at the upstream site between the conductivity reading from the sonde and the spot sample, 34%. The conductivity probe calibrated successfully and so the reason for the low sonde reading is not known. Readings from the probe stayed low for the about half the recording period after which they increased to normal levels. The probe calibrated successfully on the next occasion and recorded successfully on the next occasion. There was also a large difference between the spot and sonde nitrate values on the same occasion. The reason for this is not known. However, at the end of the recording period, 18/8/99, the probe was checked against the calibration standard and gave a reading very close to the calibration standard.

The ammonium measurements taken by the sondes have been treated with caution. This is because the probe is designed to measure in water with higher ammonium concentrations (range 1 to 100mg/l N) than found in the River Burn (0.1 to 0.25 mg/l N). Therefore, it overestimates the ammonium concentration in the River Burn. However, whilst the absolute values are overestimated the probes are still able to detect differences in concentrations and trends such as diurnal variation. Therefore, the data obtained from the ammonium probes is still considered in this report for the purposes of comparison of upstream and downstream quality.

Figures 4.1 to 4.5 show the mean dissolved oxygen, ammonium, nitrate, conductivity and pH upstream and downstream of the sewage treatment works from both monitoring periods. This data is also presented in tabular format in Appendix 2. Plots of the raw data are shown in Appendix 3.

Figure 4.1 Mean dissolved oxygen (% sat) upstream of STW in May and August and downstream in May and August

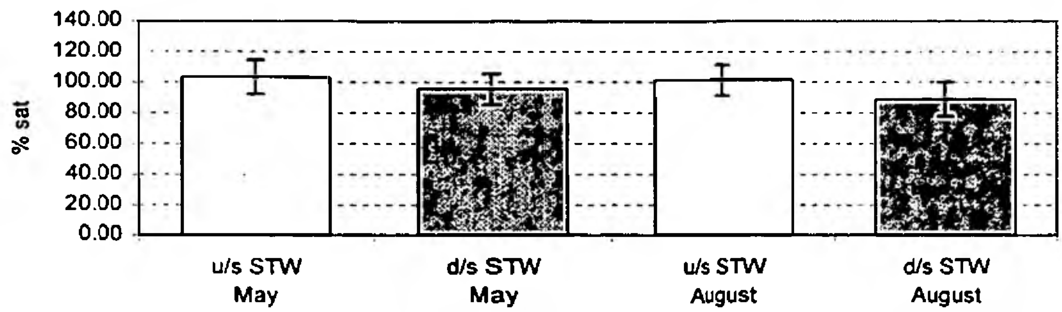


Figure 4.2 Mean ammonium concentration (+/- std deviation) upstream and downstream of Burnham Market STW in May and August (refer to text on page 3 to interpret these results)

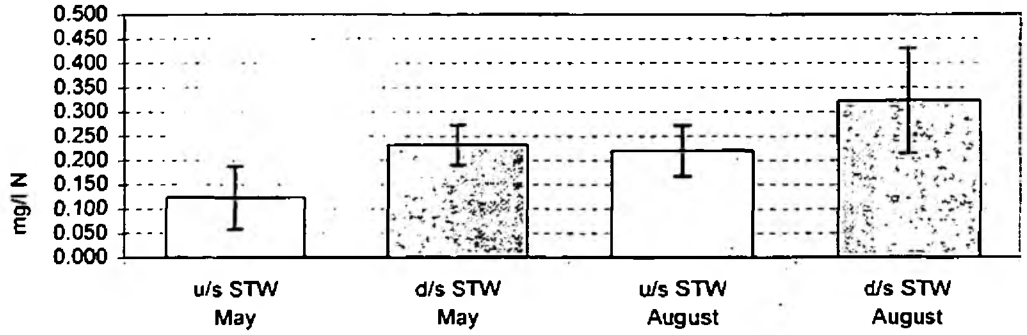


Figure 4.3 Mean nitrate concentration (+/- std deviation) upstream and downstream of Burnham Market STW in May and August

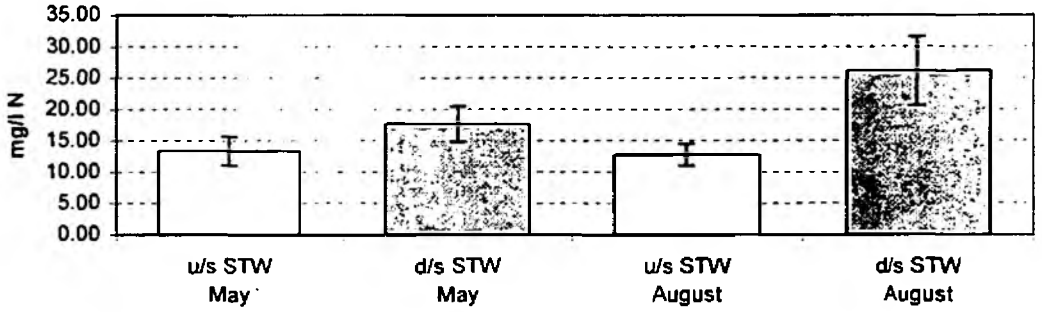


Figure 4.4 Mean conductivity (+/- std deviation) upstream and downstream of Burnham Market STW in May and August

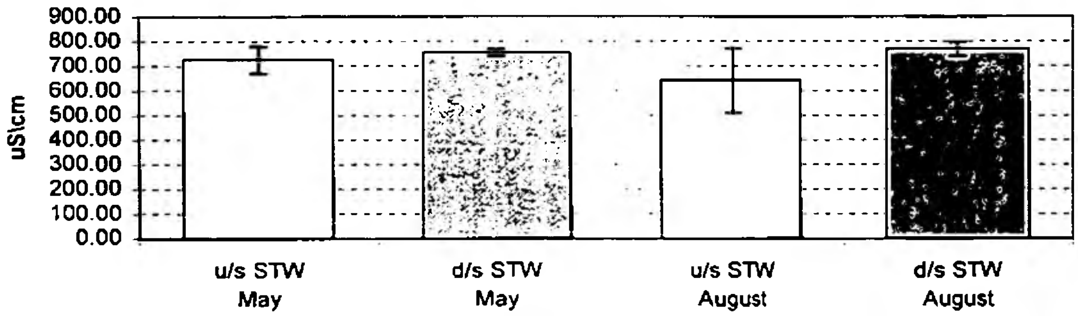
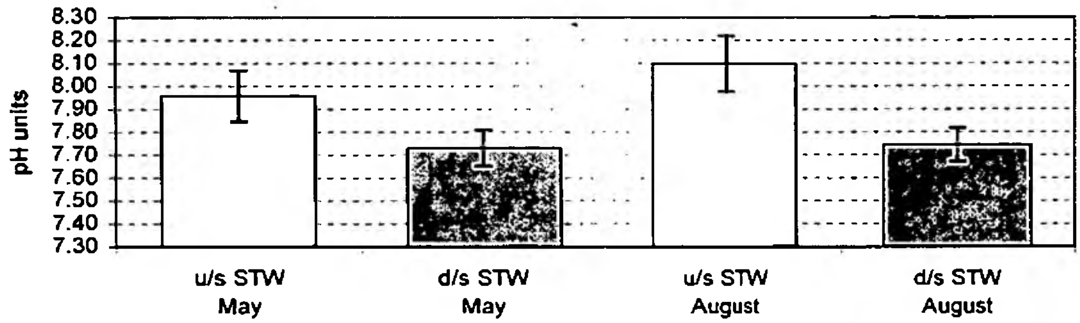


Figure 4.5 Mean pH (+/- std deviation) upstream and downstream of Burnham Market STW in May and August



For all parameters a difference in quality between the upstream and downstream sites was observed. Dissolved oxygen levels were very good at both sites with mean levels greater than 80% saturation during both monitoring periods. Dissolved oxygen concentrations were lower downstream of the sewage treatment works during both monitoring periods and, in August, were lower at both monitoring sites

From May to August ammonium concentrations increased at both the upstream and downstream sites. As would be expected there was also an increase in ammonium concentration downstream of the sewage treatment works during both monitoring periods, although there was a relatively bigger increase from the upstream to the downstream site in May.

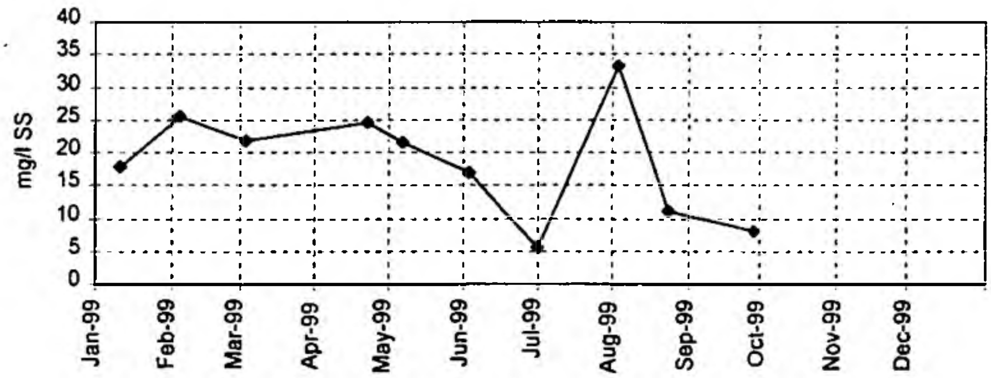
The nitrate concentrations measured at the upstream site were the same in both May and August. There is an increase in the nitrate concentration downstream of the sewage treatment works during both May and August. The relative increase in August is larger than that seen in May.

Conductivity increases downstream of the sewage treatment works during both May and August. However, at the upstream site in August a lower mean conductivity was measured than in May. However, there was high variability as can be seen from the large standard deviation. This is probably due to a problem with the probe although this was not obvious at the time it calibrated satisfactorily. pH is lower downstream of the sewage treatment works. Mean pH at the upstream site increased from May to August.

Quality of sewage treatment works effluent

Figures 4.6, 4.7 and 4.8 show the quality of Burnham Market sewage treatment works

Figure 4.6 Suspended solids concentrations of Burnham Market sewage treatment works final effluent. Consent limit = 40 mg/l SS



effluent during 1999.

Figure 4.7 Biochemical Oxygen Demand of Burnham Market sewage treatment works final effluent during 1999. Consent limit = 25 mg/l O

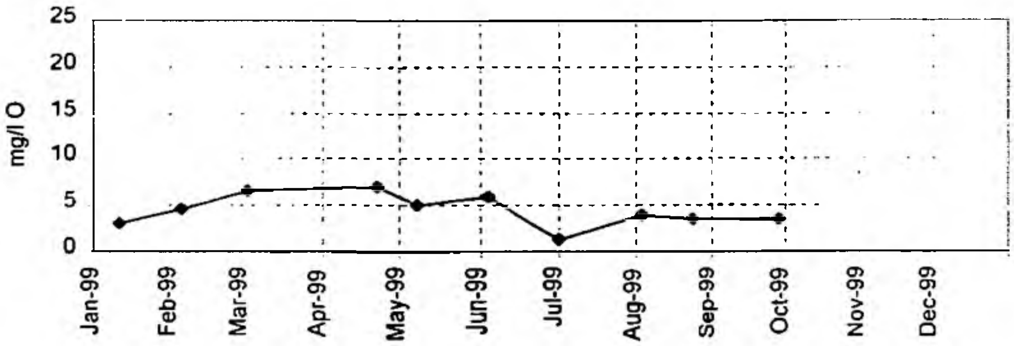
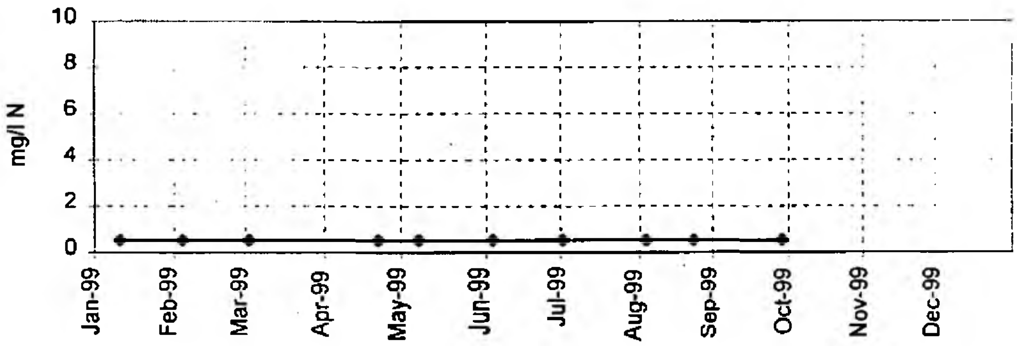


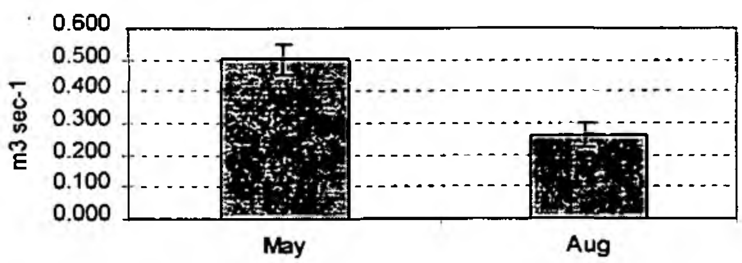
Figure 4.8 Ammonia concentration of Burnham Market sewage treatment works final effluent during 1999. Consent limit = 10 mg/l N



River Flows

Figure 3.9, below shows the average daily river flow during May and August as measured at the gauging station at Burnham Market. River flows during May were about twice those measured during August.

Figure 4.9 River Burn average daily river flow over the two monitoring periods in 1999.

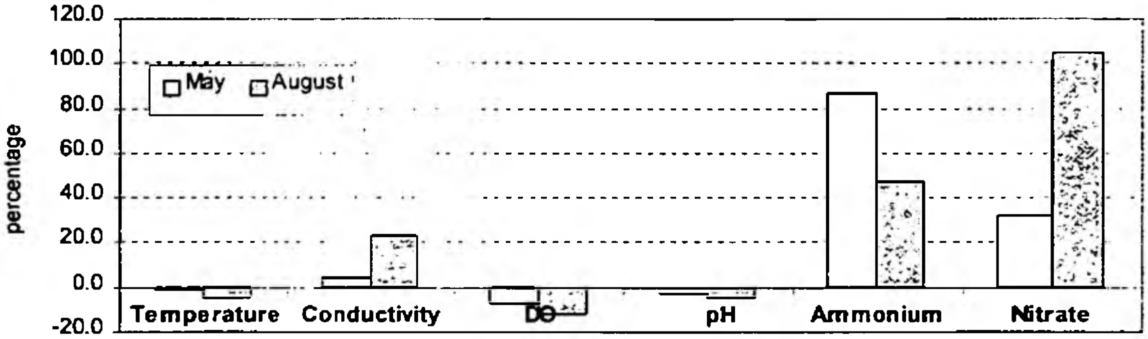


5 Discussion

Is there a difference between upstream and downstream water quality?

The monitoring exercise has shown that there is a visible difference between the water quality upstream and downstream of Burnham Market sewage treatment works during both monitoring periods. Statistical tests confirm that this is a significant difference, details are given in Appendix 4. Figure 5.1 shows the percentage change in quality for each determinand during both monitoring periods.

Figure 5.1 Percentage change in water quality downstream of Burnham Market STW compared to upstream quality



For all parameters, except ammonium, a higher percentage change was seen downstream during the August monitoring period. This is probably a reflection of the reduced dilution capacity in the river and increased water temperature in August.

Although ammonium concentrations are higher downstream of the sewage treatment works during both monitoring periods, the percentage change in August is approximately half that measured in May even though the dilution capacity of the river is substantially lower in August. This may be due to less ammonium being discharged from the sewage treatment works during the warmer weather in August. Unfortunately, this cannot be corroborated by the analysis results of the sewage treatment works as all results in 1999 have been at or less than the limit of detection.

Nitrate concentrations in the river downstream show a very large percentage change in August. Nitrate concentrations are very similar at the upstream site during both May and August. This would suggest that the increased nitrate concentration downstream of the sewage treatment works is due to the sewage treatment works discharging into the river during a period of reduced dilution.

Is the quality downstream of the sewage treatment works acceptable (even if it is worse than u/s)?

Whilst a difference in the water quality downstream of the sewage treatment works has been measured during this monitoring exercise, it is important to note that the quality of the downstream stretch is still very good. This can be seen by comparing the dissolved oxygen measurements made during both monitoring periods to the River Ecosystem target, which in the Lower River Burn is RE1.

For the majority of the time dissolved oxygen concentrations exceed the RE target. There are marginal failures downstream of the sewage treatment works during August. However, it is at this time of year that we would expect oxygen concentrations fluctuate more and, hence, to reach their lowest levels. This is due to warmer water temperatures, increased biological activity and reduced river flows. Dissolved oxygen levels are still sufficiently high that it would not be expected that they would have an effect on the river ecology.

6 Summary

The monitoring exercise has shown that there is, as would be expected downstream of a significant sewage treatment works final effluent, a difference in the water quality measured upstream and downstream.

For some parameters a bigger difference downstream was measured in August due to reduced river flows and hence effluent dilution.

However, even though there is a difference in the water quality downstream of the sewage treatment works, the water quality downstream of the sewage treatment works is still very good and does not give any cause for concern.

For the majority of the time the river is compliant with its water quality targets.

Continuous monitoring did not reveal any pollution events in the catchment.

APPENDIX 1

Calibration record of YSI sondes used during the River Burn monitoring 1999 and a comparison of spot samples and YSI sonde readings.

The readings of all probes in their respective calibration standard are recorded prior to the calibration procedure being carried out to provide an indication of potential probe faults and a record of the probes accuracy and drift over the measuring period. Unless indicated, all probes were successfully calibrated.

Sonde 1

		Observed readings in standard solutions prior to calibration					
		May				August	
Calibration Date	**Calibration standards**	**06/05/99**	**13/05/99**	**27/05/99**		**03/08/99**	**18/08/99**
Calibrator Initials		DJC	DJC	DJC		DJC	DJC
Dissolved oxgyen % saturation	100	105	102.4	101.2		will not calibrate	104.6
Conductivity us/cm	1000	971	999	1012		1114	907
Std 1 pH	7	7.17	7.08	7.05		7.1	7.08
Std 2 pH	10	9.9	9.97	9.95		10.02	9.91
Std 1 NH4-N mg/l	1	0.908	1.25	0.78		1.015	1.071
Std 2 NH4-N mg/l	100	97.7	71.48	150		90.8	102.7
Std 1 NO3-N mg/l	1	1.5	2.45	0.9		0.998	1.158
Std 2 NO3-N mg/l	100	92.9	70	73.81		65	92.54

Sonde 2

		Observed readings in standard solutions prior to calibration					
		May				August	
Calibration Date	**Calibration standards**	**06/05/99**	**13/05/99**	**27/05/99**		**03/08/99**	**18/08/99**
Calibrator Initials		DJC	DJC	DJC		DJC	DJC
Dissolved oxgyen % saturation	100	100%	99.50%	102.70%		100.7	103.6
Conductivity us/cm	1000	959	1001	1043		1010	986
Std 1 pH	7	7.19	7.03	7.11		6.8	7.09
Std 2 pH	10	9.86	9.96	9.92		9.92	10.02

Sonde 2		Observed readings in standard solutions prior to calibration					
		May				August	
Calibration Date	Calibration standards	06/05/99	13/05/99	27/05/99		03/08/99	18/08/99
Calibrator Initials		DJC	DJC	DJC		DJC	DJC
Std 1 NH4-N mg/l	1	1.026	1.085	0.851		0.9	0.972
Std 2 NH4-N mg/l	100	135	87.57	136		90.83	114.7
Std 1 NO3-N mg/l	1	1.9	1.75	1.25		1.38	1.76
Std 2 NO3-N mg/l	100	79.3	90.64	80.97		45	102.6

Comparison of spot samples and YSI sonde readings

	Site	Date	Time	Temperature °C	Conductivity uS/cm	Dissolved oxygen % sat	pH	Ammonium* mg/l N	Nitrate mg/l N
spot	downstream	12/05/99	12:50	12.9	738	102	7.7	0.05	nd
YSI sonde	downstream	12/05/99	14:01	12.98	756	105.5	7.79	0.306	13.98
% difference of YSI sonde compared to spot reading				-0.6	-2.4	-3.4	-1.2	-	-
spot	upstream	04/08/99	13:57	19	729	124	8.2	<0.03	11.3
YSI sonde	upstream	04/08/99	14:01	19.13	481	116.6	8.19	0.238	7.87
% difference of YSI sonde compared to spot reading				-0.7	34	5.9	0.1	-	30
spot	downstream	04/08/99	15:13	17	762	122	7.9	0.04	12.7
YSI sonde	downstream	04/08/99	15:16	16.73	756	120.4	7.7	0.385	11.88
% difference of YSI sonde compared to spot reading				1.6	0.79	1.3	2.5	-	6.5
spot	upstream	18/08/99	14:15	15.2	734	99	8.1	<0.03	11.8
YSI sonde	upstream	18/08/99	15:16	15.03	680	106.9	8.5	0.219	10.65
% difference of YSI sonde compared to spot reading				1.1	7.3	-8.0	-4.9	-	9.7
Spot	downstream	18/08/99	13:50	14.4	774	96.8	7.65	0.058	13.3
YSI sonde	downstream	18/08/99	13:46	14.07	788	105.2	7.9	0.378	15.23
% difference of YSI sonde compared to spot reading				2.3	-1.8	-8.7	-3.2	-	-14.5

*Spot readings are as Total ammonia mg/l N, Sonde readings are as ammonium mg/l N. Data should not be directly compared.

APPENDIX 2

Summary results of May and August monitoring for all determinands

APPENDIX 2

Table 1 Summary results of May monitoring

	Temperature °C	Conductivity uS/cm	Dissolved oxygen % sat	pH	Ammonium mg/l N	Nitrate mg/l N
Upstream (Monitoring point 1)						
Number of results	2573	2573	2573	2573	2573	2573
Mean	12.39	725.81	103.51	7.96	0.124	13.36
Standard deviation	1.89	54.48	11.13	0.11	0.065	2.26
Variance	3.57	2968.21	123.80	0.01	0.004	5.12
Maximum	18.22	763	128.1	8.17	0.73	18.92
Minimum	9.4	325	79.3	7.62	0.07	7.8
Downstream (Monitoring point 2)						
Number of results	2570	2570	2570	2570	2570	2570
Mean	12.20	754.85	95.67	7.73	0.232	17.70
Standard deviation	1.56	14.84	10.13	0.08	0.041	2.82
Variance	2.44	220.19	102.63	0.01	0.002	7.93
Maximum	16.92	774	121.4	7.94	0.86	26.13
Minimum	9.61	674	78.8	7.54	0.162	12.81
% change downstream quality compared to upstream quality	[illegible]	3.8	-7.6	-2.9	87	32

APPENDIX 2 (cont)

Table 2 Summary results of August monitoring

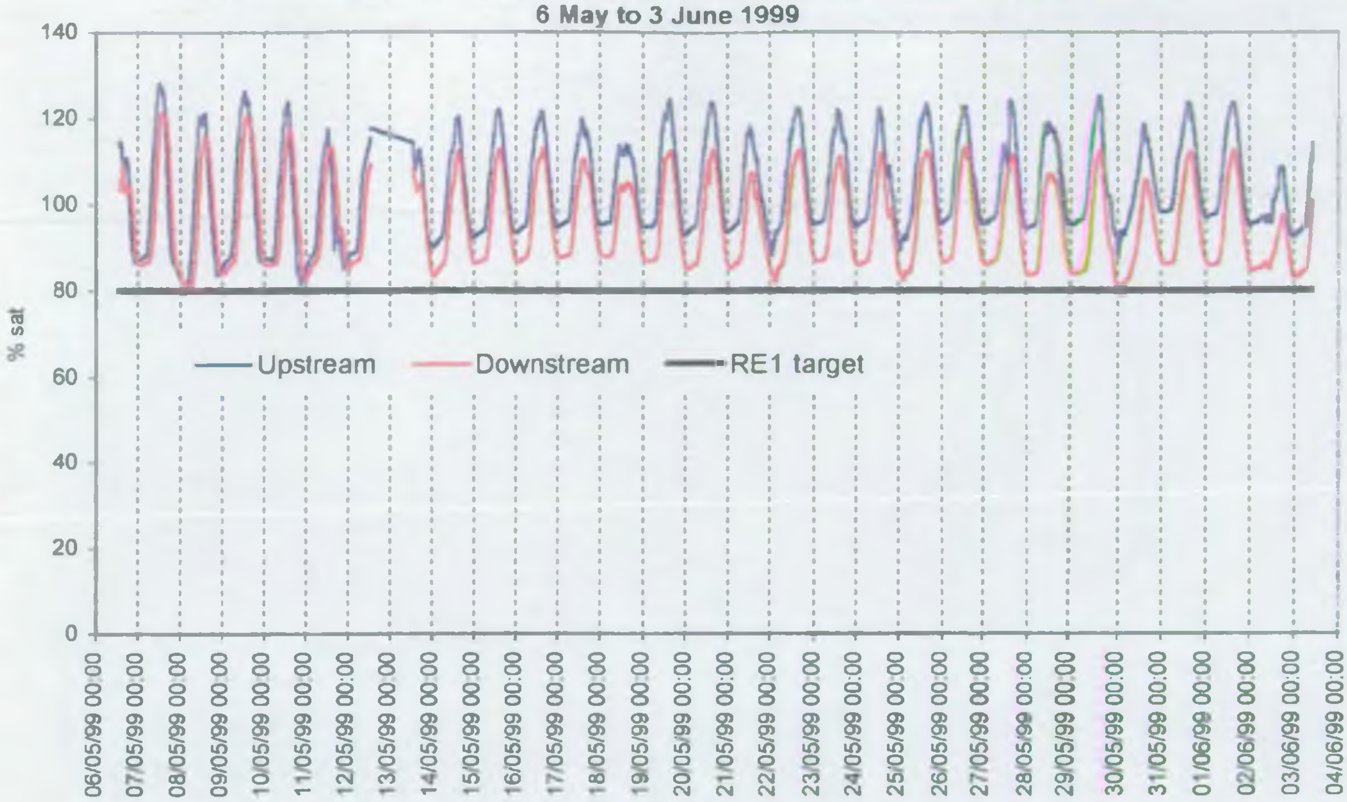
	Temperature °C	Conductivity uS/cm	Dissolved oxygen %sat	pH	Ammonium mg/l N	Nitrate mg/l N
Upstream (Monitoring point 1)						
Number of results	2757	2757	2757	2757	2757	2757
Mean	14.40	643	101.6	8.10	0.220	12.761
Standard deviation	1.84	129.79	10.0	0.12	0.052	1.726
Variance	3.37	16844.27	99.96	0.01	0.00	2.98
Maximum	20.64	824	129.9	8.37	0.5	14.0
Minimum	9.6	329	76.4	7.72	0.161	10.5
Downstream (Monitoring point 2)						
Number of results	2628	2628	2628	2628	2628	2628
Mean	13.7	769	89.1	7.75	0.323	26.125
Standard deviation	1.3	28.09	11.2	0.07	0.108	5.511
Variance	1.6	788.84	125.5	0.01	0.012	30.372
Maximum	17.59	818	123.6	7.94	1.065	40.62
Minimum	10.14	473	64.9	7.57	0.162	11.88
% change in quality downstream compared to upstream quality		23	-12	-4.3	47	105

APPENDIX 3

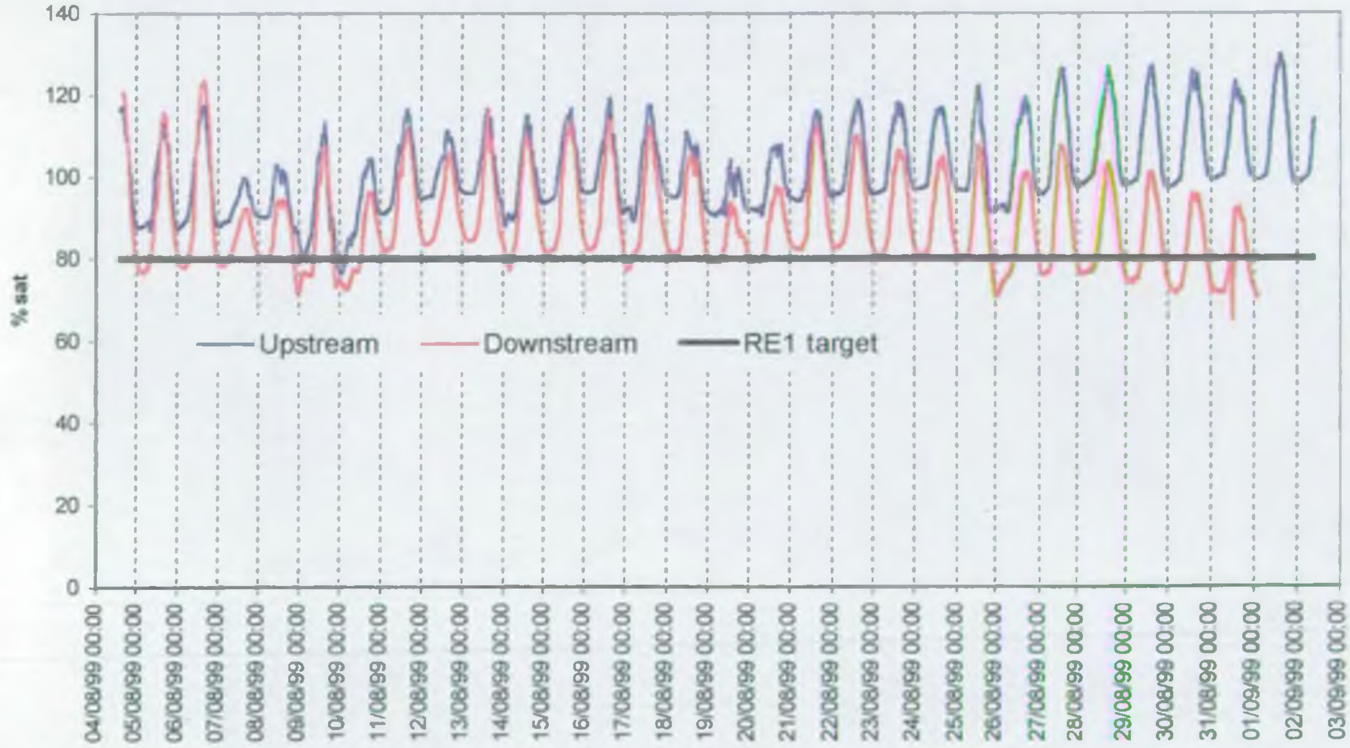
Plots of raw data

Dissolved oxygen
Ammonium
Nitrate
Conductivity
pH

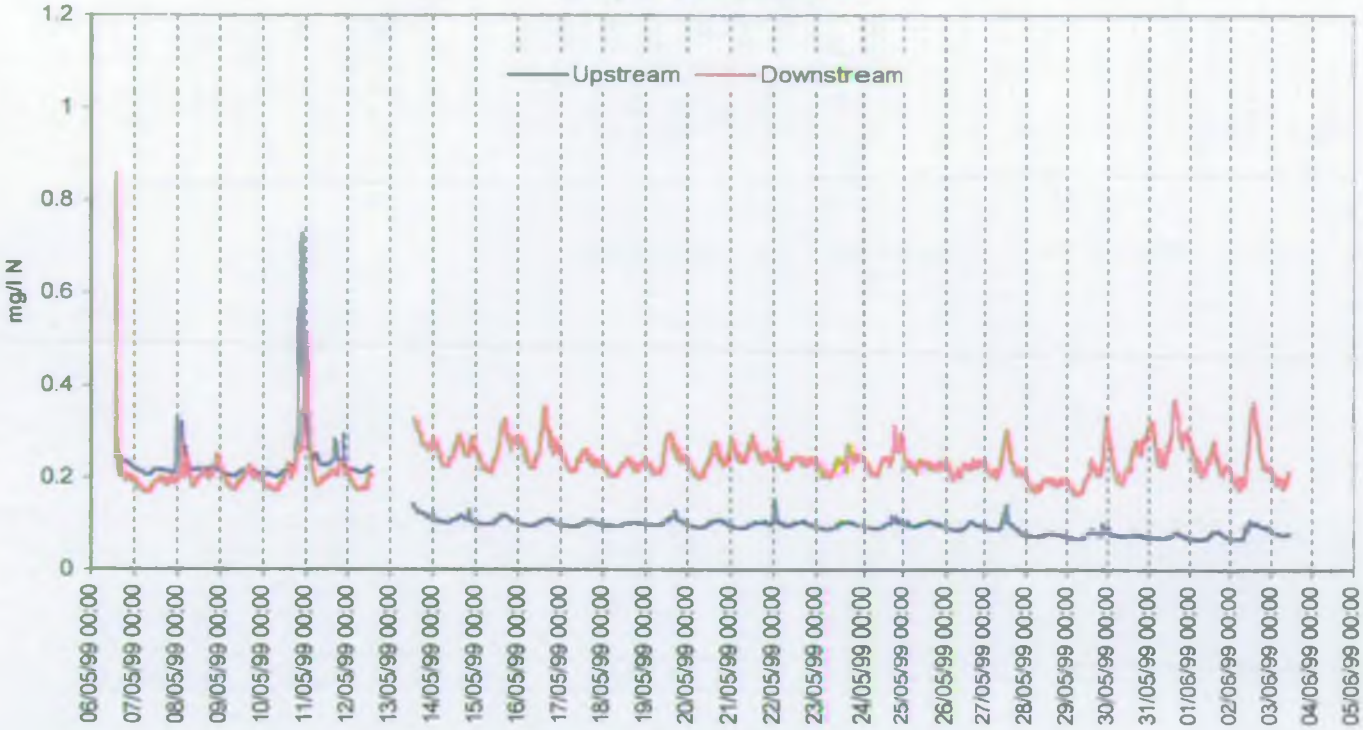
Dissolved oxygen (%sat) upstream and downstream of Burnham Market STW
6 May to 3 June 1999



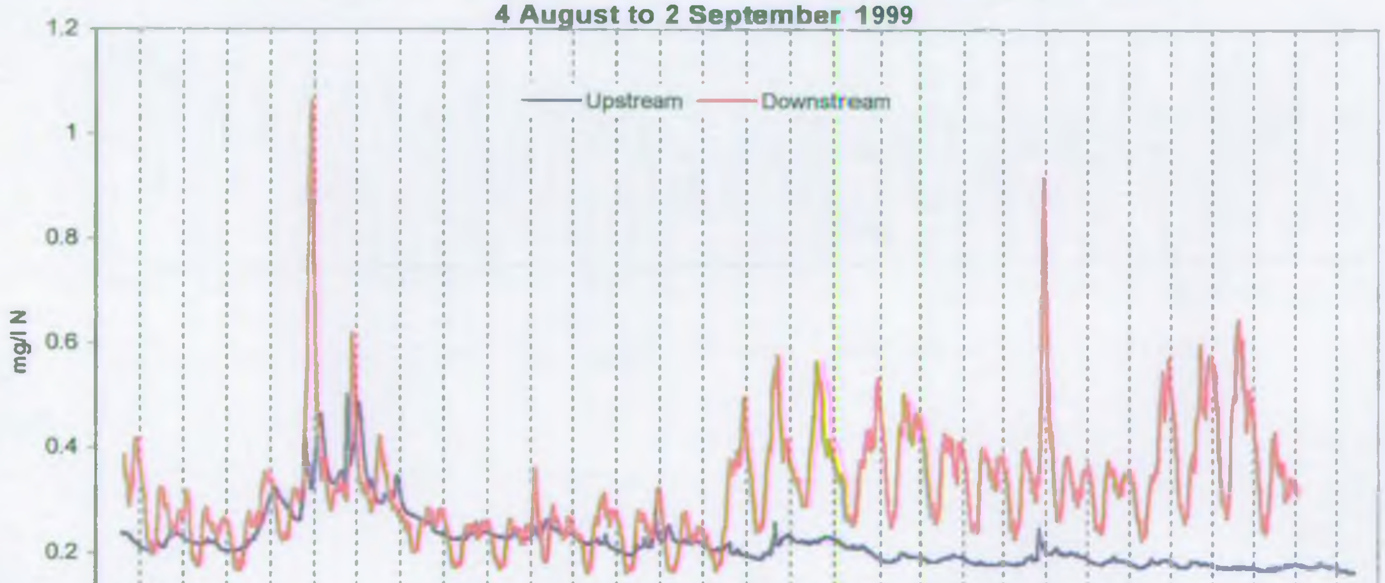
Dissolved oxygen (%sat) upstream and downstream of Burnham Market STW
4 August to 2 September 1999

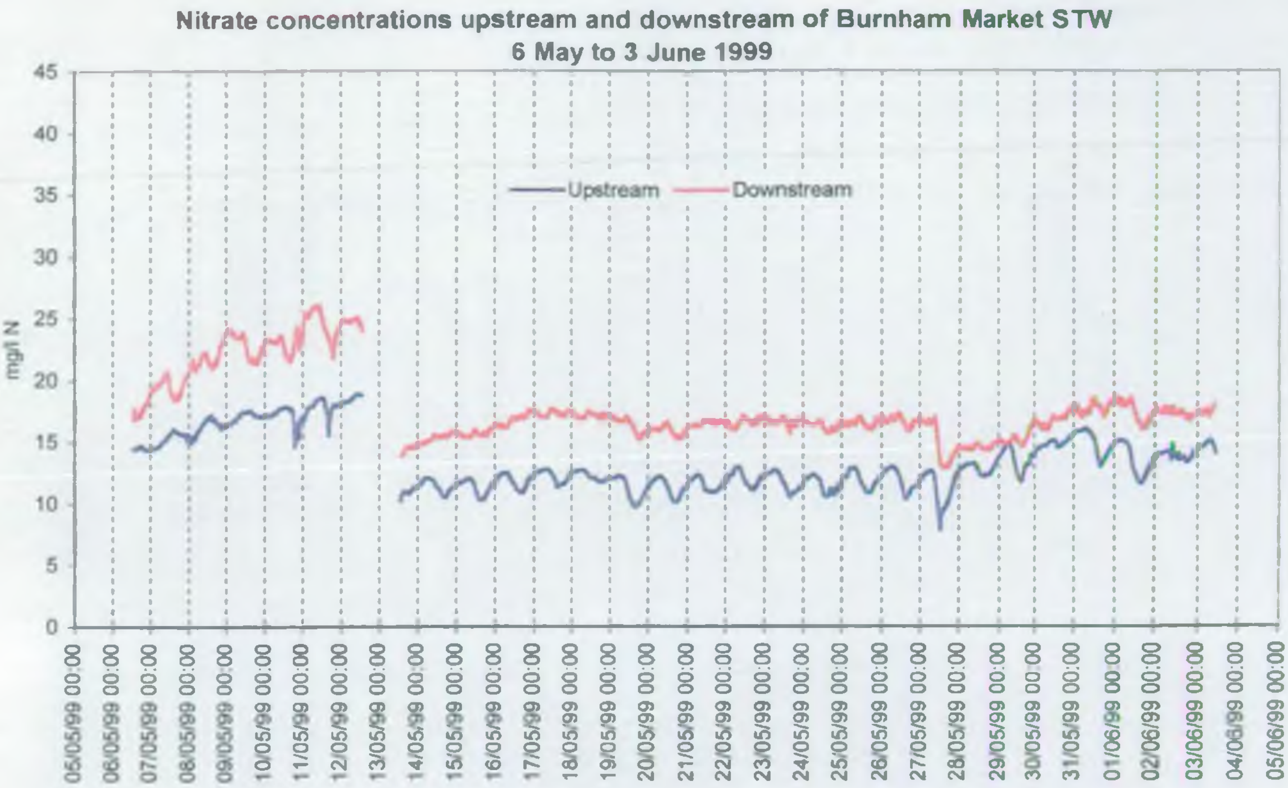


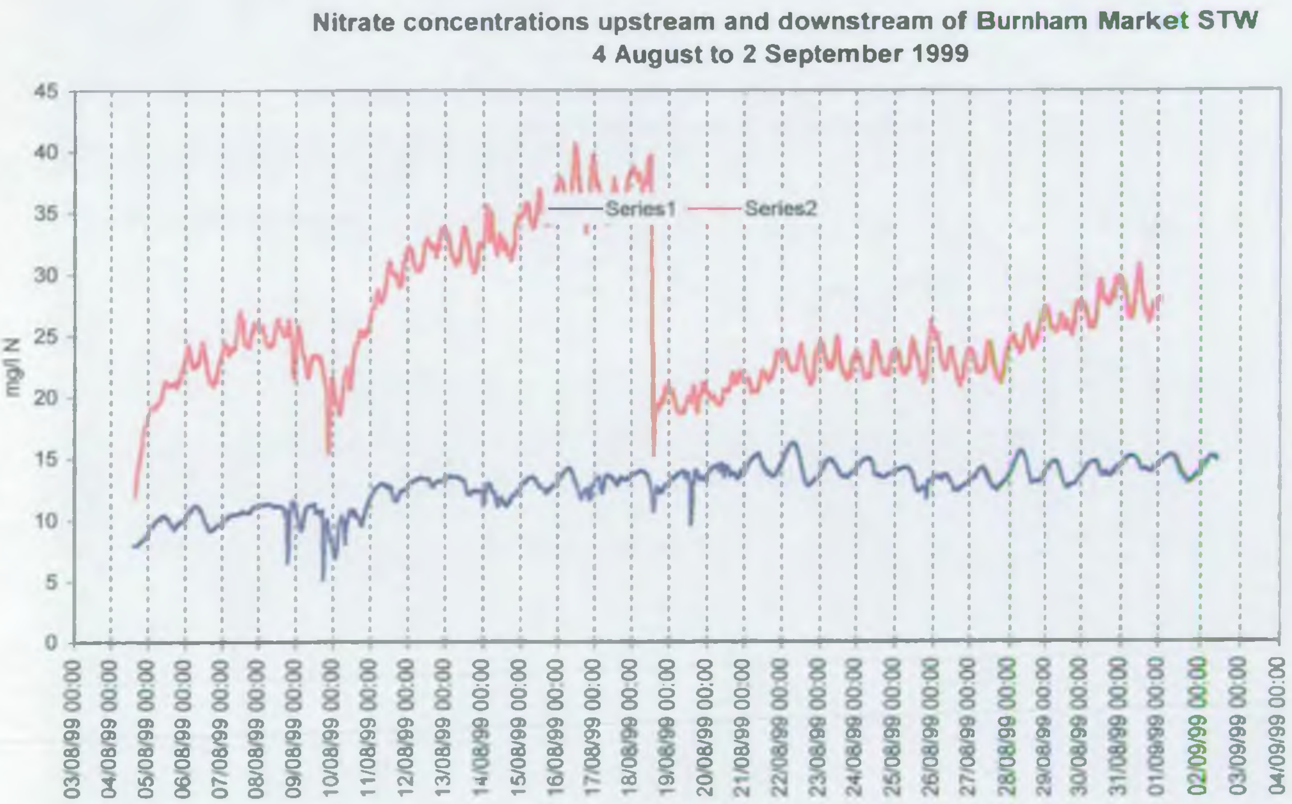
Ammonium concentration (NH_4-N) upstream and downstream of Burnham Market STW
6 May to 3 June 1999



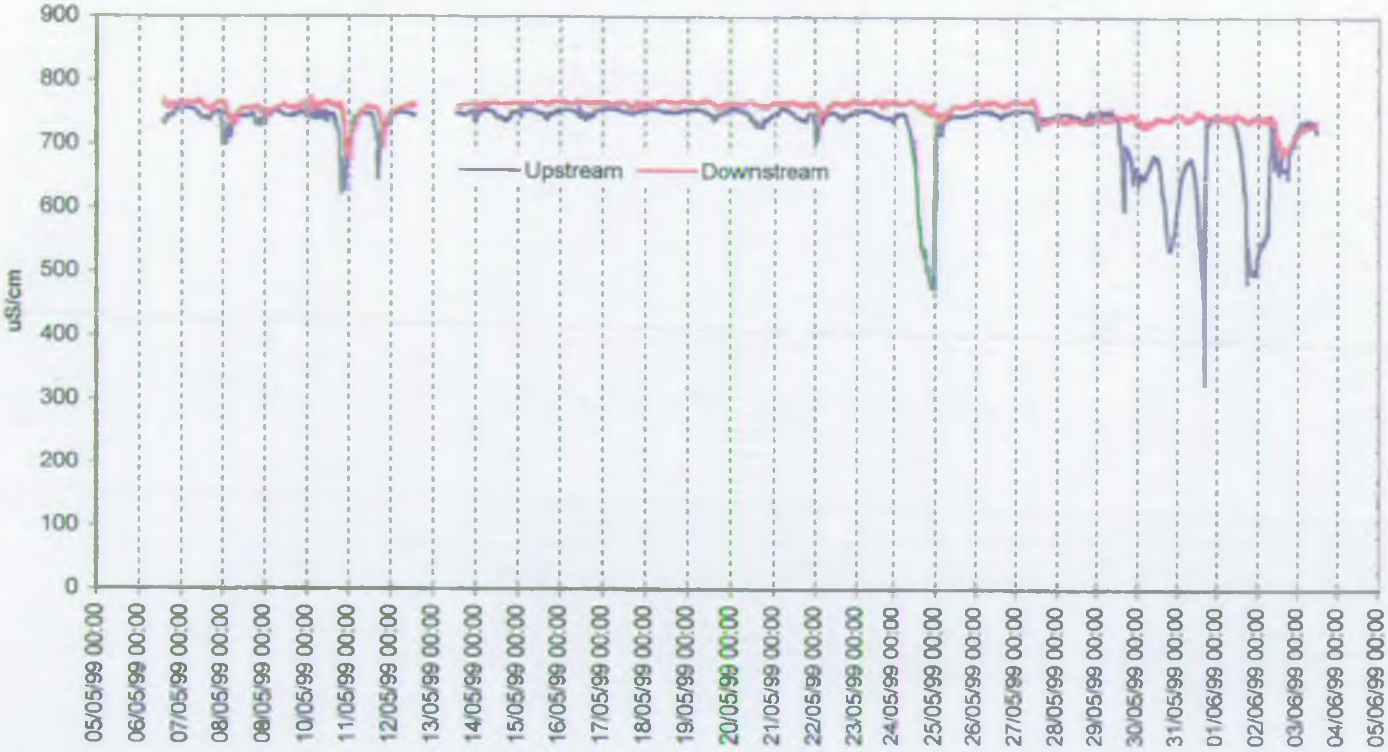
Ammonium (NH_4-N) upstream and downstream of Burnham Market STW
4 August to 2 September 1999



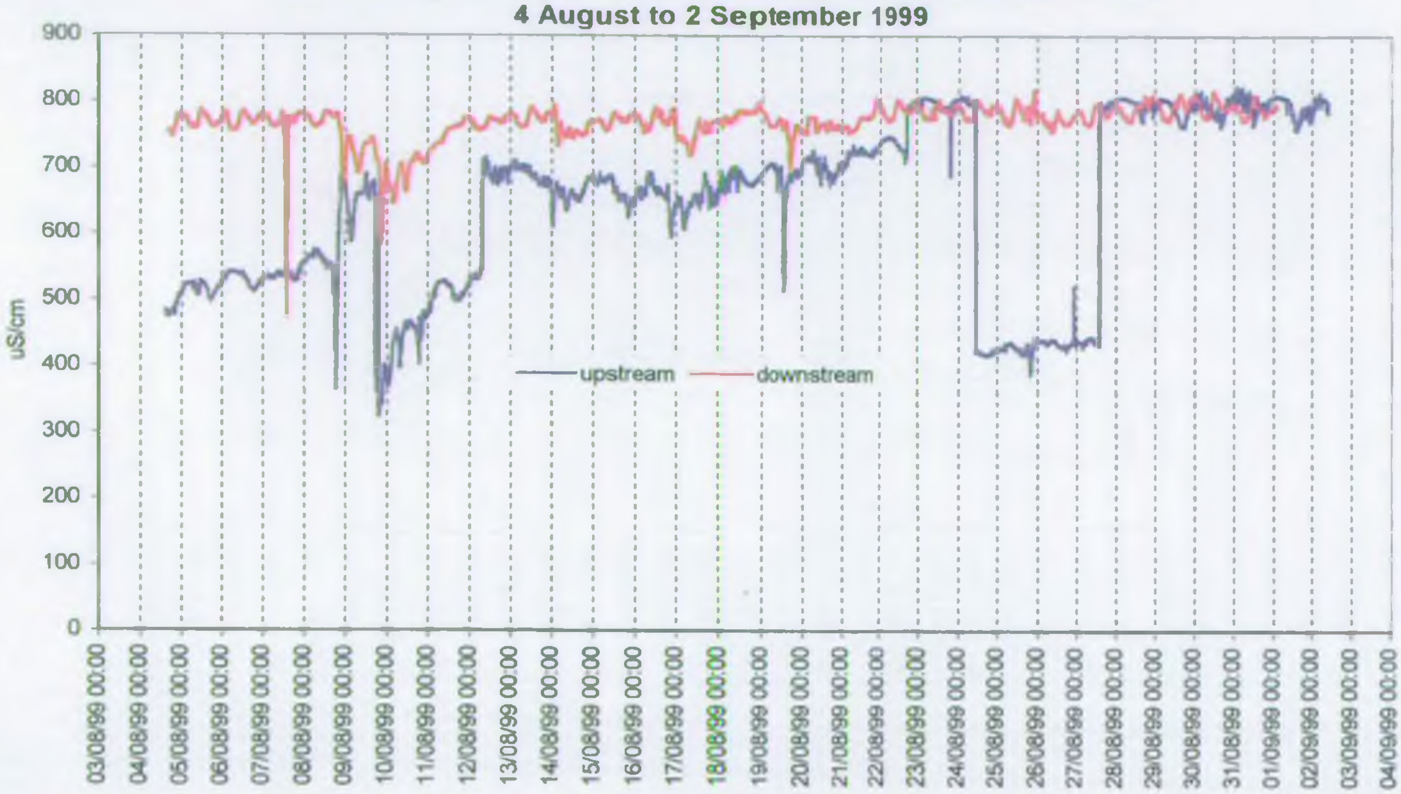

Nitrate concentrations upstream and downstream of Burnham Market STW
6 May to 3 June 1999
Upstream
Downstream
mg/l N


Nitrate concentrations upstream and downstream of Burnham Market STW
4 August to 2 September 1999
Series1
Series2
mg/l N

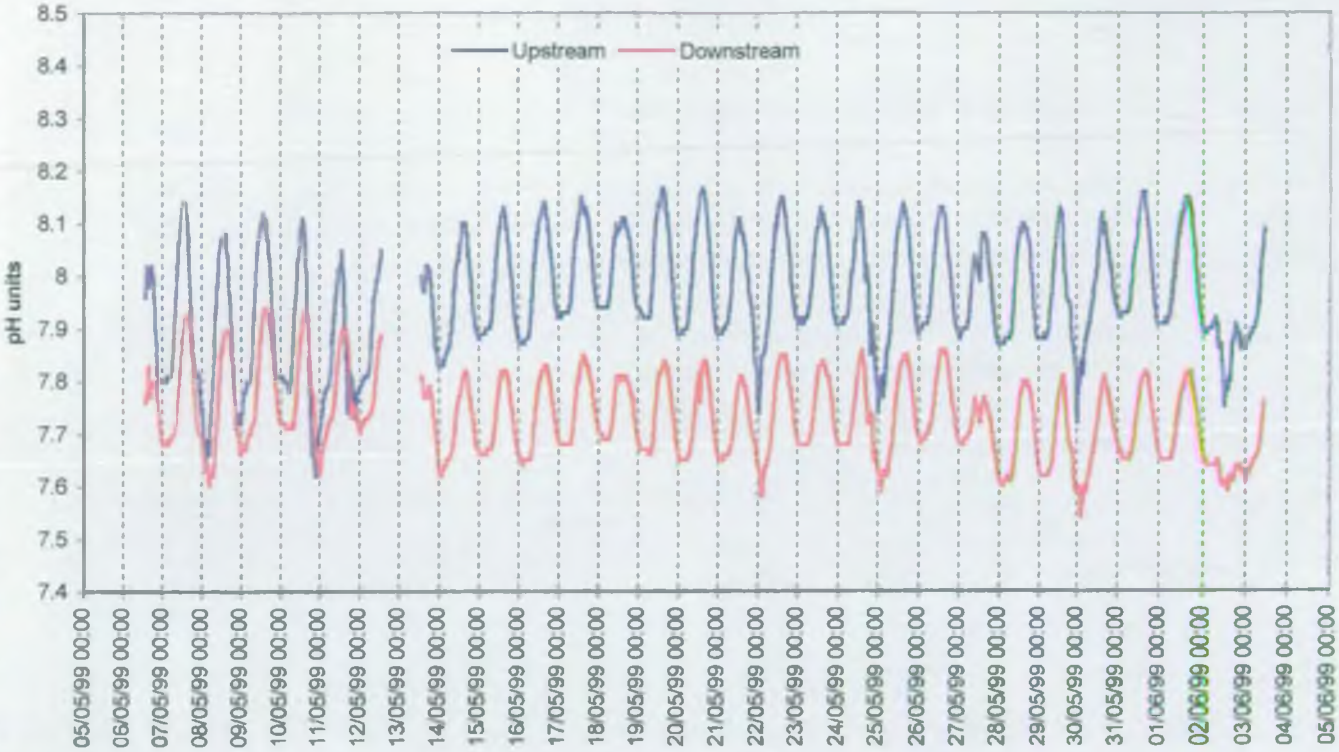
Conductivity upstream and downstream of Burnham Market STW
6 May to 3 June 1999



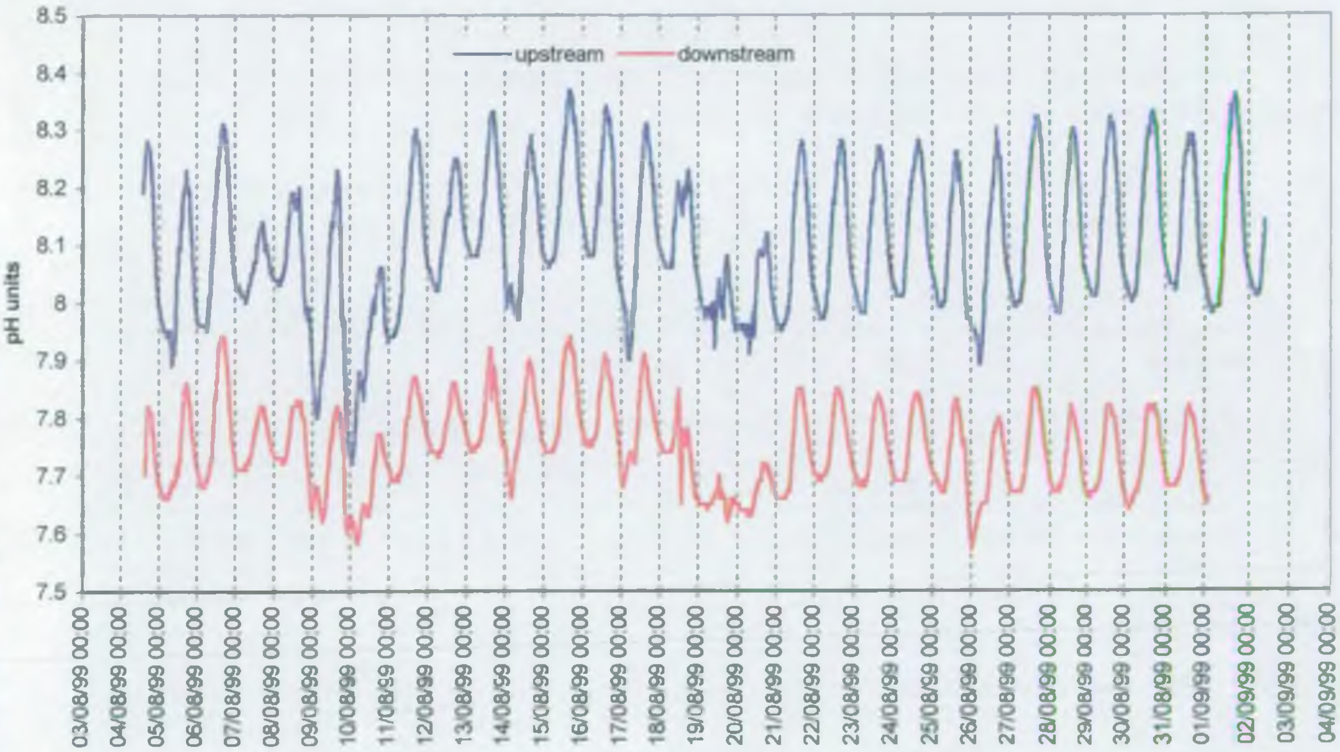
Conductivity upstream and downstream of Burnham Market STW
4 August to 2 September 1999



pH upstream and downstream of Burnham Market STW
6 May to 3 June 1999



pH upstream and downstream of Burnham Market STW
4 August to 2 September 1999



APPENDIX 4

Statistical tests on upstream and downstream data

A z-test was deemed the most suitable statistic to use to test if there was a significant difference between the results of the upstream and downstream sites during both monitoring periods. The outcomes of the tests are shown below.

Table 1 Results of a z test to determine if there is a significant difference between upstream and downstream water quality

Null hypothesis: There is no difference between upstream and downstream sample points

	May			August		
	Dissolved oxygen	Ammonium	Conductivity	Dissolved oxygen	Ammonium	Conductivity
z test result	26.4	-70.7	-26.1	43.2	-27.3	-49.9
Verdict	Reject null hypothesis (P=0.01)	Reject null hypothesis (P=0.01)	Reject null hypothesis (P=0.01)	Reject null hypothesis (P=0.01)	Reject null hypothesis (P=0.01)	Reject null hypothesis (P=0.01)

For all determinands the null hypothesis was rejected which means that there is a significant difference between the upstream and downstream water quality for the above determinands during both May and August.

A z-test was also undertaken to determine if there was a significant difference between the results obtained in May and August at each site.

Table 2 Results of a z test to determine if there is a significant difference between the results obtained in the two monitoring periods at each site

Null hypothesis: There is no difference between the monitoring results obtained in the two monitoring periods at each site

	Upstream (Monitoring point 1)			Downstream (Monitoring point 2)		
	DO	Ammonium	Conductivity	DO	Ammonium	Conductivity
z test	Reject null hypothesis (p=0.05)	Reject null hypothesis (p=0.05)	Reject null hypothesis (p=0.01)	Reject null hypothesis (p=0.01)	Reject null hypothesis (p=0.01)	Reject null hypothesis (p=0.01)

This found that there was a significant difference between the results obtained in May and August.