HIGHWAYS AGENCY

ENVIRONMENT AGENCY

THE LONG TERM MONITORING OF POLLUTION FROM HIGHWAY RUNOFF

M4/BRINKWORTH BROOK - SITE REPORT

R&D Technical Report P2-038/TR2

THE LONG TERM MONITORING OF POLLUTION FROM HIGHWAY RUNOFF: FINAL REPORT M4/BRINKWORTH BROOK – SITE REPORT

R&D Technical Report P2-038/TR2

F Moy, R W Crabtree

Research Contractor:
WRc plc

Publishing Organisation
Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, BRISTOL, BS32 4UD.

Tel: 01454 624400 Fax: 01454 624409
Website: www.environment-agency.gov.uk

ISBN: 1 844 32209 2

Dissemination Status
Internal: Released to Regions
External: Publicly Available

Statement of Use
This site report is part of a long term study on road runoff (P2-038/TR1) that will assist in the development of guidance for inclusion in the Design Manual for Roads and Bridges and to inform Environment Agency policy on road runoff.

Research Contractor
This document was produced under R&D Project P2-038 by:
WRc, Frankland Road, Blagrove, Swindon, Wiltshire, SN5 8YF

Project Managers
Project P2-038 was a collaborative project between the Highways Agency and the Environment Agency.

The Highways Agency's Project Managers were:
Peter Wilson and Michael Whitehead, Heron House, Bedford Tel: 01234 796154

The Environment Agency's Project Manager was:
Alan Roe, Lower Trent Area, Trentside Office, Nottingham

Further copies of this report are available from:
Environment Agency R&D Dissemination Centre, c/o
WRc, Frankland Road, Swindon, Wilts SN5 8YF

tel: 01793-865000 fax: 01793-514562 e-mail: publications@wrcplc.co.uk

CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF PHOTOGRAPHS

1. INTRODUCTION

Highway surface runoff discharges may contain pollutants that have accumulated on the carriageway, particularly following periods of dry weather. These pollutants can then be transported via the surface water drainage system to discharge to ground or watercourses depending on the local geology. Various treatment facilities have been designed and incorporated into recent trunk road and motorway construction.

WRc plc was contracted to obtain information regarding the quantity and quality of highway surface water drainage and of the receiving waters at 6 sites incorporating 8 different drainage treatment facilities. These data have been archived in a database and used to evaluate the efficiency of the treatment facilities in removing the pollutants and to evaluate the effect of the run-off quality on the receiving water quality and its environmental impact.

The first monitoring site selected was on the M4 where discharge of the surface drainage, for a section of motorway to the west of junction 16, is to Brinkworth Brook, a tributary of the River Avon. This site was selected as a control site, where surface water drainage receives no treatment prior to discharge to the receiving water. Untrapped gullies discharge directly to open, unlined ditches on either side of the motorway embankment which in turn discharge directly to Brinkworth Brook.

This report relates to the Flow Measurement and Water Quality data collection programme implemented at the M4/Brinkworth Brook site.

Installation of the continuous monitoring equipment was completed on 17 December 1997. Two depth and velocity monitors were installed in Brinkworth Brook, upstream and downstream of the motorway drainage discharge point, a single depth and velocity monitor was installed in one of the motorway drainage ditches and a raingauge was installed within the catchment. Automatic water samplers and water quality sondes were deployed immediately prior to storm event sampling and monthly sampling where applicable.

Analysis of samples collected by WRc was carried out by WRc Analysis Laboratories at Medmenham, using approved subcontractors where appropriate.

I OBJECTIVES

1. to provide continuous measurement of rainfall and river flow throughout the monitoring period.

2. to provide liquid samples and in-situ measurements of the upstream and downstream watercourse monitoring points, taken at monthly intervals, under dry weather conditions.

3. to provide continuous measurement of flow and corresponding liquid samples of runoff for ten storm events.

4. to collect sediment sample at the beginning and conclusion of the monitoring period from the highway runoff ditch and the watercourse at the upstream and downstream monitoring points.

5. to carry out a biological surveys of the receiving watercourse on three occasions upstream and downstream of the point of discharge.

6. to create a database of flows, pollutant load, rainfall and site details obtained during the study.

II OBSERVATIONS

A total of 949.7 mm of precipitation was recorded during the survey period.

Ten storm events with a range of rainfall totals, intensities and antecedent dry periods were sampled throughout the 12 month monitoring period.

Monthly data, sediment sampling and the biological surveys were obtained as per the objectives of the project.

2. DETAILS OF SITES

The M4, London South Wales motorway, was constructed in 1969 with 3 lanes per carriageway. The section of motorway between Reading and Bristol has remained largely unaltered and much of the storm drainage systems remain as originally installed, although some local modifications have been made. One of the drainage arrangements installed is for surface run-off, generated by the camber of the carriageway, to collect in a formed concrete channel at the margin of the hard shoulder. The runoff migrates along the concrete channel to untrapped gullies installed at 30m intervals. These discharge into an open, unlined ditch which in turn discharges to a local watercourse.

This arrangement satisfied the project criteria for a control site (untreated drainage system). Following confirmation that access, traffic density and the suitability of the watercourse for long term monitoring met the specification of the study, a section of motorway west of junction 16, was selected for monitoring as the control site for the study (Figure 1 and Photo 1).

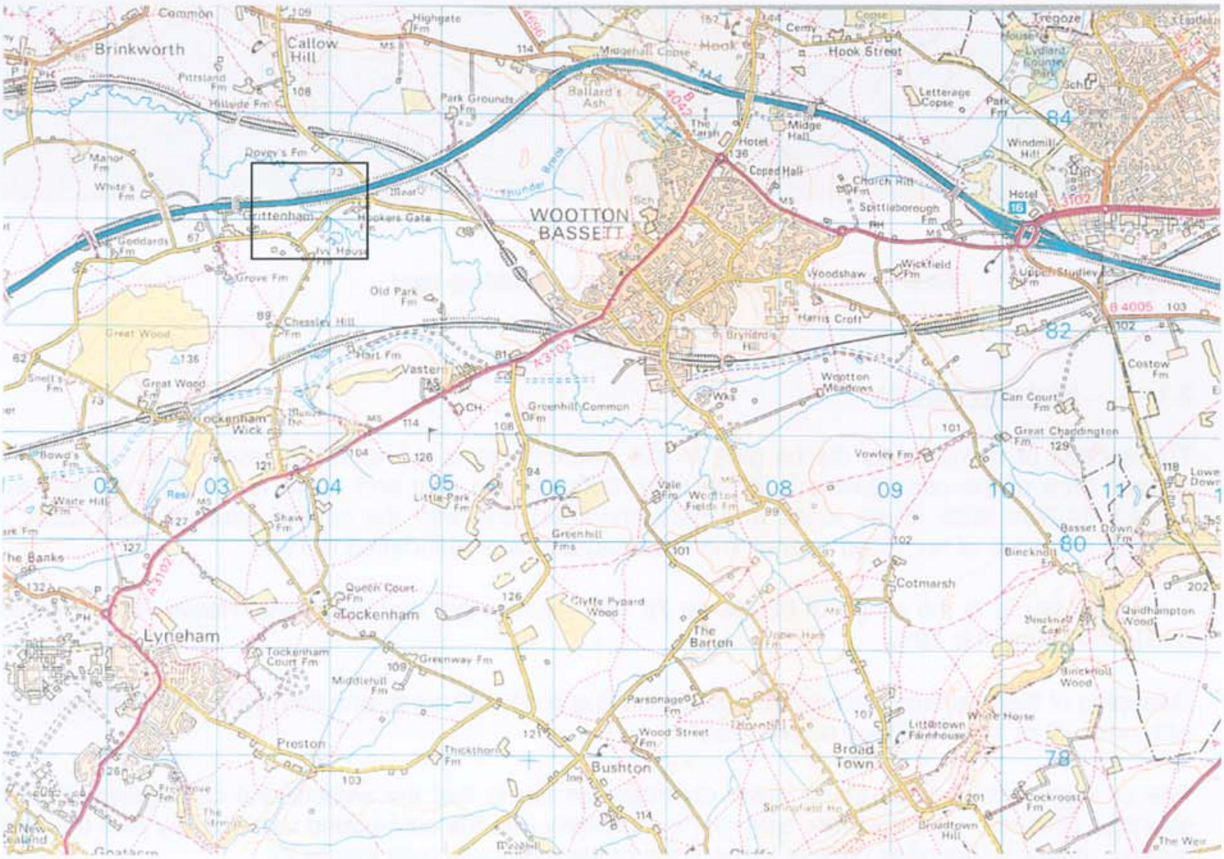


Figure 1 M4/Brinkworth Brook Location Plan

Photo 1 **View of monitored carriageway - looking east**

2.1 Highway Details

The section of carriageway discharging to the watercourse is 6.5 to 7.1km west of junction 16. The surface area of the carriageway is 724m long (600m to the east and 124m to the west of Brinkworth Brook), 14.35m wide (three lanes and hard shoulder) and with the central reserve 4.0m wide. The wearing course is of hot rolled asphalt (non-porous) and was resurfaced in 1995.

Traffic density is in the range of 62,230 to 79,433 vehicles per day (two way). Heavy Goods Vehicles (HGV) component is 18%.

Sweeping of the drainage channel and gully cleaning is carried out bi-annually (Spring and Autumn), with removal of straw build-up as required.

The arrangement of the surface water drainage system is that the west-bound carriageway drains to drainage ditches on the southern side of the motorway and the east-bound carriageway plus the central reserve, drains to drainage ditches to the north of the motorway (see Figure 2).

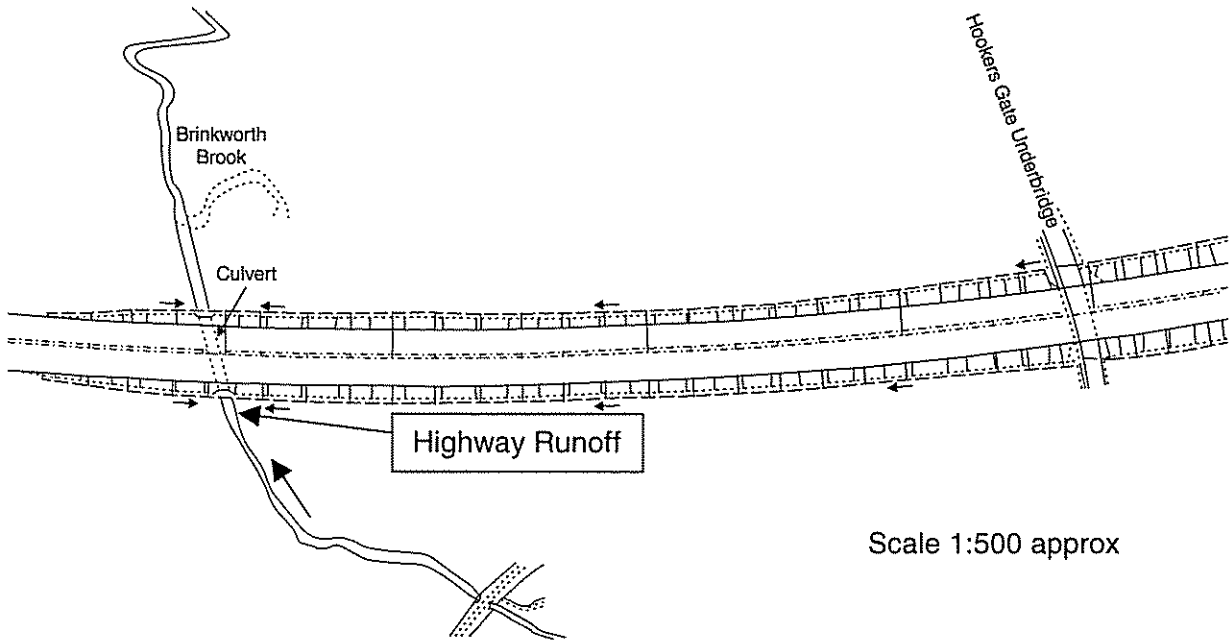


Figure 2 Carriageway Drainage

2.2 Watercourse Details

Brinkworth Brook is a tributary of the Wiltshire Avon. It rises at the Wiltshire Downs escarpment to the south of Wooton Bassett and flows in a north easterly direction crossing the M4 motorway to the west of Wooton Basset (NGR SU 03758320). North of the M4 motorway the brook flows west to its confluence with the River Avon west of Great Somerford. The major contributions to the brook upstream of the motorway are the final effluent discharge from Wooton Bassett sewage treatment works, surface water drainage from Wooton Bassett and Tokenham Brook. The major contribution downstream of the motorway is Thunder Brook. A 5%ile flow of 273l/s was recorded during the monitoring period.

The upper limit of the study reach is Whitehill Lane roadbridge (NGR SU 03958305) and the lower limit the confluence with Thunder Brook (NGR SU 03758350) a total of 740m. The Monitoring point for the motorway run-off to the brook (NGR SU 03758315) is 240m downstream of the upper limit. See Figure 3.

The course of the brook through the study reach was deepened and reprofiled to a trapezoidal cross section during construction of the motorway and straightened for c.100m downstream of the motorway culvert. The trapezoid cross section of the brook varies between 6-8m wide closing to a channel width of 2-3m wide. The channel is incised and varies in depth during dry weather with riffles c.100mm deep to pools c.600mm deep. The substrate varies with sections of undisturbed Lias clay and sections of gravel.

2.3 Monitoring Locations

Site and location codes have been created to facilitate interrogation of the Database.
Monitor locations identifier codes are given below and the locations are shown on the schematic Figure 3.

Monitoring Location	Monitoring Location Code	Database Code
Highway Runoff (Untreated)	Location 1	BB 1
Upstream Watercourse	Location 2	BB 2
Downstream Watercourse	Location 3	BB 3

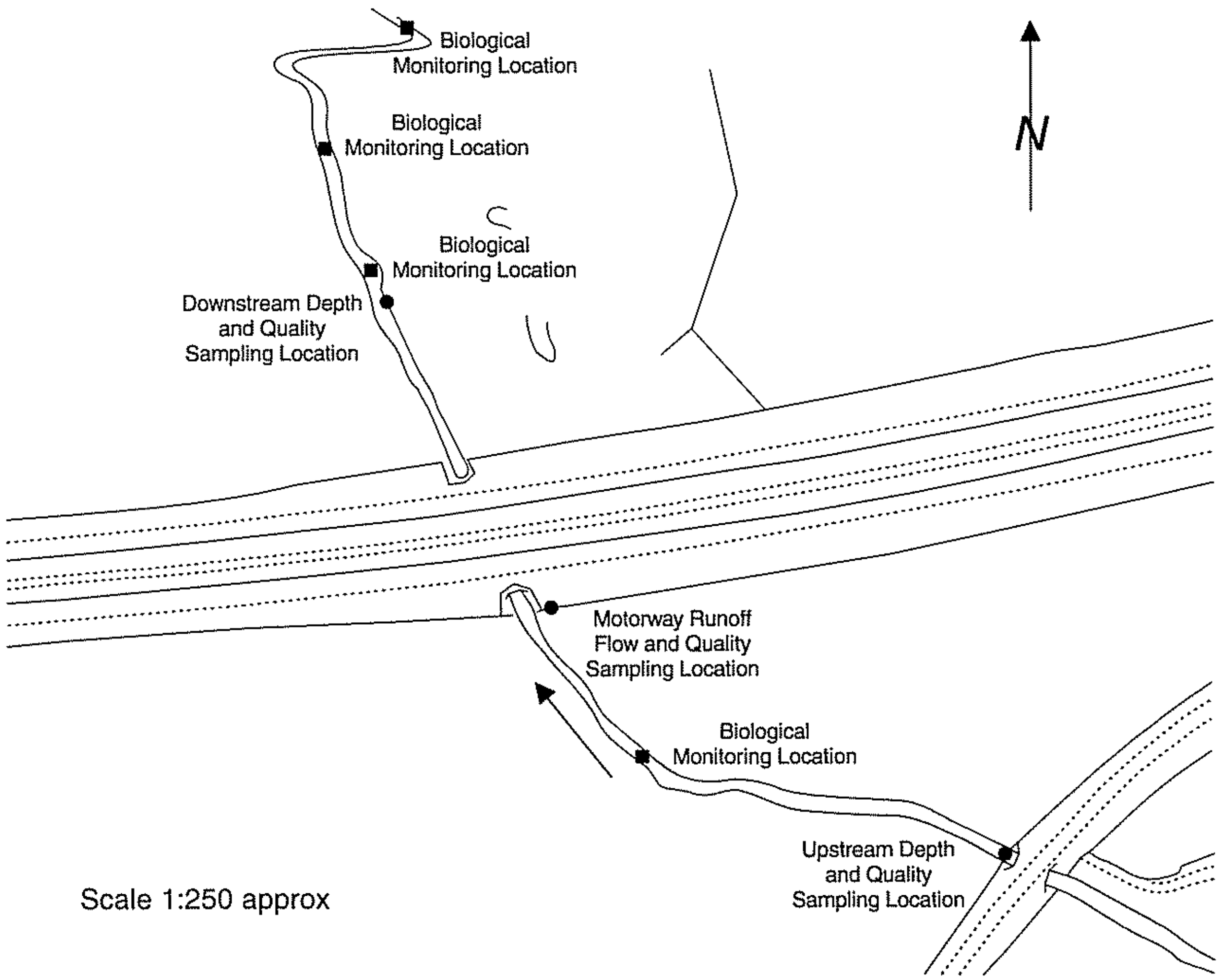


Figure 3 Study reach and monitoring locations

2.3.1 Upstream Monitoring Location

The upstream monitoring location was at the Whitehill Lane road bridge. This is a box culvert 5m wide by 3m high (Photo 2). The depth of flow during dry weather is maintained by a small boulder dam 15m downstream of the culvert and variable depths of silt, between 0 and 150mm, have been deposited on the culvert floor. During low water, flows were uneven across the section of the culvert due to banks of sediment and vegetation both immediately upstream and downstream of the culvert. A depth monitor was installed on the right sidewall of the culvert 285mm above the invert. Velocity profiles were taken throughout the monitoring period and a stage discharge curve produced. Liquid samples, sediment samples and the monthly spot samples were taken at this monitoring location. For security reasons deployment of the continuous water quality monitors during storm events was located 40m downstream of the upstream monitoring location.

Photo 2 View of upstream monitoring location – viewed upstream

2.3.2 Downstream Monitoring Location

The downstream monitoring location was 70m downstream of the northern end of the motorway box culvert. The trapezoid cross section of the brook is 8.6m wide closing to a channel width of 2m wide. The channel is incised with near vertical sides 600mm deep (Photo 3). The substrate is of firm clay, free of silt. Good flow conditions were maintained by management of the channel immediately upstream of the depth and velocity monitor which was mounted on a concrete slab in the centre of the channel. Velocity profiles were taken throughout the monitoring period and a stage discharge curve produced. All downstream data collection, liquid samples, sediment samples, continuous water quality monitoring and the monthly spot samples were taken at this monitoring location.

Photo 3 **View of downstream monitoring location – viewed upstream**

2.3.3 Highway Runoff Monitoring location

The highway runoff from the monitored section of motorway discharges to Brinkworth Brook via four ditch outfalls, two at either end of the motorway box culvert, one from the east and one from the west. Each discharge was assessed for monitoring. The two discharges from the west were considerably overgrown and showed little evidence of significant/measurable flows. The discharge from the east on the north side of the motorway box culvert was also overgrown and a proportion of the flow was discharging to Brinkworth Brook via sinkholes in the ditch bed and sub surface channels. Monitoring of the highway runoff was therefore limited to a single discharge point of the westbound carriageway, where a 10m lined length of the ditch afforded good monitoring conditions (Photo 4). The paved surface area, contributing to the runoff sampling point is 8,755 m^2. Average daily traffic density of the westbound carriageway only, was in the range 30,680 to 39,864.

A depth and velocity monitor was permanently installed in the centre of the channel along with sampler intake hoses. All highway runoff data, flow measurement, liquid samples and sediment samples were taken at this monitoring location. Automatic liquid samplers were deployed prior to each storm monitoring event and were initiated by depth of flow over the flow monitor. Measured flow and pollutant concentrations would be factored up, based on the relative contributing areas discharging via the other outfalls, to assess the total load discharged to the watercourse. The total surface areas discharging to the watercourse is 23,675 m^2.

Photo 4 **View of highway runoff monitoring location**

2.4 Equipment Specifications

The instrument used for the highway runoff measurement is a Detectronic 3510 surveylogger, manufactured by Buhler Montec, Salford, U.K. These depth and velocity instruments are commonly used throughout the water industry for the measurement of wastewaters during short term sewer flow surveys. Depth is measured using a pressure transducer and velocity using ultrasonic doppler shift sensors.

Instrument specification:

	Range	Resolution
Depth	0 02 - 2 m	1 mm
Velocity	0.1 m/s to 4.0 m/s	0.001 m/s

Further details regarding the use and specification of flow monitors can be found in the Detectronic 3510 User Manual. Montec international. 1993

The instruments used for the watercourse flow monitoring are Starflow 6526 flow monitors manufactured by Unidata, Willetton, Western Australia. These depth and velocity instruments have been specifically developed for the measurement of flows in open channels with little particulate content, using a pressure transducer to measure depth and high frequency ultrasonic doppler shift sensors to measure velocity.

Instrument specification:

	Range	Resolution
Depth	0 - 5 m	2 mm
Velocity	0.021 m/s to 5.0 m/s	0.001 m/s

Further details regarding the use and specifications of Starflow monitors can be found in the Starflow 6526 User Manual. Unidata Australia. 1996.

The instruments used for taking liquid samples were manufactured by Buhler Montec, Salford, U.K. The model 1011 sampler unit consists of two main modules; the sampling module which contains all of the electronic components, pump etc., and a container module or carousel which for this sampling programme has 24 individual sample bottles, each of 0.5 l capacity. Samplers were duplicated to provide adequate sample volume.

A liquid sample is drawn up the inlet hose by vacuum and deposited directly into a sample bottle in the carousel via an outlet tube linked to a distributor module, which rotates in steps and is controlled by the microprocessor, thus allowing samples to be delivered to up to 24 individual sample bottles. Sample interval and volume are pre-programmed, sample initiation, for this sampling programme, was by depth threshold. Further details regarding the use of samplers can be found in the Epic 1011/1511 User Manual. Montec international, 1993.

The water quality sondes were manufactured by Yellow Springs Instruments, Ohio, USA. The sondes, model 6920, are pre-programmed to record values from individual sensors at selected time intervals.

Instrument specification:

	Range	Resolution
Temperature	-5 to 45 °C	0.01 °C
DO %	0 to 500 % air saturation	0.1 % in air
DO mg/l	0 to 50 mg/l	0.01 mg/l
Conductivity	0 to 100 mS/cm	0.001 mS/cm to 0.1 mS/cm
pH	0 to 14 units	0.01 units
Turbidity	0 to 1000 NTU	0.1 NTU

Further details regarding the use and specifications of the water quality monitors can be found in the YSI 6920 User Manual. Yellow Springs Instruments Incorporated, 1996.

3. SAMPLE COLLECTION AND ANALYSIS

The range of contaminants that may be present and are to be identified in this project fall into the following categories:

a) BOD, COD, NH_3, suspended solids;

b) Hydrocarbons;

c) Metals;

d) De-icing Salts;

e) Herbicides.

These may be in suspension, dissolved or attached to particulate matter.

To establish background levels and the effect of intermittent storm runoff on the watercourse, four programmes of data collection were conducted during the monitoring period;

1. continuous data collection throughout the monitoring period of rainfall and river flows,

2. monthly riverwater sampling and in-situ water quality readings upstream and downstream of the highway runoff discharge point, where possible during periods of established dry weather,

3. sampling of the highway runoff and in-situ water quality monitoring of the watercourse during storm events,

4. sediment sampling at the commencement and conclusion of the monitoring period from the upstream and downstream watercourse and highway runoff monitoring locations.

The analysis suites and logged data parameters for the four data collection programmes are given in Tables 1-4 below.

Limit of detection for each parameter is as specified in Appendices A and B. However the LOD is subject to quantity and dilution of the samples recovered.

Table 1 Continuous data collection - Hydrology

Data Type	Logging interval
Rainfall	1 minute intervals
River Flows	scanned at 5 minute intervals with logged average every 15 minutes

Table 2 Monthly water quality sampling - Receiving waters

Sample Type	Determinands	Units	LOD
Liquid	Biological Oxygen Demand	mg/l O_2	1.0 mg/l
	Chemical Oxygen Demand	mg/l O_2	10 mg/l
	Ammonia	mg/l N	0.05 mg/l
	Total Suspended Solids	mg/l	2.0 mg/l
	Hardness	mg/l $CaCO_3$	0.5 mg/l
In-situ measurement	Temperature	°C	0.01 °C
	pH	units	0.01 units
	Dissolved Oxygen	mg/l O_2	0.01 mg/l

Table 3 Storm event sampling

Sample Type	Determinands	Units	LOD
Liquid-Discrete	Biological Oxygen Demand	mg/l O_2	1.0 mg/l
	Chemical Oxygen Demand	mg/l O_2	10 mg/l
	Ammonia	mg/l N	0.05 mg/l
	Total Suspended Solids	mg/l	2.0 mg/l
Liquid- Flow weighted composite	Hardness	mg/l $CaCO_3$	0.5 mg/l
	Metals*	mg/l	*
	Polyaromatic Hydrocarbons*	ug/l	*
	Herbicides*	ug/l	*
	De-icing salts	mg/l Cl	*
In-situ measurement	Temperature	°C	0.01 °C
	pH	units	0.01 units
	Dissolved Oxygen	mg/l O_2	0.01 mg/l
	Turbidity	NTU	0.1 NTU
	Conductivity	mS/cm	0.001 mS/cm

* The full suite of determinands and LODs are given in Appendix A

Table 4 Sediment sampling

Sample Type	Determinands	Units	LOD
Sediment	Metals*	ug/l	*
	Polyaromatic Hydrocarbons*	ug/l	*
	Weathered Hydrocarbons*	ug/l	*
	Particle size distribution	mm	2µm
	Organic content	VM %	0.1%

* The full suite of determinands and LODs are given in Appendix B

River sediments are collected using a trowel or shovel. The sediments should be representative of fine grained material deposited due to low flow velocities. Sediments adjacent to river banks are likely to be sorted and unrepresentative.

The sediments of interest are those which have pollutants attached. Sediments larger than 0.2 mm will not carry significant amounts of pollutants in comparison with the smaller fractions.

4. RESULTS

4.1 Continuous data

a) Rainfall

A complete record of rainfall was achieved using a logging, tipping bucket raingauge located within the catchment. Figure 4 shows the rainfall from December 1997 to December 1998.

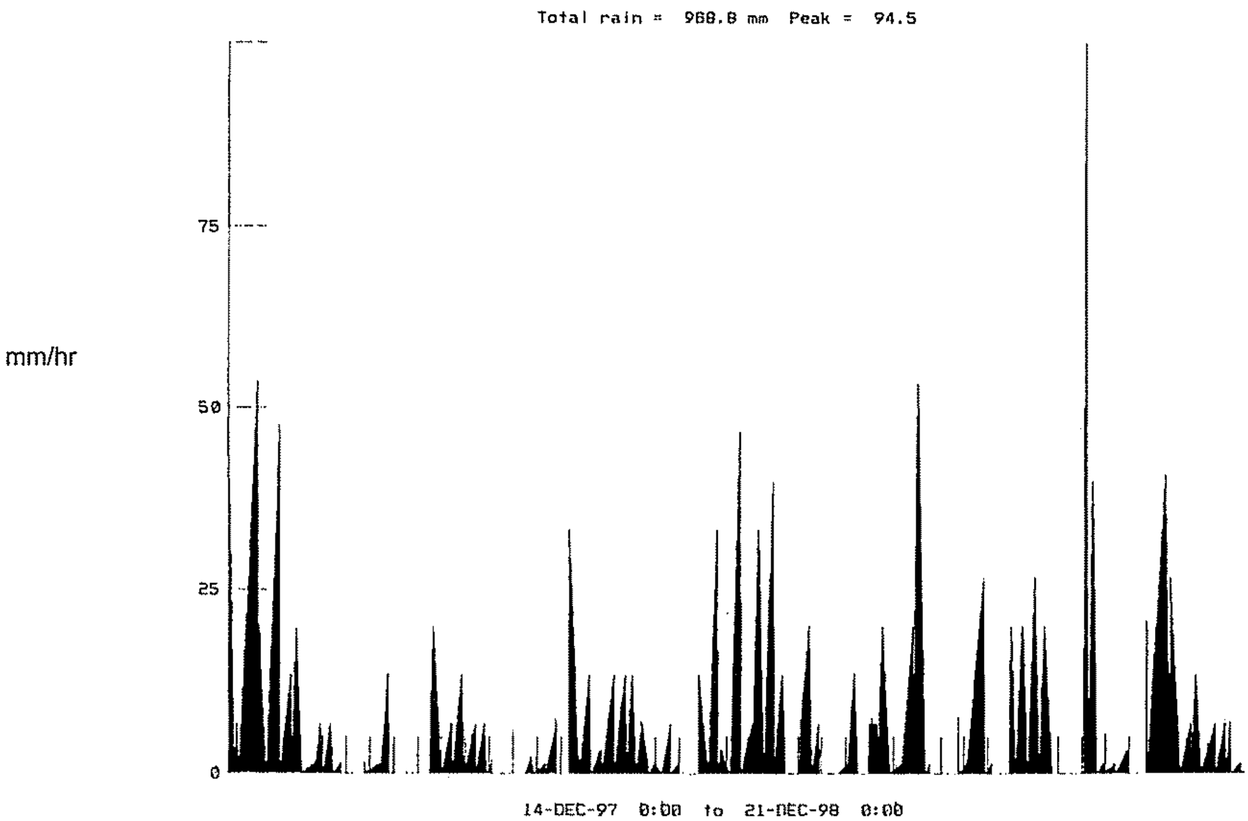


Figure 4 Total Rainfall

A total of 949.7mm of rainfall was recorded during the 12 month monitoring period. This compares with an annual average rainfall of 725mm. A monthly summary is given in Table 5 below.

Table 5 Monthly rainfall summary

Month	Monthly ave. rainfall*	Total rainfall	Days = Nil	Days < 1.0mm	Days < 5.0mm	Days < 10mm	Days > 10mm
December 1997 from 17/12/97	December 67	48.5	2	4	6	3	0
January 1998	73	91.3	12	9	3	4	3
February	35	14.3	20	5	3	0	0
March	61	73.1	14	7	5	3	2
April	45	123.5	2	10	9	6	3
May	61	57.8	15	12	1	1	1
June	64	136.1	6	9	5	6	4
July	58	30.0	15	9	7	1	0
August	70	32.3	20	7	2	1	1
September	42	100.6	10	5	7	4	4
October	77	143.1	11	5	8	3	4
November	63	67.4	10	9	8	0	2
December to 17/12/98		31.6	4	6	5	2	0

*Monthly average rainfall 1985-1988, Met Office Station, Old town, Swindon.

Hourly average rainfall and rainfall hyetographs are given in Appendix C. The full rainfall listings of 1 minute data are contained in the database.

The measured rainfall during the survey period was c.33% above the annual average. Reference to Table 5 shows the additional rainfall occurred largely during the months of April, May and June. Rainfall occurred every day during April with the exception of 16th and 30th. Two events, of 16.0 and 13.4mm contributing to the already high river flows due to 96mm of rainfall in the previous 7 days This resulted in a 10 day period (8th to 18th) during which the monitoring site and surrounding area flooded. Flooding recurred briefly at the end of October following 56mm of rainfall over a 4 day period.

b) River Flow

River flow was recorded at the upstream and downstream watercourse monitoring locations throughout the monitoring period. A pressure transducer recorded depth and an ultrasonic doppler measured velocity, scanning at 5 minute intervals and recording average values at 15 minute intervals. Where the hydraulic conditions were considered unlikely to allow representative velocity data to be recorded, velocity profiling carried out during the survey allowed production of a stage discharge curve from which the flow has been calculated (see Figure 5 and Figure 6). A 5%ile flow of 273 l/s was recorded during the monitoring period.

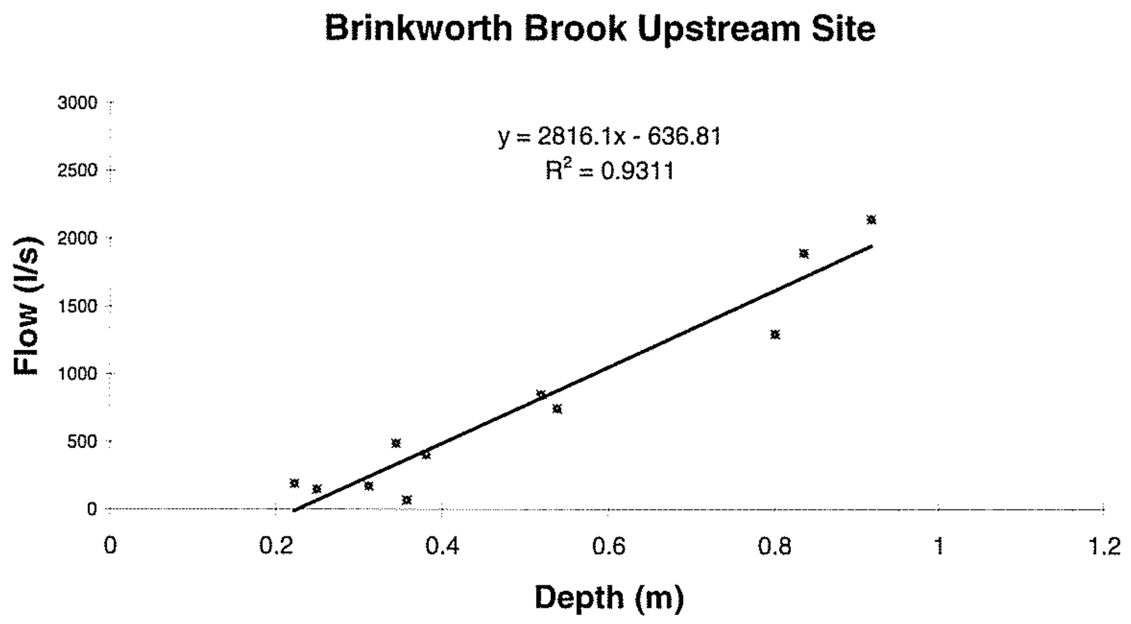


Figure 5 **Stage Discharge Curve - Watercourse Upstream monitoring location**

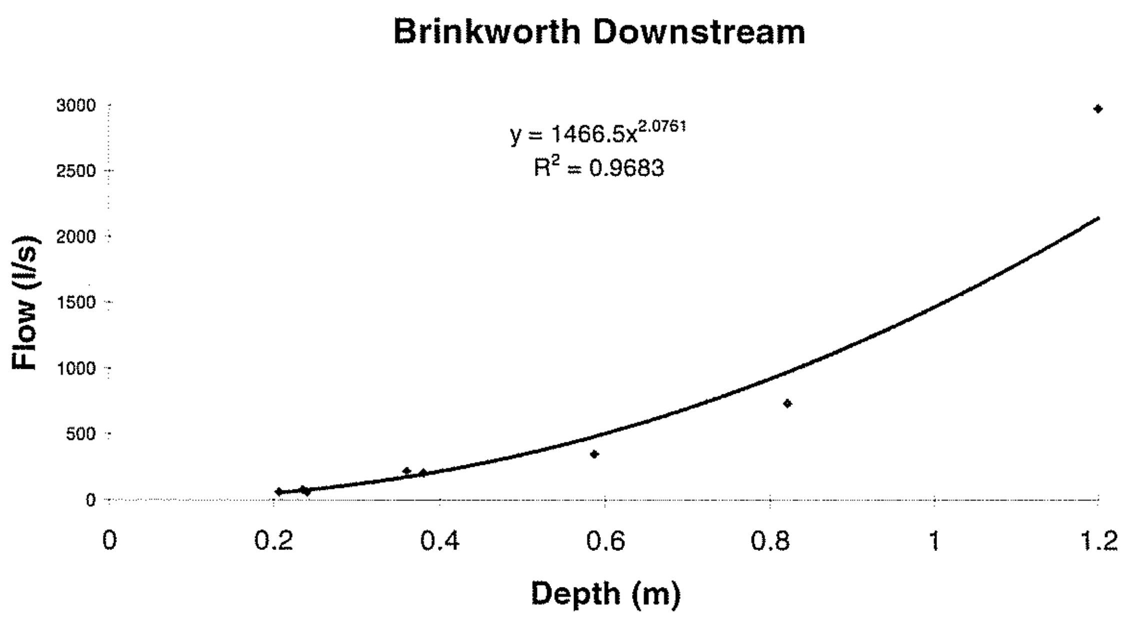


Figure 6 **Stage Discharge Curve - Watercourse Downstream monitoring location**

A 6.8% data loss occurred at the upstream monitoring location and a 21.6% data loss occurred at the downstream monitoring location. Details are given below:

Upstream monitoring location	14 February to 9 March	Battery failure
	22 to 24 April	Instrument removed to eliminate internal condensation
Downstream monitoring location	17 December to 5 February	Instrument failure (electronics)
	2 to 20 April	Instrument u/s due to floods
	20 to 29 April	Data lost during transfer
	19 August to 21 September	Data corrupted

A full record of the flow data recorded at the upstream and downstream monitoring locations are contained in the database.

4.2 Monthly data

Liquid samples and in-situ water quality measurements were taken on a quasi-monthly basis at the upstream and downstream watercourse monitoring locations. Where possible dry weather conditions were allowed to establish prior to the sampling to eliminate residual increases values in the periods following storms. Rainfall of less than 1.0mm is taken as a dry day.

The dates of monthly sampling and antecedent dry days are listed below:

Date	Antecedent dry days
17 December 1997	2
22 January 1998	4
24 February	4
17 March	7
21 April	2
12 May	1
16 June	2
21 July	1
19 August	4
21 September	8
20 October	3
1 December	2
17 December	2

The values for the upstream and downstream monitoring locations show a close correlation as would be expected for samples taken under dry weather conditions with no significant inputs between the two monitoring locations.

Temperature- This shows a gradual increase from c.6°C at the beginning of the monitoring period to c.17°C in July, August and September followed by a rapid fall to c.3°C at the beginning of December. This followed a period of sub-zero night-time temperatures during which salt was applied to the carriageway. Temperatures recovered to c.8°C at the end of the monitoring period.

Dissolved Oxygen- This is reported in both mg/l and %. Small variations are noted with individual samples that can be attributed to minor variations in flow conditions between the monitoring locations. However the trends show a close correlation.

Biological Oxygen Demand- BOD values in the range <1.0 to 4.8mg/l were recorded at both the upstream and downstream monitoring locations. A reasonable correlation exists between the two trends with two notable anomalies on 24 February 1998 and 1 December 1998. Disparities of 1.2mg/l and 1.4mg/l were recorded respectively.

Chemical Oxygen Demand- COD values in the range 19.7 to 57.9mg/l and 30.4 to 73.4mg/l were recorded for the upstream and downstream monitoring locations respectively. Values are generally within 10mg/l of one another with the exception of the samples taken on 20 October and 1 December 1998 when the downstream demand was c100% higher than upstream.

pH pH values show a close correlation throughout the monitoring period

Ammonia A large proportion of the values are below the 0.05mg/l limit of detection. The exception to these values occurred in the 22 January samples when values of 1.53 and 1.55mg/l were recorded.

Total Suspended Solids Recorded values were generally in the range 3.0 to 12mg/l with exceptions on 22 January and 1 December when high values and large disparities between the two monitoring locations were recorded.

Hardness A close correlation of values, in the range 290 to 368 mg/l $CaCO_3$, was recorded between the two monitoring locations.

Full details of the monthly analysis results are contained in the database, graphical plots of the above parameters are given in Appendix E

4.3 Sediment Sampling

Sediment samples were taken at the commencement and termination of the monitoring period from the upstream, downstream and highway runoff monitoring locations. Comparative analysis results are given in Table 6 below:

Table 6 Sediment sample analysis results

Parameter	Units	Upstream		Downstream		Highway Runoff	
		17/12/97	3/2/99	17/12/97	3/2/99	17/12/97	3/2/99
Copper	ug/g	33.4	24.0	40.7	23.6	151.0	95.7
Zinc	ug/g	120	134	130	155	401	487
Cadmium	ug/g	14.7	<1.0	9.1	<1.0	1.01	<1.0
Aluminium	ug/g	16950	18520	23050	16110	8420	10250
Lead	ug/g	92.0	38.4	99.5	35.0	170	128
Platinum	ug/g	<2.7	<0.2	<2.7	<0.2	<2.7	<0.2
Palladium	ug/g	<3.7	0.79	<3.7	0.36	<3.7	<0.15
Nickel	ug/g	65.4	35.4	43.2	45.7	19.0	21.5
Chromium	ug/g	62.2	39.3	50.4	41.1	29.0	59.2
Napthalene	ug/gx10^3	128	170	121	127	1114	313
Acenapthylene	ug/gx10^3	28	66	27	26	168	103
Acenapthene	ug/gx10^3	47	149	16	66	551	296
Fluorene	ug/gx10^3	52	209	24	83	698	332
Phenanthrene	ug/gx10^3	554	759	168	178	4594	2171
Anthracene	ug/gx10^3	226	220	68	87	1405	715
Fluoranthene	ug/gx10^3	1163	1275	523	242	6889	3455
Pyrene	ug/gx10^3	922	1052	413	215	5064	2871
Benzo(a)anthracene	ug/gx10^3	381	378	204	80	2797	1218
Chrysene	ug/gx10^3	498	635	335	107	3023	2004
Benzo(b)fluoranthene	ug/gx10^3	313	391	276	111	2637	1567
Benzo(k)fluoranthene	ug/gx10^3	440	635	349	141	2167	1410
Benzo(a)pyrene	ug/gx10^3	412	531	301	116	2657	1415
Indeno(1,2,3-cd)pyrene	ug/gx10^3	305	431	267	112	1800	1485
Dibenzo(a,h)anthracene	ug/gx10^3	76	93	83	18	675	428
Benzo(g,h,i)perylene	ug/gx10^3	278	356	226	79	1667	1036
Diesel Range	ug/g	77	202	112	57	909	1511
Organic content (VM)	%	4.8	6.8	8.0	5.9	5.0	4.6

Particle size distribution was determined using 8 sieve sizes. The percentage of material passing each of the 8 size bands is given in Table 7 below:

Table 7 **Particle size distribution - percent passing**

Sieve Size	Upstream		Downstream		Highway Runoff	
µm	17/12/97	3/2/99	17/12/97	3/2/99	17/12/97	3/2/99
4000	100	100	100	100	100	100
2000	48.2	100	77.2	100	47.9	100
600	29.5	99.6	54.9	99.9	25.1	97.2
212	25.8	96.2	42.8	98.3	18.1	79.4
63	19.9	77.7	32.7	76.8	10.2	53.0
20	14.7	58.8	15.2	60.7	4.2	35.5
6	6.8	41.2	10.4	41.2	2.9	21.0
2	4.2	27.7	6.4	24.4	2.0	10.6

4.4 Storm Event Sampling

Storm event selection was based on a number of criteria. Following access to Meteorological Office forecasts, total rainfall, peak intensity and rainfall duration were considered in conjunction with the antecedent dry period, comparison of the forecast storm with previous captured storm profiles and the possible occurrence of flooding of the highway runoff channel and/or surrounding land. If the forecast storm fulfilled the criteria the liquid samplers and water quality monitors were deployed. The equipment was deployed on 19 occasions, of which 9 occasions the sampling was abandoned due to insufficient highway runoff. Table 8 below gives details of the 10 successful sampling exercises.

During the majority of events, little runoff arrived at the runoff sampling monitoring location, until c.3.0mm of rainfall had occurred. Depths of flow were typically 20-30 mm with discharges of c.3 to 5 l/s. Graphical plots of depth, flow and rainfall are given in Appendix D.

Table 8 **Storm event details**

Event No	Date	Sampling Interval (mins)	Event Rainfall (mm)	Peak Intensity (mm/hr)	Antecedent Dry Period
1	7 February	15	4.6	12.6	17 days ‡
2	2 March	30	7.2	6.3	2.5 days †‡
3	23 April	5	6.1	6.3	9.5 hrs ‡
4	26 May	10	21.9	31.5	24 hrs
5	2 June	10/20	9.5	6.3	4.5 days
6	25 June	10	4.8	18.9	24 hrs
7	11 July	10	4.3	12.6	11 days
8	9 September	10	6.4	18.9	16 hrs *
9	12 November	15	4.8	6.3	2 days
10	8 December	30	4.7	6.3	4 days **‡

* 4 days since last significant rainfall, drizzle in interim period.
** 10 days since last significant rainfall, drizzle in interim period.
† Herbicide application 3 days prior to storm event sampling.
‡ Road salt application prior to storm event sampling (see Table 10).

During each event discrete samples were taken at the highway runoff monitoring location along with continuous measurements of rainfall, and continuous measurement of upstream and downstream flow.

Discrete samples were taken at intervals ranging from 5 to 30 minutes, the sample interval being determined by the forecast duration of the storm event. Discrete samples were analysed for:

- Biological Oxygen Demand
- Chemical Oxygen Demand
- Total Suspended Solids
- Ammonia

Flow proportional composite samples were prepared from these discrete samples. The analysis suite used is given in Appendix A. Full details of the composite sample analysis results are contained in the database, graphical plots are given in Appendix F.

For the graphical plots for PAH analysis, sample determinands have been selected to cover the range of the ranked PAH in order of toxicity and persistence as ranked in the Environment Agency R&D Technical Report P45, 1999.

Continuous in-situ water quality monitoring at the upstream and downstream monitoring location was carried out, for the duration of the liquid sampling period, for the following parameters:

- Temperature
- Dissolved Oxygen
- Conductivity
- Turbidity
- PH

4.5 Additional Data

Traffic density

Traffic density data have been provide by WSP Graham Limited, from TITAN monitoring station site reference number 4032 (Ballards Ash), 3km East of the Brinkworth Brook site. Details of the monthly averages based on 24 hour, 7 day averages are given in Table 9 below. HVG component is 13% calculated from DETR 1997 manual counts.

Table 9 Average daily total traffic density

Month	Westbound		Eastbound	
		HGV component		HGV component
December 1997	33202	4316	32949	4283
January 1998	30762	3999	31525	4098
February	33731	4385	34596	4497
March	34286	4457	nr	
April	35785	4522	nr	
May	nr		nr	
June	39390	5121	39277	5106
July	39250	5103	39037	5075
August	39211	5097	39820	5177
September	37136	4828	37608	4889
October	36691	4770	36784	4782
November	34723	4514	35746	4647
December	33891	4406	33961	4415

N.B. Westbound traffic density data have been used for the analysis of runoff concentrations.

Herbicide Application

Herbicide application took place on one occasion during the monitoring period. A Glyphosate based herbicide (Roundup) was applied on 27 February 1998 to the drainage channel/hard shoulder at the rate of 5l/Ha using a 2.0m boom.

Road Salt Application

Road salt was applied as detailed in Table 10 below:

Table 10 Road salt application

Month	Date of application
December 1997	3, 4, 5, 13, 16, 17, 27, 29.
January 1998	1, 5, 16, 19, 20, 22, 24, 26, 27, 28, 29, 30, 31.
February	1, 2, 3.
March	1.
April	15.
November	15, 16, 29.
December 1998	1, 2, 4, 5, 6.

The road salt specification is to BS3247:1991 Salt for Spreading on Highways for Winter Maintenance.

Application to the carriageway at the rate of 0.01kg/m^2 equates to 80.4 kg NaCl to the runoff monitoring location contributing area, and a total of 217 kg to the total carriageway area discharging to the watercourse per application. 34 applications, equating to a total application of 7378 kg, were made during the monitoring period.

Table 11 Road salt composition

Property	Unit	Specification	Typical Analysis
Soluble Chlorides	%m/m NaCl	>90.0	91.8
Soluble Sulphate	%m/m $CaSO_4$	<2.5	1.5
Insolubles	%m/m	<7.5	5.8
Moisture	%m/m	<4.0	3.1
Anti-caking agent	mg/kg $Na_2Fe(CN)_6$	>30	60

5. RESULTS OF ANALYSIS OF DATA FOR STORM EVENTS

An analysis of discrete and composite sample analysis results has been undertaken on the conclusion of the monitoring of the control site (untreated drainage). Examination of the relationships between event criteria have been based on the event characteristics summarised in Table 12 below.

Discrete and composite analysis results are plotted against event parameters and included in Appendices H and I

Table 12 Event parameters

Event	Date	Total Rainfall mm	Peak Intensity mm/hr	Event Duration hrs	Total Event Highway Runoff ltr.ϕ	Antecedent Dry Conditions	Sampling Duration hrs
Storm 1	7 February	4.6	12.6	2.5	44275	17 days (399hrs)	1.25
Storm 2	2 March	7.7	6.3	7.5	68500	2.5 days (65hrs)	5.5
Storm 3	23 April	6.1	6.3	5.9	96000	9.5 hrs	1.0
Storm 4	26 May	21.5	31.5	2.5	143825	24 hrs	2.0
Storm 5	2 June	9.5	6.3	10.75	27225	4.5 days (113hrs)	3.0
Storm 6	25 June	4.4	18.9	1.25	13750	24 hrs	1.8
Storm 7	11 July	4.1	12.6	3.3	25850$	11 days (277hrs)	2.0
Storm 8	9 Sept	5.7	18.9	1.4	15400	16hrs*	2.0
Storm 9	12 Nov.	4.2	6.3	5.6	90750$	40 hrs	2.75
Storm 10	8 Dec.	4.7	6.3	4.5	300000$	4 days (101hrs)**	5.5

ϕ Total event flow is calculated from the measured runoff from the sampled carriageway, factored up to give the total runoff from the highway discharged to the brook.

* 4 days since last significant rainfall, drizzle in interim period

** 10 days since last significant rainfall, drizzle in interim period

$ Includes high background groundwater flow.

Flow proportional composite samples were analysed as per the analysis suite listed in Appendix A and the parameter concentrations are given in Table 13 below.

The event load has been calculated as the composite sample concentration multiplied by the flow for the duration of the sampling period only. A summary of event load is given in Table 14 below.

The event load has been also been calculated as the composite sample concentration multiplied by the flow for the duration of the sampling period per 1000m^2 of highway surface for comparison with other site results. A summary of event load per 1000m^2 is given in Table 15 below.

		Storm 1	Storm 2	Storm 3	Storm 4	Storm 5	Storm 6	Storm 7	Storm 8	Storm 9	Storm 10	Minimum	Maximum	Average
		BB-1-S-1	BB-1-S-2	BB-1-S-3	BB-1-S-4	BB-1-S-5	BB-1-S-6	BB-1-S-7	BB-1-S-8	BB-1-S-9	BB-1-S-10	> LOD	> LOD	
	Units													
Copper	ug/l	67.00	29.00	13.00	*0.00*	25.00	31.00	28.00	23.00	*0.00*	24.00	13.00	67.00	24.40
Filtered Copper	ug/l	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.00*	ND	ND	ND
Zinc	ug/l	246.00	160.00	84.00	32.00	81.00	85.00	54.00	94.00	66.00	105.00	32.00	246.00	100.70
Filtered Zinc	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	86.00	0.00	86.00	8.60
Cadmium	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	ND	ND	ND
Aluminium	ug/l	2650.00	4130.00	1490.00	450.00	610.00	290.00	130.00	1450.00	190.00	460.00	130.00	4130.00	1185.00
Lead	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	ND	ND	ND
Platinum	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	120.00	120.00	*0.00*	*0.00*	*0.00*	*0.00*	120.00	120.00	24.00
Palladium	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	ND	ND	ND
Nickel	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	ND	ND	ND
Chromium	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	ND	ND	ND
Simazine	ug/l	*0.00*	0.02	*0.00*	*0.00*	*0.00*	*0.00*	0.15	*0.00*	*0.00*	*0.00*	0.02	0.15	0.02
Amitrole	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	ND	ND	ND
Glyphosate	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	0.03	0.06	0.02	0.11	*0.00*	*0.00*	0.02	0.11	0.02
Diuron	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	ND	ND	ND
Bromacil	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	ND	ND	ND
Atrazine	ug/l	*0.00*	*0.00*	*0.00*	*0.00*	0.06	0.08	0.18	*0.00*	*0.00*	*0.00*	0.06	0.18	0.04
Naphthalene	ug/l	0.09	0.16	0.03	0.06	0.05	0.05	0.02	0.11	0.04	*0.00*	0.02	0.16	0.04
Acenaphthylene	ug/l	0.04	0.09	0.01	0.02	0.22	0.18	0.02	*0.00*	*0.00*	*0.00*	0.01	0.22	0.06
Acenaphthene	ug/l	0.10	0.20	0.01	0.09	0.11	0.31	0.01	*0.00*	*0.00*	*0.00*	0.01	0.31	0.08
Fluorene	ug/l	0.04	0.15	0.01	0.01	0.16	0.26	0.01	0.01	*0.00*	*0.00*	0.01	0.26	0.07
Phenanthrene	ug/l	0.18	0.10	0.03	0.05	0.80	0.66	0.03	0.02	*0.00*	*0.00*	0.02	0.80	0.19
Anthracene	ug/l	0.24	0.39	0.03	0.01	0.30	0.26	0.04	*0.00*	*0.00*	*0.00*	0.01	0.39	0.13
Fluoranthene	ug/l	0.61	0.44	0.05	0.06	0.28	0.27	0.02	0.04	*0.00*	0.02	0.02	0.61	0.18
Pyrene	ug/l	0.53	0.41	0.04	0.06	0.39	0.34	0.01	0.03	*0.00*	0.03	0.01	0.53	0.17
Benzo(a)anthracene	ug/l	0.33	0.96	0.01	0.02	0.12	0.10	0.03	0.02	*0.00*	*0.00*	0.01	0.96	0.16
Chrysene	ug/l	0.33	0.83	0.02	0.04	0.15	0.12	*0.00*	0.04	*0.00*	0.02	0.02	0.83	0.16
Benzo(b)fluoranthene	ug/l	0.58	1.10	0.03	0.03	0.11	0.12	0.07	0.02	*0.00*	0.02	0.02	1.10	0.20
Benzo(k)fluoranthene	ug/l	0.30	0.35	0.03	0.03	0.07	0.07	0.05	0.03	*0.00*	0.02	0.02	0.35	0.10
Benzo(a)pyrene	ug/l	0.60	0.49	0.06	0.07	0.17	0.15	*0.00*	0.05	*0.00*	0.04	0.04	0.60	0.16
Indeno(1,2,3-cd)pyrene	ug/l	0.40	0.50	0.02	0.01	0.04	0.06	*0.00*	0.02	*0.00*	0.01	0.01	0.50	0.11
Dibenzo(a,h)anthracene	ug/l	0.40	0.58	0.01	0.02	0.10	0.06	*0.00*	*0.00*	*0.00*	*0.00*	0.01	0.58	0.12
Benzo(g,h,i)perylene	ug/l	0.30	0.87	0.03	0.03	0.03	0.08	*0.00*	0.02	*0.00*	0.03	0.02	0.87	0.14
Na	mg/l	2100.00	348.00	68.90	16.40	29.60	32.50	37.80	*NR*	1.02	732.00	1.02	2100.00	374.02
Hardness	mg/l	619.00	221.00	200.00	53.70	78.00	128.00	168.00	*NR*	228.00	341.00	53.70	619.00	226.30
De-IcingSalts	mg/l	3120.00	570.00	90.50	16.60	29.00	32.00	46.40	23.90	70.00	1364.00	16.60	3120.00	536.24
BOD	mg/l	31.27	3.70	11.70	3.13	5.91	6.99	6.92	10.06	6.35	4.96	3.13	31.27	9.10
COD	mg/l	189.83	76.26	92.05	69.23	49.59	73.83	86.41	109.18	59.15	69.67	49.59	189.83	87.52
TSS	mg/l	235.67	41.23	246.50	29.23	47.61	21.77	96.46	15.15	87.94	64.48	15.15	246.50	88.60
NH4 N	mg/l	0.48	0.27	0.28	0.10	0.51	0.60	0.16	0.69	0.07	0.17	0.07	0.69	0.33

Value < or = LOD reported in blue *italics*.
Average values include <LOD as 0.0
ND = Not Detected
NR = No Result (analysis unreliable)
IS = Insufficient Sample

Table 13 Flow proportional composite sample concentrations – Highway runoff

		Storm 1	Storm 2	Storm 3	Storm 4	Storm 5	Storm 6	Storm 7	Storm 8	Storm 9	Storm 10	Minimum	Maximum	Average
		BB-1-S-1	BB-1-S-2	BB-1-S-3	BB-1-S-4	BB-1-S-5	BB-1-S-6	BB-1-S-7	BB-1-S-8	BB-1-S-9	BB-1-S-10	> LOD	> LOD	
	Load													
Copper	mg	876.36	396.72	36.06	*0.00*	65.70	33.54	76.22	47.15	*0.00*	1016.64	0.00	1016.64	254.84
Filtered Copper	mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	*0.00*	0.00	0.00	ND
Zinc	mg	3217.68	2188.80	233.02	1857.60	212.87	91.97	146.99	192.70	1496.88	4447.80	91.97	4447.80	1408.63
Filtered Zinc	mg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3642.96	0.00	3642.96	364.30
Cadmium	mg	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	ND	ND	ND
Aluminium	mg	34662.00	56498.40	4133.26	26122.50	1603.08	313.78	353.86	2972.50	4309.20	19485.60	313.78	56498.40	15045.42
Lead	mg	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	ND	ND	ND
Platinum	mg	*0.00*	*0.00*	*0.00*	*0.00*	315.36	129.84	*0.00*	*0.00*	*0.00*	*0.00*	1584.00	3072.00	44.52
Palladium	mg	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	ND	ND	ND
Nickel	mg	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	ND	ND	ND
Chromium	mg	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	*ND*	ND	ND	ND
Simazine	ug	*0.00*	273.60	*0.00*	*0.00*	*0.00*	*0.00*	408.30	*0.00*	*0.00*	*0.00*	1360.00	2685.00	68.19
Amitrole	ug	*ND*	*ND*	*ND*	*ND*	*IS*	*IS*	*ND*	*ND*	*ND*	*ND*	ND	ND	ND
Glyphosate	ug	*0.00*	*0.00*	*0.00*	*0.00*	78.84	64.92	54.44	225.50	*0.00*	*0.00*	358.00	1694.00	42.37
Diuron	ug	*ND*	*ND*	*ND*	*ND*	*IS*	*IS*	*ND*	*ND*	*ND*	*ND*	ND	ND	ND
Bromacil	ug	*ND*	*ND*	*ND*	*ND*	*IS*	*IS*	*ND*	*ND*	*ND*	*ND*	ND	ND	ND
Atrazine	ug	*0.00*	*NR*	*0.00*	0.00	157.68	86.56	489.96	*0.00*	*0.00*	*0.00*	1056.00	4282.00	73.42
Naphthalene	ug	1177.20	2188.80	83.22	3483.00	131.40	54.10	54.44	225.50	907.20	*0.00*	0.00	3483.00	830.49
Acenaphthylene	ug	523.20	1231.20	27.74	1161.00	578.16	194.76	54.44	*0.00*	*0.00*	*0.00*	0.00	1231.20	377.05
Acenaphthene	ug	1308.00	2736.00	27.74	5224.50	289.08	335.42	27.22	*0.00*	*0.00*	*0.00*	0.00	5224.50	994.80
Fluorene	ug	523.20	2052.00	27.74	580.50	420.48	281.32	27.22	20.50	*0.00*	*0.00*	0.00	2052.00	393.30
Phenanthrene	ug	2354.40	1368.00	83.22	2902.50	2102.40	714.12	81.66	41.00	*0.00*	*0.00*	0.00	2902.50	964.73
Anthracene	ug	3139.20	5335.20	83.22	580.50	788.40	281.32	108.88	*0.00*	*0.00*	*0.00*	396.00	5335.20	1031.67
Fluoranthene	ug	7978.80	6019.20	138.70	3483.00	735.84	292.14	54.44	82.00	*0.00*	847.20	0.00	7978.80	1963.13
Pyrene	ug	6932.40	5608.80	110.96	3483.00	1024.92	367.88	27.22	61.50	*0.00*	1270.80	0.00	6932.40	1888.75
Benzo(a)anthracene	ug	4316.40	13132.80	27.74	1161.00	315.36	108.20	81.66	41.00	*0.00*	*0.00*	0.00	13132.80	1918.42
Chrysene	ug	4316.40	11354.40	55.48	2322.00	394.20	129.84	*0.00*	82.00	*0.00*	847.20	0.00	11354.40	1950.15
Benzo(b)fluoranthene	ug	7586.40	15048.00	83.22	1741.50	289.08	129.84	190.54	41.00	*0.00*	847.20	0.00	15048.00	2595.68
Benzo(k)fluoranthene	ug	3924.00	4788.00	83.22	1741.50	183.96	75.74	136.10	61.50	*0.00*	847.20	0.00	4788.00	1184.12
Benzo(a)pyrene	ug	7848.00	6703.20	166.44	4063.50	446.76	162.30	*0.00*	102.50	*0.00*	1694.40	770.00	7848.00	2118.71
Indeno(1,2,3-cd)pyrene	ug	5232.00	6840.00	55.48	580.50	105.12	64.92	*0.00*	41.00	*0.00*	423.60	264.00	6840.00	1334.26
Dibenzo(a,h)anthracene	ug	5232.00	7934.40	27.74	1161.00	262.80	64.92	*0.00*	*0.00*	*0.00*	*0.00*	0.00	7934.40	1468.29
Benzo(g,h,i)perylene	ug	3924.00	11901.60	83.22	1741.50	78.84	86.56	*0.00*	41.00	*0.00*	1270.80	308.00	11901.60	1912.75
Na	g	27468.00	4760.64	191.13	952.02	77.79	35.17	102.89	*NR*	23.13	31007.52	23.13	31007.52	268.21
Hardness	g	8096.52	3023.28	554.80	3117.29	204.98	138.50	457.30	*NR*	5171.04	14444.76	138.50	14444.76	150.96
De-IcingSalts	g	40809.60	7797.60	251.05	963.63	76.21	34.62	126.30	49.00	1587.60	57779.04	34.62	57779.04	428.63
BOD	g	408.97	50.62	32.46	181.41	15.53	7.56	18.83	20.63	144.02	210.04	7.56	408.97	50.79
COD	g	2483.02	1043.21	255.35	4019.00	130.33	79.89	235.20	223.82	1341.52	2951.08	79.89	4019.00	510.18
TSS	g	3082.52	563.96	683.79	1697.00	125.11	23.55	262.56	31.07	1994.52	2731.16	23.55	3082.52	554.22
NH4 N		6.23	3.67	0.79	5.81	1.34	0.65	0.43	1.42	1.68	7.31			
Total runoff during sampling perio	ltr	13080.00	13680.00	2774.00	58050.00	2628.00	1082.00	2722.00	2050.00	22680.00	42360.00	1082.00	58050.00	16110.60

Value < or = LOD reported in blue *italics*.
Average values include <LOD as 0.0
ND = Not Detected
NR = No Result (analysis unreliable)
IS = Insufficient Sample

Table 14 Composite sample event load –Highway Runoff

		Storm 1	Storm 2	Storm 3	Storm 4	Storm 5	Storm 6	Storm 7	Storm 8	Storm 9	Storm 10	Minimum	Maximum	Average
		BB-1-S-1	BB-1-S-2	BB-1-S-3	BB-1-S-4	BB-1-S-5	BB-1-S-6	BB-1-S-7	BB-1-S-8	BB-1-S-9	BB-1-S-10	> LOD	> LOD	
	Load													
Copper	mg/1000m2	101.78	46.08	4.19	0.00	7.63	3.90	8.85	5.48	0.00	118.08	0.00	118.08	29.60
Filtered Copper	mg/1000m2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	ND
Zinc	mg/1000m2	373.71	254.22	27.06	215.75	24.72	10.68	17.07	22.38	173.85	516.59	10.68	516.59	163.60
Filtered Zinc	mg/1000m2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	423.11	0.00	423.11	42.31
Cadmium	mg/1000m2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Aluminium	mg/1000m2	4025.78	6561.95	480.05	3033.97	186.19	36.44	41.10	345.24	500.49	2263.14	36.44	6561.95	1747.44
Lead	mg/1000m2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Platinum	mg/1000m2	0.00	0.00	0.00	0.00	36.63	15.08	0.00	0.00	0.00	0.00	1584.00	3072.00	5.17
Palladium	mg/1000m2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	mg/1000m2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	mg/1000m2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Simazine	ug/1000m2	0.00	31.78	0.00	0.00	0.00	0.00	47.42	0.00	0.00	0.00	1360.00	2685.00	7.92
Amitrole	ug/1000m2	ND	ND	ND	ND	IS	IS	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/1000m2	0.00	0.00	0.00	0.00	9.16	7.54	6.32	26.19	0.00	0.00	358.00	1694.00	4.92
Diuron	ug/1000m2	ND	ND	ND	ND	IS	IS	ND	ND	ND	ND	ND	ND	ND
Bromacil	ug/1000m2	ND	ND	ND	ND	IS	IS	ND	ND	ND	ND	ND	ND	ND
Atrazine	ug/1000m2	0.00	NR	0.00	0.00	18.31	10.05	56.91	0.00	0.00	0.00	1056.00	4282.00	8.53
Naphthalene	ug/1000m2	136.72	254.22	9.67	404.53	15.26	6.28	6.32	26.19	52.68	0.00	0.00	404.53	91.19
Acenaphthylene	ug/1000m2	60.77	143.00	3.22	134.84	67.15	22.62	6.32	0.00	0.00	0.00	0.00	143.00	43.79
Acenaphthene	ug/1000m2	151.92	317.77	3.22	606.79	33.57	38.96	3.16	0.00	0.00	0.00	0.00	606.79	115.54
Fluorene	ug/1000m2	60.77	238.33	3.22	67.42	48.84	32.67	3.16	2.38	0.00	0.00	0.00	238.33	45.68
Phenanthrene	ug/1000m2	273.45	158.89	9.67	337.11	244.18	82.94	9.48	4.76	0.00	0.00	0.00	337.11	112.05
Anthracene	ug/1000m2	364.60	619.65	9.67	67.42	91.57	32.67	12.65	0.00	0.00	0.00	396.00	619.65	119.82
Fluoranthene	ug/1000m2	926.69	699.09	16.11	404.53	85.46	33.93	6.32	9.52	0.00	98.40	0.00	926.69	228.01
Pyrene	ug/1000m2	805.16	651.43	12.89	404.53	119.04	42.73	3.16	7.14	0.00	147.60	0.00	805.16	219.37
Benzo(a)anthracene	ug/1000m2	501.32	1525.30	3.22	134.84	36.63	12.57	9.48	4.76	0.00	0.00	0.00	1525.30	222.81
Chrysene	ug/1000m2	501.32	1318.75	6.44	269.69	45.78	15.08	0.00	9.52	0.00	98.40	0.00	1318.75	226.50
Benzo(b)fluoranthene	ug/1000m2	881.11	1747.74	9.67	202.26	33.57	15.08	22.13	4.76	0.00	98.40	0.00	1747.74	301.47
Benzo(k)fluoranthene	ug/1000m2	455.75	556.10	9.67	202.26	21.37	8.80	15.81	7.14	0.00	98.40	0.00	556.10	137.53
Benzo(a)pyrene	ug/1000m2	911.50	778.54	19.33	471.95	51.89	18.85	0.00	11.90	0.00	196.79	770.00	911.50	246.08
Indeno(1,2,3-cd)pyrene	ug/1000m2	607.67	794.43	6.44	67.42	12.21	7.54	0.00	4.76	0.00	49.20	264.00	794.43	154.97
Dibenzo(a,h)anthracene	ug/1000m2	607.67	921.53	3.22	134.84	30.52	7.54	0.00	0.00	0.00	0.00	0.00	921.53	170.53
Benzo(g,h,i)perylene	ug/1000m2	455.75	1382.30	9.67	202.26	9.16	10.05	0.00	4.76	0.00	147.60	308.00	1382.30	222.15
Na	g/1000m2	3190.24	552.92	22.20	110.57	9.03	4.08	11.95	NR	2.69	3601.34	2.69	3601.34	750.50
Hardness	g/1000m2	940.36	351.14	64.44	362.05	23.81	16.09	53.11	NR	600.59	1677.67	16.09	1677.67	408.93
De-IcingSalts	g/1000m2	4739.79	905.64	29.16	111.92	8.85	4.02	14.67	5.69	184.39	6710.69	4.02	6710.69	1271.48
BOD	g/1000m2	47.50	5.88	3.77	21.07	1.80	0.88	2.19	2.40	16.73	24.39	0.88	47.50	12.66
COD	g/1000m2	288.39	121.16	29.66	466.78	15.14	9.28	27.32	26.00	155.81	342.75	9.28	466.78	148.23
TSS	g/1000m2	358.02	65.50	79.42	197.10	14.53	2.74	30.49	3.61	231.65	317.21	2.74	358.02	130.03
NH4 N	g/1000m2	0.72	0.43	0.09	0.67	0.16	0.08	0.05	0.16	0.20	0.85	0.05	0.85	0.34
Runoff during sampling period	ltr/1000m2	4503.00	7897.00	1533.00	16576.00	2973.00	1533.00	2079.00	1787.00	10000.00	15874.00	1533.00	16576.00	6475.50

Value < or = LOD reported in blue *italics*.
Average values include <LOD as 0.0
ND = Not Detected
NR = No Result (analysis unreliable)
IS = Insufficient Sample

Table 15 Composite sample event load / 1000m^2 paved area

6. BIOLOGICAL SURVEY

6.1 Methodology

Sampling was undertaken at four sites within Brinkworth Brook: one site upstream of the discharge and three sites downstream. The sampling sites were chosen to be as similar as possible with the stream bed at each site consisting of variable amounts of coarse gravel overlying a soft substrate. Sampling was undertaken at the four sites on three occasions: December 1997 ("late Autumn" sample); June 1998 ("late Spring" sample); and September 1998 ("late Summer" sample).

Invertebrates were sampled with a hand net using a standard three-minute kick sample (Furse *et al* 1981) with a one-minute search of surrounding emergent vegetation. Samples were preserved in alcohol in the field and returned to the laboratory where the animals were sorted from the debris, identified to family level and enumerated. Biological Monitoring Working Party (BMWP) scores and ASPT (Average Score Per Taxon) scores were calculated in the same way as used by the Environment Agency.

Data on BMWP score, ASPT and Total Number of Taxa were analysed statistically using WRc's LOBSTER software (Wyatt *et al* 1998), designed on behalf of the Environment Agency specifically for identifying spatial patterns in biological data. The LOBSTER software is based on WRc's LAPWING software (LOBSTER = "Lapwing On Biology: Spatial Trend Evaluation Routine"), which is concerned primarily with spatial trends in chemical quality between sampling points along a river.

Prior to embarking on the spatial analysis, the software reduces the within-site variation by removing any temporal variation that is common to all sites. This is achieved by standard Analysis Of Variance (ANOVA) techniques, considering both within-year (seasonal) variation and year-to-year variation. Year-to-year effects are not relevant to this analysis, since the survey programme has only yielded one year of data. Seasonal effects are detected by applying ANOVA to seasonal mean values (generated from data across all sites). If significant differences are found, the resulting model is used to correct for the seasonal component of the variation.

Following this 'detrending' exercise, the software carries out a spatial analysis which uses a methodical search procedure to find the most parsimonius grouping of sites, resolving spatial variations into a combination of step changes and linear trends that explains the highest proportion of site-to-site variation. It should be noted that in many cases there may be little statistical difference between fitting a step change and fitting a linear trend along a section of river, and for this reason outputs from the software should be regarded as indicative only. The very small sample sizes involved in the current assessment limit what can be achieved with the software, but the approach is still valid.

6.2 Results and Discussion

The survey results are presented in Tables 3.1 to 3.3, containing data on all families encountered in each sample during the survey. The results of the LOBSTER analysis on the data collected from Brinkworth Brook are presented in Figures 3.1 to 3.3 for BMWP, ASPT and Total Taxa respectively. Note that the graphs produced by the LOBSTER software are based on a standard 12 monthly axis, since multiple years of data are typically available for analysis and year-on-year plots are generated. For this reason Figures 3.1 to 3.3 do not reflect the chronology of sampling at Brinkworth Brook (December samples were taken in the year preceding the June sampling date). This does not affect the validity of the analysis, since the exact chronology of sampling is immaterial to detecting spatial differences between sites.

Figure 3.1a shows the spatial analysis carried out on the BMWP scores. The model fitted to the data (the two discrete horizontal lines) shows that there is a significant difference ($P<0.02$) in BMWP scores between the upstream site and the three sites downstream (although no differences in BMWP scores between the downstream sites is identified). In biological terms, the difference is not great (some 25 BMWP units), equating to the absence of 2 or 3 sensitive taxa downstream compared to upstream.

Superficially, this suggests that the untreated runoff is having a relatively small adverse effect on the macroinvertebrate community downstream. However, the results should be interpreted with caution, since the gravels of the upstream reach of the brook were of higher quality for macroinvertebrates than the downstream reaches, providing a greater proportion of coarse sediments on a firmer underlying substrate. This would tend to give the upstream site higher BMWP scores than downstream sites even in the absence of water quality impacts. Given these habitat differences (which are difficult to overcome in this type of spatail comparison) and the relatively small differences observed in BMWP score, it is not possible to say with any certainty that run-off from the motorway is having an impact on the macroinvertebrate community. If it is having an impact, it is only minor.

Figure 3.1b illustrates the seasonal effect on BMWP score. The bold solid line in the figure shows the seasonal model that has been fitted to the data. which demonstrates a clear tendency for depressed BMWP scores at all sites during the "late Summer" sampling round. One might expect a depression in scores in the autumn following the onset of rain, washing off pollutants accumulated during the dryer summer months. However, the depressed scores may also be explained, at least in part, by seasonal cycles in the macroinvertebrate community. Many species with annual life cycles become absent from samples during the summer. The presence of fewer insect taxa (Table 3.3), may be due to large individuals emerging from the river as aerial adults and the next generation of juveniles being too small to be sampled for some time. Again, the size of the seasonal differences is not large enough to discount natural seasonal patterns as the cause.

Figures 3.2a and 3.2b show the results of the analysis for ASPT. The model has fitted a linear trend to the "deseasonalised" data and shows a steady decrease in scores from the upstream to the downstream site. The spatial pattern of mean ASPT values is broadly similar to that of mean BMWP scores, and it is likely that there is little difference in the amount of variation accounted for by fitting a linear trend as opposed to a stepped change. between the control site and downstream sites. As with BMWP scores, given the habitat differences and the small changes in biological quality observed, it is not possible to attribute spatial changes in ASPT to the discharge of motorway run-off into the river. Again as with the BMWP scores, ASPT scores are depressed in the "late Summer" samples, with the same mechanisms being potentially responsible.

Figures 3.3a and 3.3b show the results for Total Taxa. Although the number of taxa recorded are generally higher at the upstream sites, LOBSTER has failed to detect any significant spatial trends in number of taxa. A larger number of samples in the analysis may have allowed the software to detect a difference between the upstream site and downstream sites, but in any case habitat differences would again be sufficient to explain the small differences involved. As with the BMWP and ASPT scores, the number of taxa are generally depressed in the "late Summer" samples.

In summary, there are small statistically significant differences in biological quality between sites upstream and downstream of the point of run-off entry, but of insufficient size to discount physical habitat and life cycle influences as the cause.

Table 3.1 Results from kick samples taken from Brinkworth Brook on 16/12/97

Family	(BMWP Scores)	Abundance Upstream	Downstream 1	Downstream 2	Downstream 3
Agriidae	*(8)*	13	4		4
Coenagriida	*(6)*	4			
Baetidae	*(4)*	2	4	3	
Caenidae	*(7)*	250	58	14	25
Ephemerida	*(10)*	2	2		
Goeridae	*(10)*	1			
Leptoceridae	*(10)*	17	10	8	6
Limnephilida	*(7)*	2	1	2	
Hydropsychi	*(5)*	21	17	20	28
Chironomida	*(2)*	93	40	10	30
Simulidae	*(5)*	15	150	52	57
Tipulidae	*(5)*	2		1	
Sialidae	*(4)*				
Dytiscidae	*(5)*				
Elmidae	*(5)*	59	106	25	50
Haliplidae	*(5)*				
Asellidae	*(3)*	109	40	47	20
Gammaridae	*(6)*	100	29	9	5
Ancylidae	*(6)*	4			4
Hydrobidae	*(3)*	11	11	8	5
Lymnaeidae	*(3)*	16	10	5	3
Planorbidae	*(3)*	2	4	3	1
Sphaeriidae	*(3)*	50	40	18	30
Unionidae	*(6)*	3		2	
Valvatidae	*(3)*	1	2		
Erpobdellida	*(3)*				2
Glossiphonid	*(3)*				
Oligochaete	*(1)*	20	18	15	65
Total taxa		23	18	18	16
BMWP		121	88	84	70
ASPT		5.3	4.9	4.7	4.4

Table 3.2 Results from kick samples taken from Brinkworth Brook on 11/06/98

Family	(BMWP Scores)	Abundance			
		Upstream	Downstream 1	Downstream 2	Downstream 3
Agriidae	*(8)*	12	1	1	2
Coenagriida	*(6)*			1	
Baetidae	*(4)*	28	1	2	2
Caenidae	*(7)*	88	68	76	90
Ephemerida	*(10)*				
Goeridae	*(10)*				
Leptoceridae	*(10)*	8			
Limnephilida	*(7)*	1	1		
Hydropsychi	*(5)*	16	6	8	
Chironomida	*(2)*	28	94	62	56
Simulidae	*(5)*	84	15	12	16
Tipulidae	*(5)*	16	25	8	16
Sialidae	*(4)*				
Dytiscidae	*(5)*				
Elmidae	*(5)*	12	64	20	34
Haliplidae	*(5)*				
Asellidae	*(3)*	8	8	8	22
Gammaridae	*(6)*	164	40	52	68
Ancylidae	*(6)*			1	2
Hydrobidae	*(3)*	12	12	6	26
Lymnaeidae	*(3)*	4	2	6	
Planorbidae	*(3)*	8	4	4	8
Sphaeriidae	*(3)*	140	158	116	86
Unionidae	*(6)*		1	2	
Valvatidae	*(3)*				
Erpobdellida	*(3)*	3		2	
Glossiphonid	*(3)*	1			
Oligochaete	*(1)*	24	38	9	52
Total taxa		19	17	19	14
BMWP		86	76	84	61
ASPT		4.5	4.5	4.4	4.4

Table 3.3 **Results from kick samples taken from Brinkworth Brook on 08/09/98**

Family	(BMWP Scores)	Abundance			
		Upstream	Downstream 1	Downstream 2	Downstream 3
Agriidae	*(8)*	6	5	2	5
Coenagriida	*(6)*				
Baetidae	*(4)*	3	2		
Caenidae	*(7)*	2			
Ephemerida	*(10)*				
Goeridae	*(10)*				
Leptoceridae	*(10)*				
Limnephilida	*(7)*				
Hydropsychi	*(5)*	27			18
Chironomida	*(2)*	30	27	27	8
Simulidae	*(5)*	2		4	2
Tipulidae	*(5)*	5	1	6	8
Sialidae	*(4)*		1		
Dytiscidae	*(5)*		1		
Elmidae	*(5)*	50	4	12	22
Haliplidae	*(5)*	2			
Asellidae	*(3)*	3	12	7	
Gammaridae	*(6)*	60	50	33	14
Ancylidae	*(6)*				
Hydrobidae	*(3)*	16	4	18	10
Lymnaeidae	*(3)*	10	5	35	2
Planorbidae	*(3)*	6	3	11	3
Sphaeriidae	*(3)*	30	5	14	8
Unionidae	*(6)*	1			
Valvatidae	*(3)*			5	1
Erpobdellida	*(3)*	3		4	2
Glossiphonid	*(3)*		4	3	1
Oligochaete	*(1)*	10		8	10
Total taxa		18	14	14	15
BMWP		77	57	56	58
ASPT		4.3	4.1	4.0	3.9

7. DATABASE

The database is a major component of the output of the overall study. It is a Microsoft Access 97 archive for all acquired data with basic manipulation and output tools.

The archive is table based with data for each location as listed below:

1. General site details	location, treatment devices, photographs etc.
2. Continuous data	rainfall,
3. Continuous data	river flow,
4. Monthly spot data	watercourse liquid samples, in-situ water quality measurements,
5. Storm event data	runoff flow,
6. Storm event data	discrete samples,
7. Storm event data	composite sample data,
8. Storm event data	continuous watercourse quality measurements,
9. Sediment data	analysis results,
10.Sediment data	particle size distribution,
11.Reports	individual site reports,
12.Reports	literature review.

All measured rainfall and flows for each site and each location are archived in individual tables.

All analytical results archived in combined tables for each data type.

Site codes and codes for rainfall events and monthly data have been created to facilitate interrogation of the Database. These are listed in the accompanying Database Manual.

Access to Database Tables is achieved by selection of the standard Microsoft Access screen Window, Unhide facility.

The Database output gives access to four folders through which there is access to the following:

General Site Details

Graphical Output

- Rainfall Histogram
- Compare Discrete Data for Runoff Monitoring Locations
- Compare Watercourse Storm Data
- Compare Watercourse Monthly Data

Tabular Output

- Composite samples: Location based
- Composite samples: Event based
- Sediment samples: Analysis results
- Sediment samples: Particle size

Associated Reports

- Site reports
- Final Report
- Literature Review
- Database Manual

APPENDIX A STORM EVENT COMPOSITE LIQUID SAMPLES - ANALYSIS SUITE

Polyaromatic Hydrocarbons	Units	LOD*	Metals	Units	LOD*
Napthalene	µg/l	0.01-0.05	Copper (total)	µg/l	4.0
Acenapthylene	µg/l	0.01-0.05	Copper (dissolved)	µg/l	4.0
Acenapthene	µg/l	0.01-0.05	Zinc (total)	µg/l	4.0
Fluorene	µg/l	0.01-0.05	Zinc (dissolved)	µg/l	4.0
Phenanthrene	µg/l	0.01-0.05	Cadmium	µg/l	4.0
Anthracene	µg/l	0.01-0.05	Aluminium	µg/l	40.0
Fluoranthene	µg/l	0.01-0.05	Lead	µg/l	50.0
Pyrene	µg/l	0.01-0.05	Platinum	µg/l	0.1
Benzo(a)anthracene	µg/l	0.01-0.05	Palladium	µg/l	0.1
Chrysene	µg/l	0.01-0.05	Nickel	µg/l	10.0
Benzo(b)fluoranthene	µg/l	0.01-0.05	Chromium	µg/l	10.0
Benzo(k)fluoranthene	µg/l	0.01-0.05	Sodium	mg/l	0.5
Benzo(a)pyrene	µg/l	0.01-0.05	**Hardness** ($CaCo_3$)	mg/l	0.5
Indeno(1,2,3-cd)pyrene	µg/l	0.01-0.05	**Chloride**	mg/l	0.2
Dibenzo(a,h)anthracene	µg/l	0.01-0.05	**BOD**	mg/l	1.0
Benzo(g,h,i)perylene	µg/l	0.01-0.05	**COD**	mg/l	20.0
			TSS	mg/l	1.0
Herbicides			**NH_4-N**	mg/l	0.05
Glyphosate	µg/l	0.1			
Diuron	µg/l	0.01			
Bromacil	µg/l	0.02			
Simazine	µg/l	0.02			
Amitrole	µg/l	0.1			

* LOD stated is subject to quantity of sample available for analysis

APPENDIX B SEDIMENT SAMPLES - ANALYSIS SUITE

Polyaromatic Hydrocarbons	Units	LOD*
Napthalene	µg/gx10^3	0.01-0.1
Acenapthylene	µg/gx10^3	0.01-0.1
Acenapthene	µg/gx10^3	0.01-0.1
Fluorene	µg/gx10^3	0.01-0.1
Phenanthrene	µg/gx10^3	0.01-0.1
Anthracene	µg/gx10^3	0.01-0.1
Fluoranthene	µg/gx10^3	0.01-0.1
Pyrene	µg/gx10^3	0.01-0.1
Benzo(a)anthracene	µg/gx10^3	0.01-0.1
Chrysene	µg/gx10^3	0.01-0.1
Benzo(b)fluoranthene	µg/gx10^3	0.01-0.1
Benzo(k)fluoranthene	µg/gx10^3	0.01-0.1
Benzo(a)pyrene	µg/gx10^3	0.01-0.1
Indeno(1,2,3-cd)pyrene	µg/gx10^3	0.01-0.1
Dibenzo(a,h)anthracene	µg/gx10^3	0.01-0.1
Benzo(g,h,i)perylene	µg/gx10^3	0.01-0.1
Weathered Diesel/Carboxylic Acids	mg/kg	1.0

Metals	Units	LOD*
Copper	µg/g	0.25
Zinc	µg/g	0.1
Cadmium	µg/g	0.1
Aluminium	µg/g	1.0
Lead	µg/g	1.0
Platinum	µg/g	2.0
Palladium	µg/g	2.0
Nickel	µg/g	0.5
Chromium	µg/g	0.1
Organic content	%	0.1

* LOD stated is subject to quantity of sample available for analysis

APPENDIX C RAINFALL

Hourly Average Rainfall

Brinkworth Brook Hourly Average Rainfall (mm)

Hookers Gate Farm

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
December																									
15	2.5																2.5								
17	1.5														0.2	0.2			0.4	0.4	0.2				
18	8					0.4	2.6	0.6	0.3	1.7	1.8		0.4				0.2								
19	0.2									0	0.2														
22	4.9																0.1	1.6	0.6	0.9	0.5	1.1			0.2
23	3		0.2													0.4	1.9	0.2						0.2	
24	8.5		0.2						0.6	2	0.4	0.4	1.7	2.1	0.6	0.4									
25	10.6										1.8	4.8	0.2		0.4	0.2				0.2	0.2			2.5	0.2
26	5.3	1.1			0.4	2.4	1.4																		
27	0.2															0.1	0.1								
28	0.4								0.2				0.2												
29	0.6										0.2								0.2			0.2			
30	5.9																			0.4	0.4	0.6	1.2	1.7	1.5
31	1.2	1	0.2																						

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
January																									
1	13.1														0.2		1.4	1.7	2	6.8	0.2	0.9			
2	6.6					0.7	2.4	1.7			0.4	0.9	0.4												
3	16.9			0.2	2.3	2.8	2.5	0.9	1.1	0.2	0.6	0.4	1.3		0.4	0.2	0.2	0.4						1.9	1.5
4	8.3		0.5	0.3				1.8	0.2	2.7	0.6	0.1	0.3		0.2	0.8	0.6								
5	9.9	0.2		0.1	0.1			2	0.8	1.1	3.2	0.6				0.2	1.7								
6	8.4										0.2		0.4				2.5	1.6	1.4	1.9	0.2				0.2
7	3	0.3			1.9					0.6							0.2								
8	0.6						0.2			0.2		0.2													
9	0.2				0.2																				
13	4.3									0	0.2		0.2		0.2				0.4	1.2	0.6	0.8	0.4		0.2
14	0.6	0.2	0.2	0.2																					
15	2.4	0.4	1.1	0.2	0.2				0.4																
16	0.2						0.2																		
17	0.9																			0.2			0.4	0.2	
18	15		0.2	0.4		2.3	0.6		1.9	3.2	0.8	0.2	0.6	1.4	2.4	0.2	0.6								
19	0.2												0.1	0.1											
21	1.1								0.2	0.4	0.2			0.2											
22	0.2							0.2																	
30	0.2						0.2																		

February																									
4	0.2											0.2													
7	4.9	1.1	1.5	2.1				0.2																	
20	0.2																					0.2			
21	5.3										0.6	1.9	2.4	0.1								0.2			
23	1.3								0.2	0.6	0.4														
24	0.2													0.2											
26	0.2																				0.2				
27	0.4										0.2												0.2		
28	1.7																								1.7

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
March																									
1	0.4				0.2	0												0.2							
2	6.8																		0.4	0.3	0.3	0.9	2.3	1.6	0.9
3	15.6	0.6	0.2		0.3	4	2	1.1	1.2	0.5	0.5	0.6	0.8	0.5				0.2	1.9	0.2		1	0		
4	4.1	0.8	1.3	0.6			0.2					0.2							0.4			0.4			
5	2.3															0.3	1.4		0.4			0.1	0.1		
6	16.1		0.2	0.6	0.9	0.4	1.1	0.6	2.4	1	0.4	0.2	0.3	0.7	1.4	1	0.6	0.3	0.5	0.4	0.2	0.2	0.2	0.5	1.6
7	6.4	1.1	1.3	1.7					1.5													0.8			
8	0.9						0	0.3	0.3				0.2												
10	3.2												0.2	0.3	0.3	0.4				0.2		0.1	1.4	0.2	
11	0.9	0.4	0		0.2					0.2															
13	0.2						0.2																		
24	1.9									0.6	0.1											0.2	0.3	0.1	0.6
25	9.8	0.4	0.2	0.3	0.5	0.8	1	1	1	0.6	0.5	1	0.4	0.2										0.4	1.3
26	4.7	0.9	0.8	0.9	0.2	0.1	0.1		0.6	0.6	0.2													0.2	
28	0.4										0.2		0.2												
29	0.6													0.2	0.2					0.2					
30	0.2																	0.2							

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
April																									
1	1.7													0.4								1.1			0.2
2	3.2																				0.2	1.8	0.6	0.5	0.1
3	8.7			1.7		0.4	0.2		0.9		0.1	0.4	0.7			0.2		1.2	0.7		0.4	0.6	0.4	0.3	0.3
4	4.7		0.6			0.3	0.3						0.2			1.1			1.1		0.8	0.3			
5	3.2												1		0.9	0.8			0.2			0.2			
6	0.2				0.2																				
7	7.2					0.2	0.2			0.2				0.1	0.6	4.2	0.2		0.8	0.3	0.4				
8	7									0.8	0.2		0.6	3.2		1.1	0.6	0.4							
9	16.9		1.1	0.2	0.1	0.1	0.2	1.5	4.1	2.4	0.8	5.2	1.1												0
10	3.6	0.2	0.2						0.2	0.3	0.3				0.3	0.6		0.3	1.2	0					
11	1.1			0.2	0.2		0.6																		
12	0.2								0.2																
13	0.9								0.2									0.3	0.1	0.2					
14	14.2						0.2	0.7	3.1	0.4						0.6	0.9	0.4	1.5	2.5	2.9	0.7	0.1	0.1	
15	4.3									0.2	1.6	1.2	0.6	0.5	0.2										
16	0.6										0.2								0.2	0.2					
18	1.1															0.4	0.6								
19	6.6							0.2					0.4	0.3	1.7	0.5	0.8	0.2	0.4	2.1					
20	0.4														0.4										
21	0.9					0.2		0.2										0.2							0.2
22	4.5	0.2	0.2							0.2					0.4	1.3	0.4					0.1	0.3	0.3	1
23	6.1										0.2	0.6	2.5	1.1	1.1	0.4	0.2								
24	0.9										0.2	0.2		0.4											
25	14.3	0.3	0.4	0.9	3.6	3.7	2	1.7	0.2									1.7							
26	6.6						0.4	0.8	2.9	0.6	0.2		0.2	0.1	1	0.2									
27	2.5																2.1		0.2	0.2					
28	0.8															0.1	0.8								
29	2.4															0.1	1	0.2	0.3	0.6		0.2			

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
May																									
1	0.9																				0.2	0.2		0.4	
2	0.2			0.2																					
3	0.2						0.2																		
4	0.2							0.2																	
6	0.4		0.2		0.2																				
8	0.2															0.2									
9	0.2																								0.2
10	0.4																							0.2	0.2
11	7.8		0.3	3.3	0.6	0.2	0.4	2.1	0.6			0.2													
14	0.4	0.2	0.2																						
20	1.1																				0.8	0.2			
23	0.4																0.2			0.2	0				
25	5.3																	3.8	1.2	0.3					
26	36.3					0.2				0.2									0.2	18.3	2.4	4.3	8	2.5	0.2
27	0.6			0.4	0.2																				
28	2.4			0.3	1.1	0.6		0.2	0																
29	0.4	0.4																							
31	0.4			0.2	0.2																				

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
June																									
1	0.7																					0.2	0.2		0.3
2	22.3	2.7	2.9	2.4	1	1	1.5	1.7	2.3	0.2	0.6	0.6			0.2		2.7	1.5	0.8						
3	10.3					0.5	1.4				2.9	2.3	2.5	0.2	0.2	0.2									
5	0.2																							0.2	
6	0.2														0.2										
7	0.2										0.2														
8	8.1												0.2		1.4	1.5	2.5	0.9	1.2	0.3					
9	7.6	0	0.8	0.2	0.4												1.7	4.2	0	0.2					
10	1.5							0.4	0.4		0.2	0.3													0.2
11	5.3	2.5	0.9		0.2					0.2		0.6	0.5	0.4											
12	0.4																0.4								
13	11.8			0.6		0.2			0.2			0.1	4.1	2.2	3.2	0.2	0.2	0.6							
14	12.8												2.4	0.2	8.4			0.1	1	0.2	0.4	0.2			
16	0.4																0.4	0							
17	5.9											0.2	4.6							0.3	0.6	0.2			
18	3.7				0.2				0.2	0.3	0.4	0.2		0.6	1.2	0.3	0.2								
20	0.6								0.4	0.2															
23	4.1					0.4	0.4	0.2				0	0.2	0.2	0.2	0.9		1.5							
24	0.2																0.2								
25	5.3															0.4		0.2	4.2	0			0.4		
26	17.2						0.4	0.9	2.5	1.1	1.3	0.4	0.2		0.3	2.9		0.4	0.2	0.2	3.9	0.8	1.7		
27	8	3	4.3										0.2		0.4										
29	9.8																			2.4	2.8	2.7	1.2	0.3	0.4
30	0.3	0		0.2																					

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
July																									
6	0.4						0.2		0.2																
7	0.2						0.2																		
8	0.2																								0.2
9	0.2	0.2																							
10	0.9									0.7	0.1														
11	5.1														0.2	1.1	1.2	1.1	0.6		0.2	0.2	0.2		0.2
12	6.1							0.4	1.5	1.7	1.3		0.2	0.4	0.7										
16	4.2	0.2	1.1	2	0.4	0.4																			
17	1.3				0.2	0.8				0.2															
19	0.4					0.4																			
20	2.3																							0.8	1.5
21	3.6	2.1	0.4										0.2		0.4	0.3			0.2						
22	1.1																		1.1						
23	0.4			0.2	0.2																				
26	0.2																						0.2		
29	2.1					0.4	0.4		0.2		0.6		0.4												
30	1.7											0.2					0.2		0.5	0.7					

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
August																									
1	16.4													2.9	11.4	0.4		0.2	0.2		0.6	0.2	0.5		
3	4.1							0.5	1.4	0.3	1.1	0.6											0.2		
5	0.2						0.2																		
15	1.5	0.7	0.4	0.4																					
17	0.2																0.2								
20	0.4																		0.2				0.2		
21	1.3		0.3	0.1						0.8															
23	6.8								0.9	0.6			0.6	3	1	0.2		0.2	0.2						
25	0.2																								0.2
26	0.2		0.2																						
31	1.1																						0.2	0.9	

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
September																									
1	3.8			0.6		0.4	0.2					2.5													
2	7.7																			0.2	1.2	2.5	1.6	1.1	1
3	1.3	0.7	0.3	0.2																					
4	6.8																		0.2	0.6	1.6	0.7	1.6	1.3	0.7
5	5.5	0.8	1.5	0	0.4	0.2	0.2		2.1		0.2														
6	0.4																		0.2			0.2			
7	1.5						0.2									0.4	0.4					0.2		0.2	
8	2.8					1	0.7			0.4	0.6														
9	12.6		0.2				3.1	2.5		1.3	0.6	4.2	0.6												
10	0.6					0.2																		0.4	
11	0.2										0.2														
12	9.8							0.9	2.8	2.1						0.8	0.6	1.9		0.4					0.1
13	1.1	0.9													0.2										
15	0.6								0.4	0.2															
25	2.4																								2.4
26	14.9	0.6	0.8									0.4	2.3			5.5	2.5	0.5	0.8	0.5		0.2	0.3	0.4	0.2
27	12.3	0.4	0.6	1	1	1.4	0.2	0.2	2.3	1.2	2.6	1.3													
28	11.4																				0.4	0.2		9.7	1.1
29	0.4						0.2																		0.2
30	5.1	1.1	0.6		0.4	1.5				0.2	0.1	0.1							0.4	0.4		0.2			

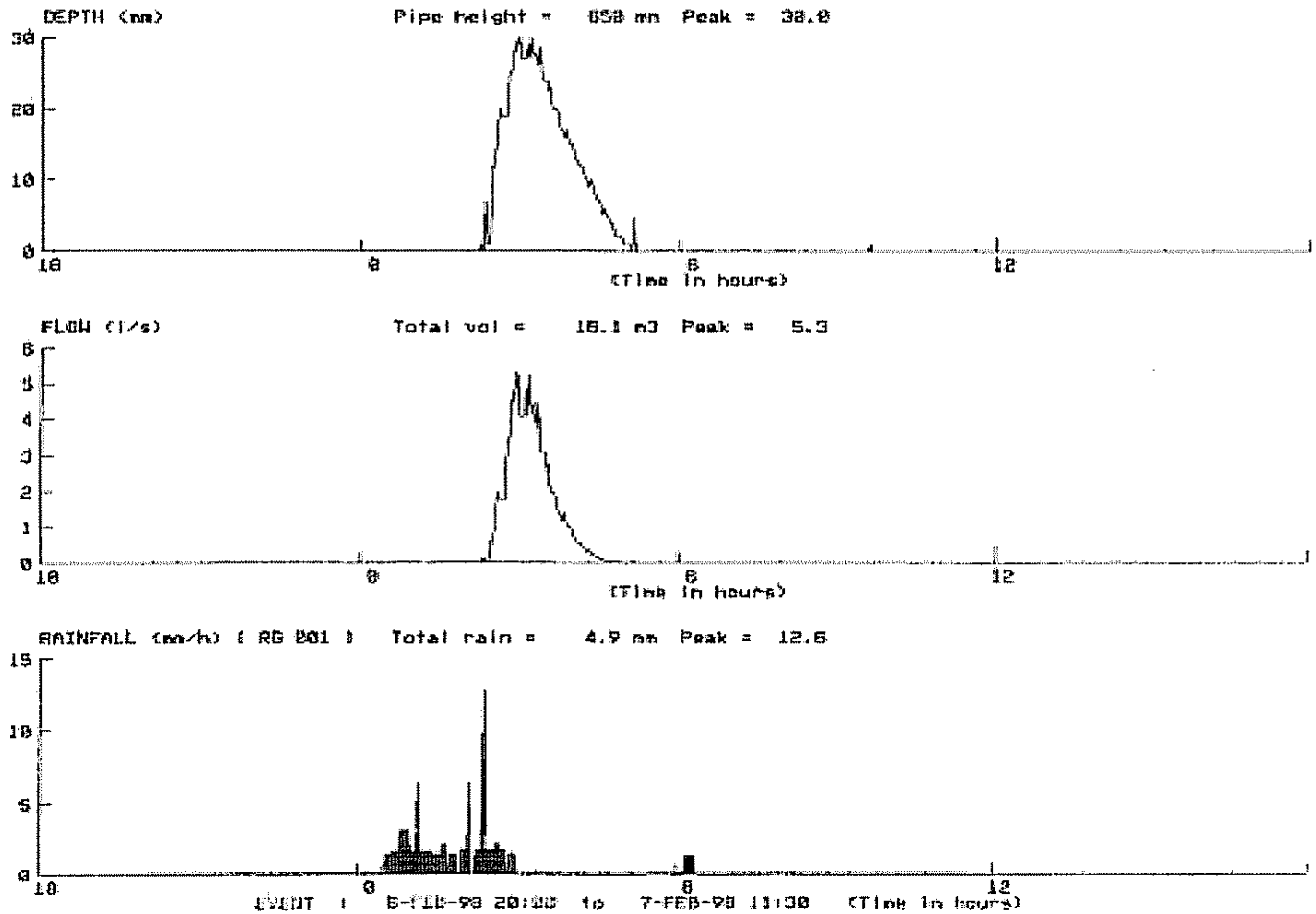
Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
October																									
1	1.3				0.4			0.2								0.4			0.2						
2	1.3										0.6	0.2	0.3	0.2											
4	0.4																		0.2			0.2			
5	0.4															0.2									0.2
6	2.8	0.7	0.6		0.5	0.4		0.4	0.1	0.1															
9	2.1															0.2	0.2		0.9	0.4	0.2	0.2			
11	1.3				1.1	0.2																			
13	4.4						0.1	2.4	1.5						0.2	0.1	0.1								
14	1.5			0.2			0.1	0.1	0.6	0.5															
16	10.3								1.3											0	1.3	3.5	1.8	1.9	0.6
17	11.8	0.4	3.6	3.6	2	1.8	0.4																		
20	0.6																							0.2	0.4
21	4.9	0.6	0.9	0.4	1.3	0.6	0.8				0.2														
22	9.8							0.4			0.4				0.1	4.5	0.2	0.9	0.1				0.2	0.4	2.5
23	13.5	3.6	1.7	1.3	0.2	3				3.6										0.2					
24	30.9						0.2	0.6	1.2	1.4	4.6	4.8	5.2	3.7	1.3	2.8	0.3			0.3	4.4				
26	2.4			0.6	0.1	0.1							0.2	0.3									0.2	0.4	0.4
27	9.6	0.2		0.2							0.7	0.8	2.7	1.7	1.1	0.8		0.4	0.2	0.2			0.4		0.1
28	4	0.2	0.6	0.8	0.4	1.2	0.1									0.4						0.2			
30	0.6																								0.6
31	29.9						0.9	0.8	0.3	1.5	2.6	1.4	3.7	2.1	1.1	0.4	0.2	2.2	1.8	1.3	3.4	2.9	2.4	0.9	

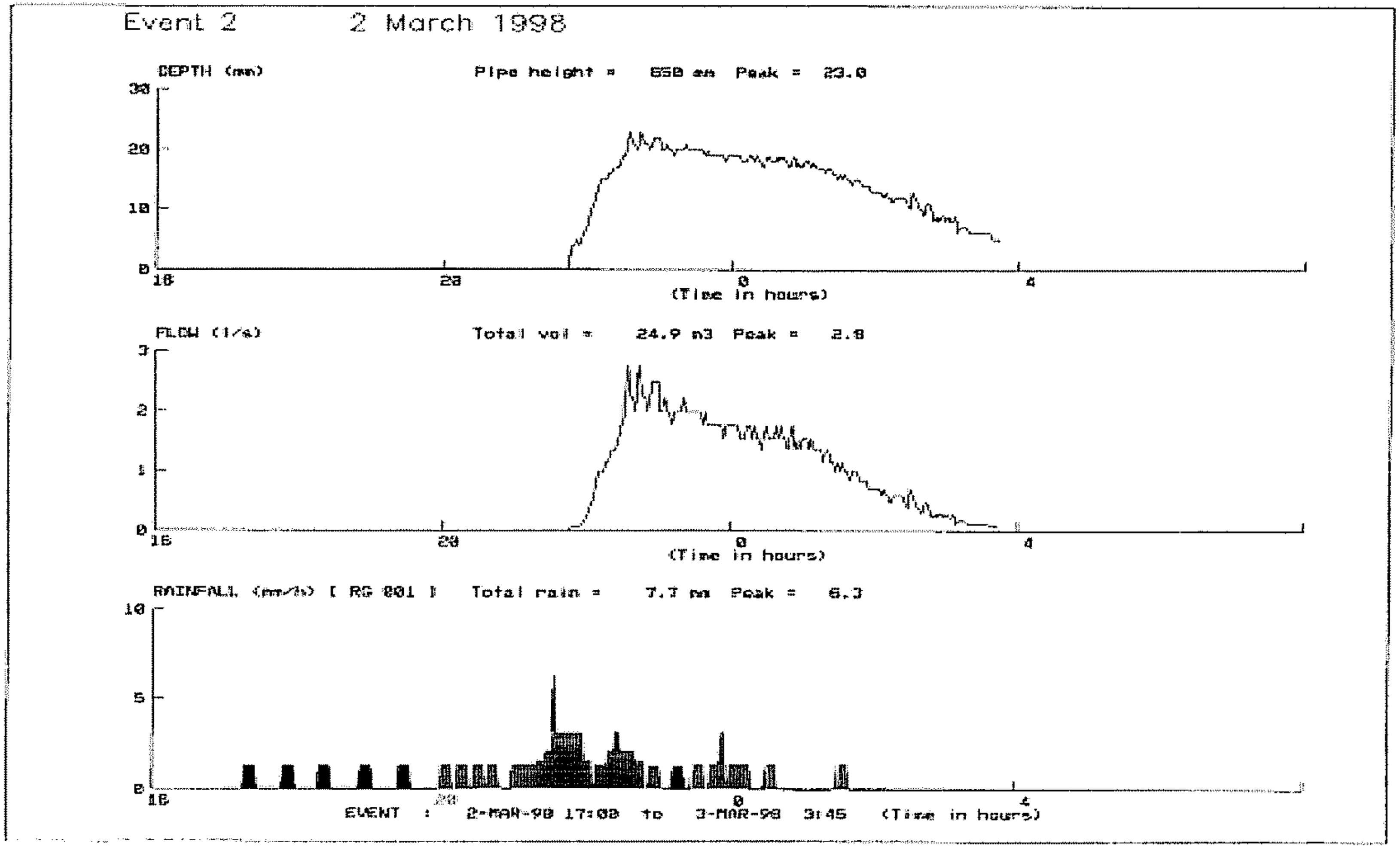
	mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
November																									
2	18		0.1	0.8	0.2	0.3	0.3							1.4	3.5	6	0.3					0.8	1.4	2	1
3	5.2	3	1.1	0.4		0.4											0.2								
4	0.2									0.2															
5	0.9												0.6	0.2											
8	15.2			0.9	0.6	1.7	2.3	2.9	1.3												0.6	0.9	0.2	1.7	2.1
9	4.5	1.5	1.6	0.6	0.4	0.2																			
10	2.5		0.5	1.8			0.2																		
11	0.6																							0.4	0.2
12	4.7	0.6	0.6	1.8	1.2						0.2		0.2												
13	1.8																						0.2	0.5	1.1
14	2.5	1.6	0.6							0.2															
17	0.2											0.2													
24	4.5							0.2	0.4	0.6	0.9	0.2	0.5	0.8	0	0.2		0.2	0.4						
25	0.4										0.2							0.2							
26	0.2																								0.2
27	0.9									0.6									0.1	0.1					
28	5.3									2.3	1.2	1.6					0.2								
29	0.2												0.2												
30	0.2											0.2													

Day	Day Total mm.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
December																									
1	0.2										0.2														
3	0.2																								0.2
4	1.5				0.4	0.9	0.2																		
5	0.4																0.3	0.2							
6	0.2													0.2											
8	5.1					0.1	0.1	0.1	0.1			0.4	2.6	0.6	0.4	0.6									
9	0.4					0.2					0	0.2													
10	5.7								0.2	0.2				1.8	1.1	1.1	0.8	0.2					0.2		
11	0.9																	0.2	0.4				0.2		
12	4.7		0.1	0.1									0.5	0.2		1.9	1.2	0	0.2	0.2	0.3				
13	1.3	1.1								0.2															
15	7				0.4	0.2				0.6	0.4	0.2			1.2	1.4	2.5								
16	0.2		0.2	0																					
17	2.4																						0.6	1.3	0.5
18	8.4																0.2	1.7	5.3	0.6	0.2	0.4			
21	0.4													0.4											

APPENDIX D GRAPHICAL PLOTS OF DEPTH, FLOW AND RAINFALL AT THE HIGHWAY RUNOFF MONITORING LOCATION FOR STORM EVENTS 1 TO 10

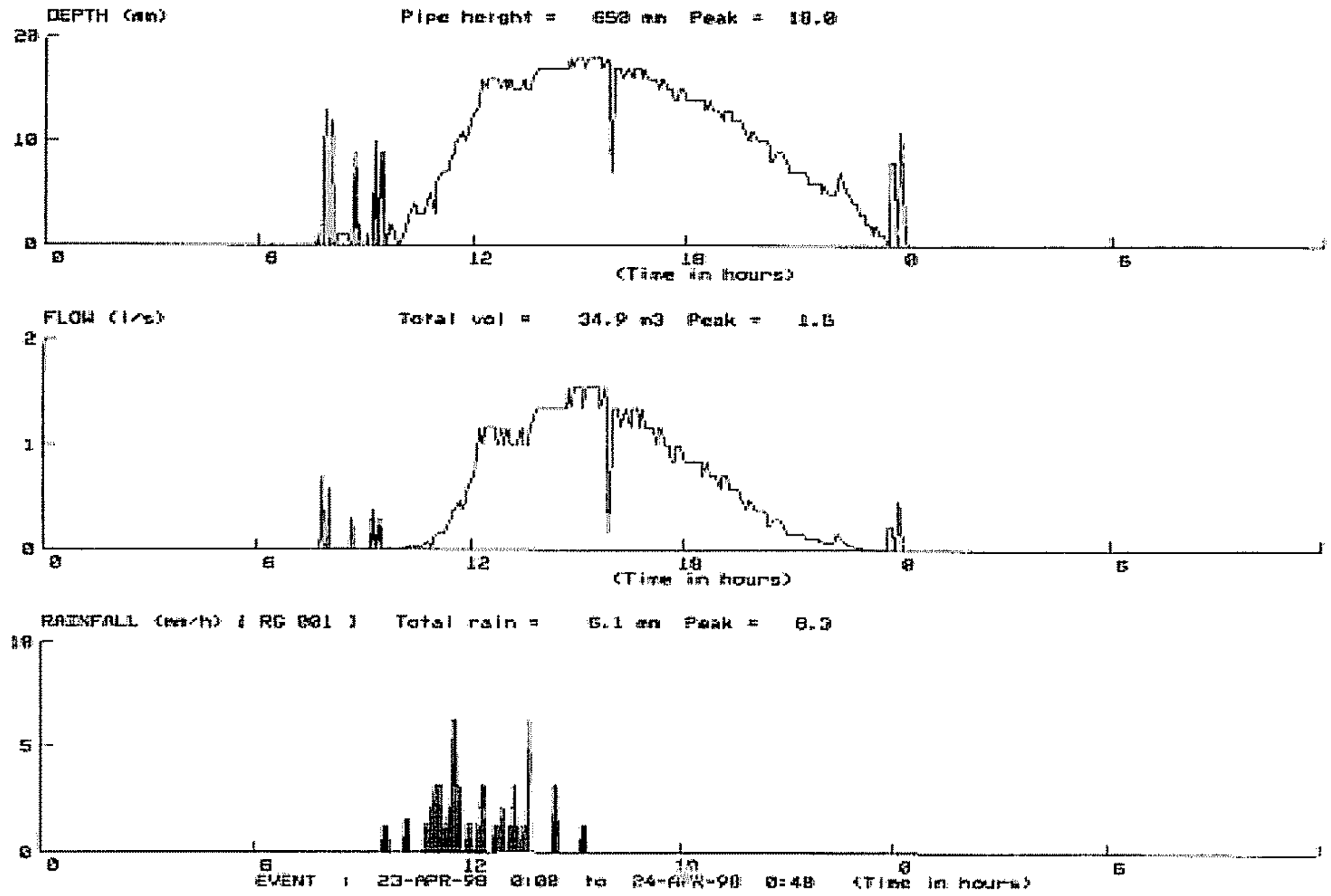
Event 1 7 February 1998

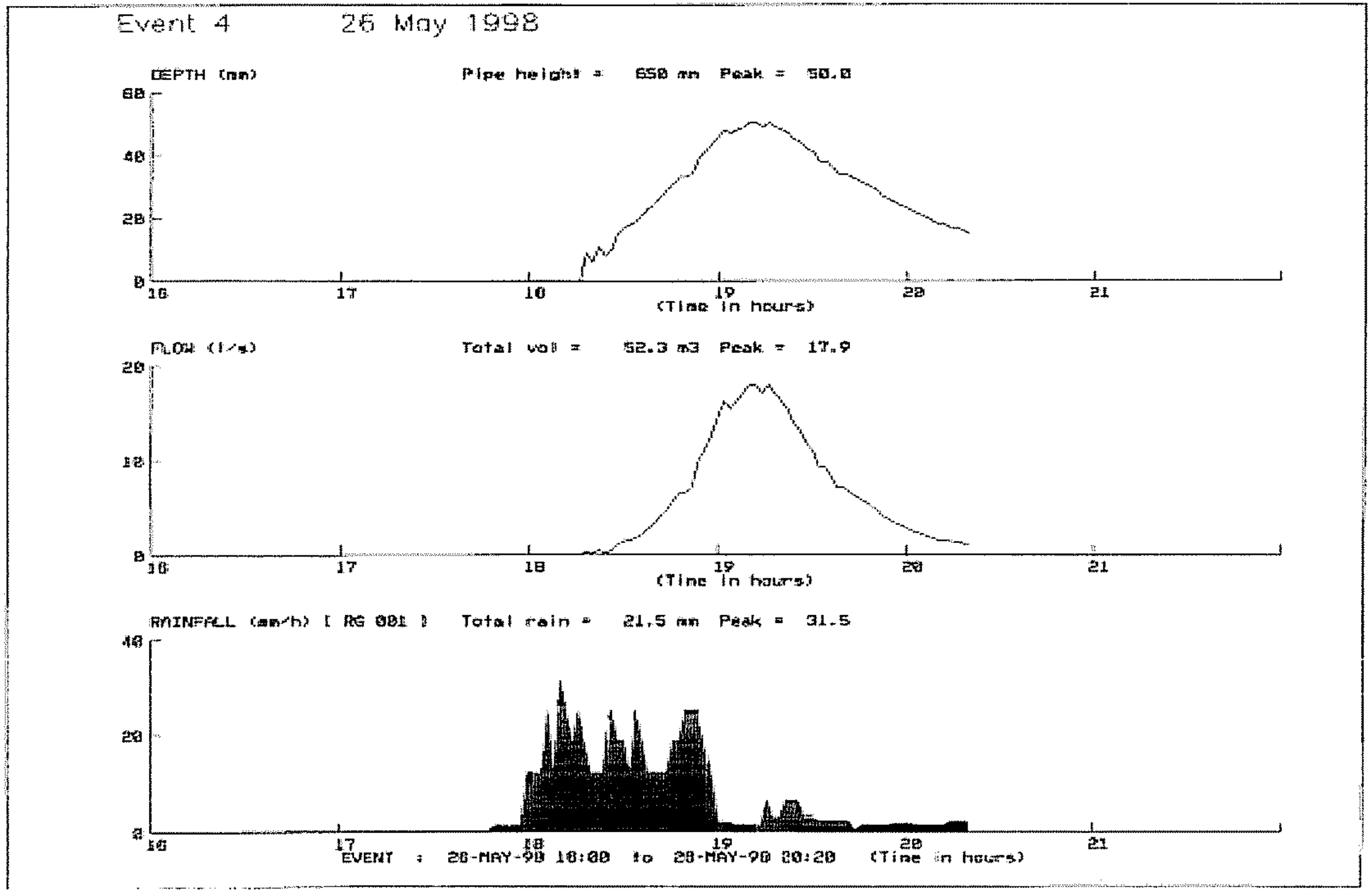


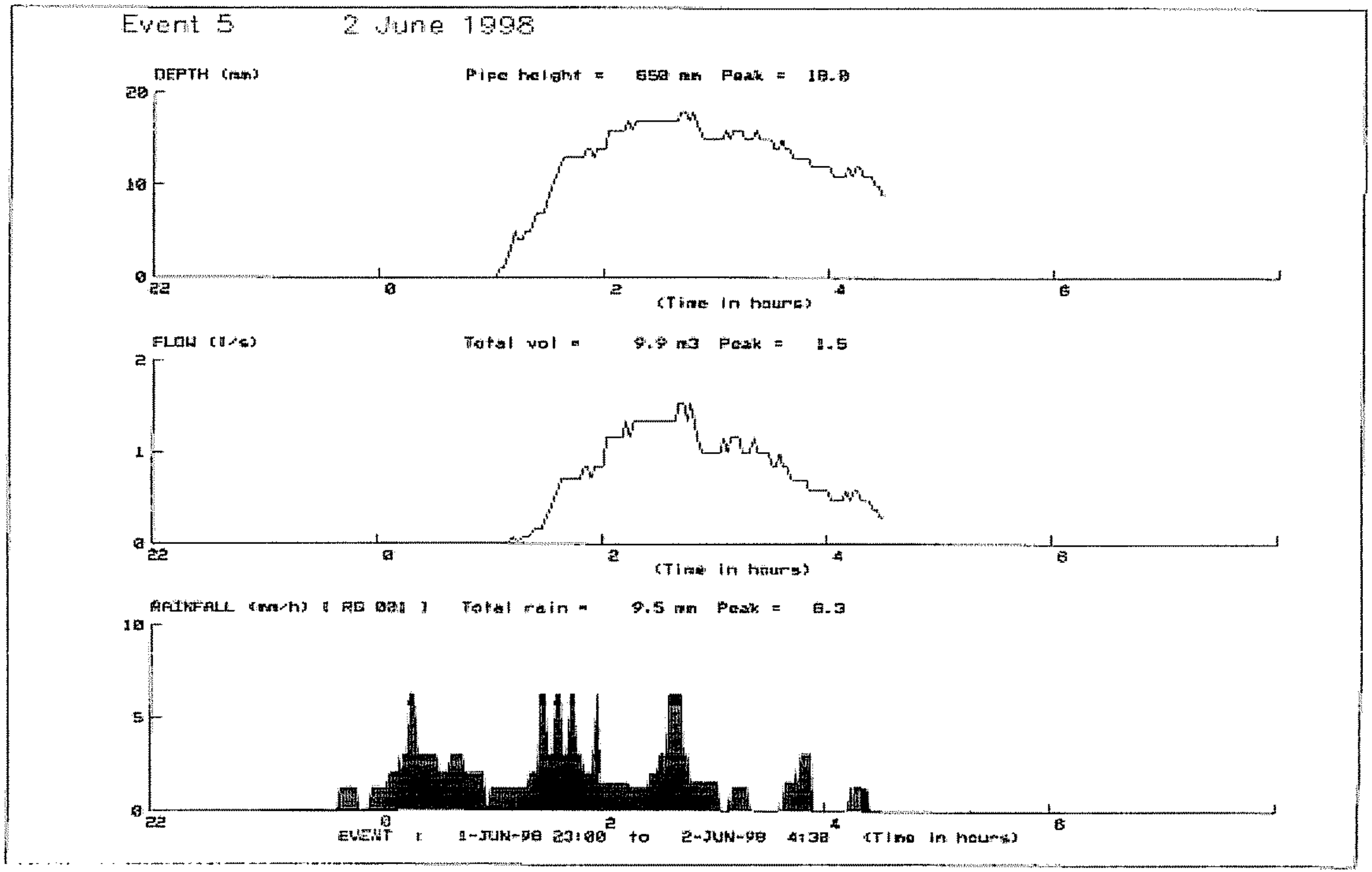


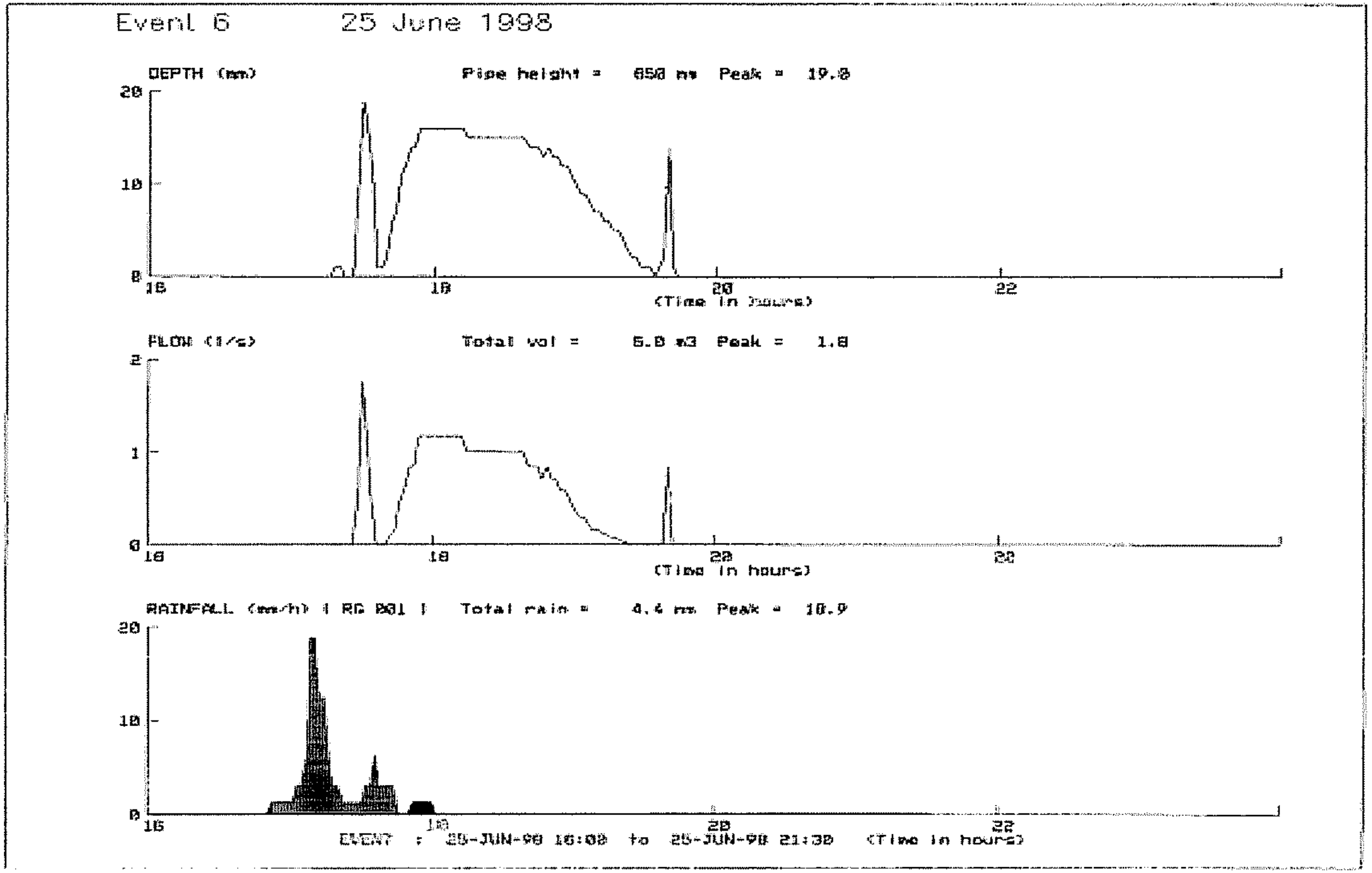
Event 2 2 March 1998
DEPTH (mm)
Pipe height = 650 mm Peak = 23.0
30
20
10
0
16
20
0
4
(Time in hours)
FLOW (l/s)
Total vol = 24.9 m3 Peak = 2.8
3
2
1
0
16
20
0
4
(Time in hours)
RAINFALL (mm/h) [RG 001] Total rain = 7.7 mm Peak = 6.3
10
5
0
16
20
0
4
EVENT : 2-MAR-98 17:00 to 3-MAR-98 3:45 (Time in hours)

Event 3 23 April 1998

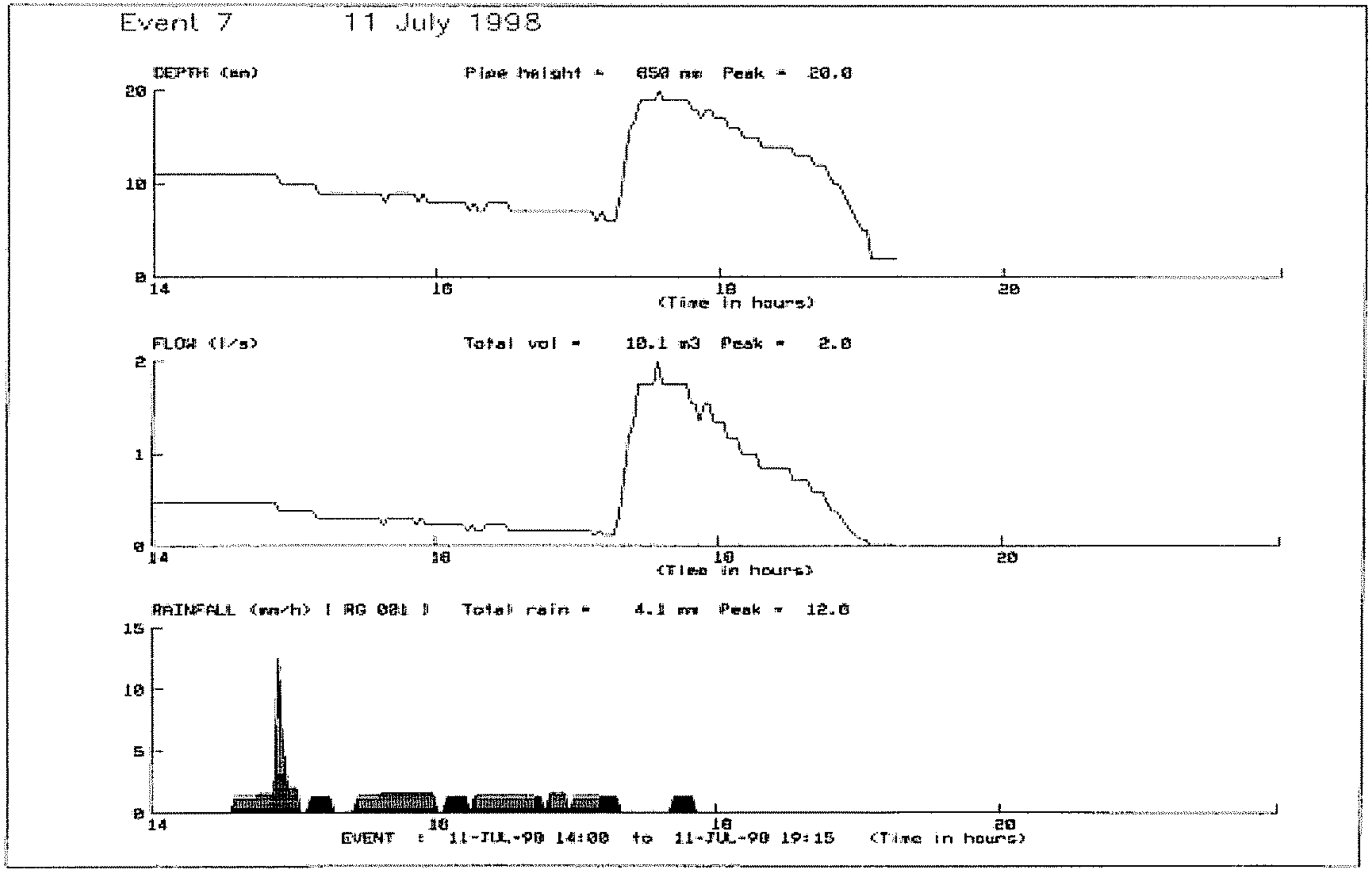


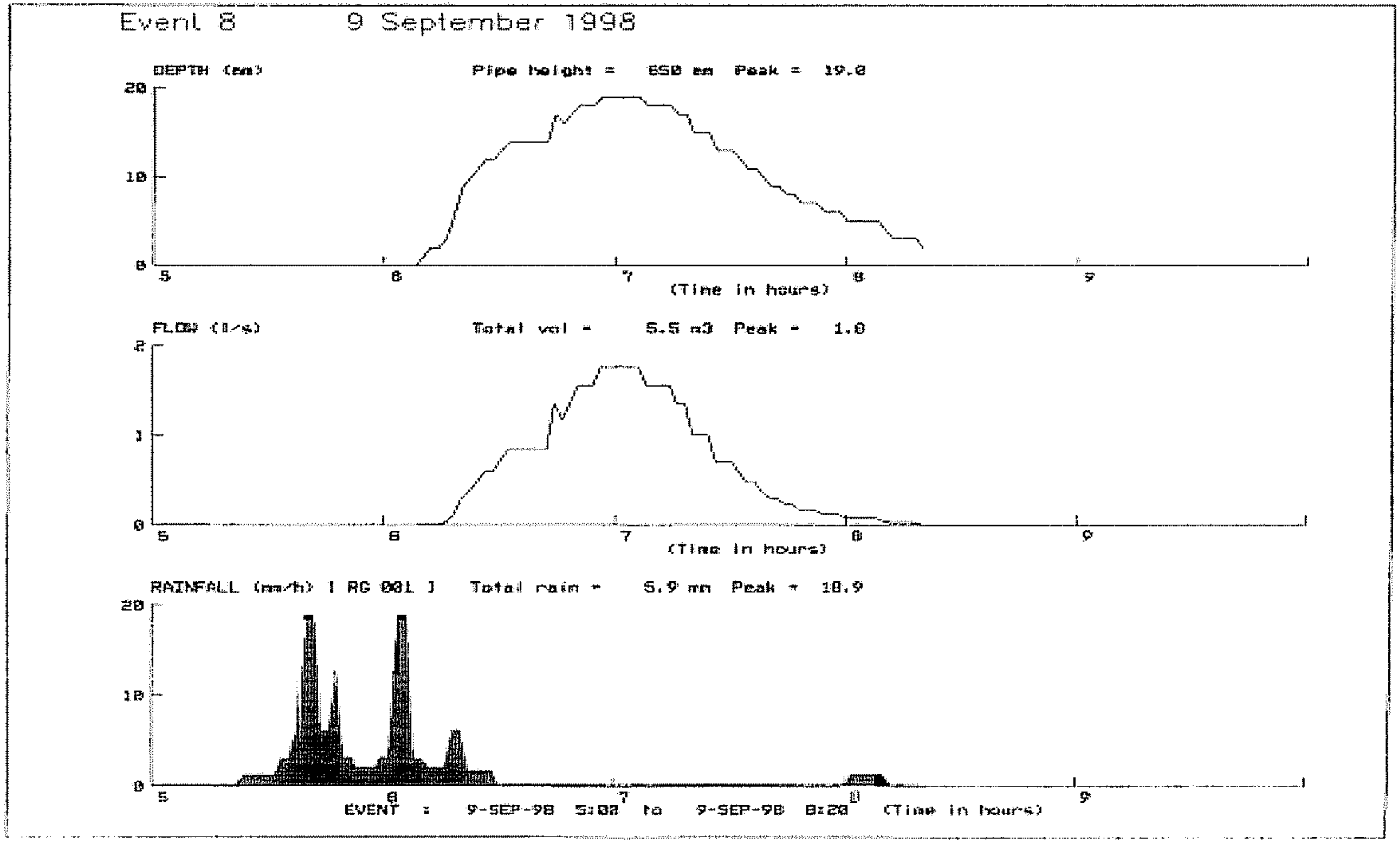

Event 4 26 May 1998
DEPTH (mm)
Pipe height = 650 mm Peak = 50.0
(Time in hours)
FLOW (l/s)
Total vol = 52.3 m3 Peak = 17.9
(Time in hours)
RAINFALL (mm/h) [RG 001] Total rain = 21.5 mm Peak = 31.5
EVENT : 26-MAY-98 18:00 to 26-MAY-98 20:20 (Time in hours)

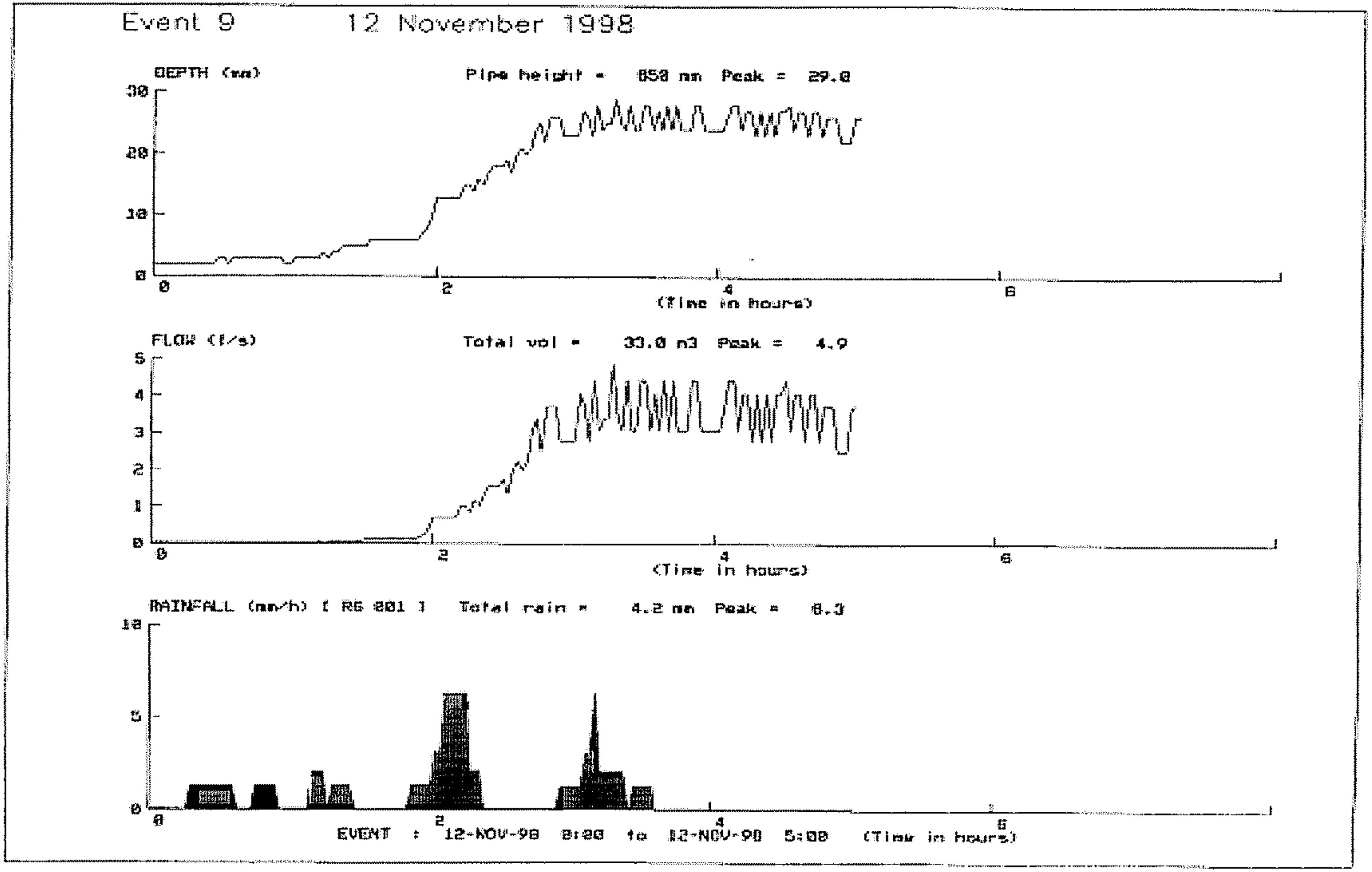

Event 5 2 June 1998
DEPTH (mm)
Pipe height = 650 mm Peak = 18.0
(Time in hours)
FLOW (l/s)
Total vol = 9.9 m3 Peak = 1.5
(Time in hours)
RAINFALL (mm/h) [RG 001] Total rain = 9.5 mm Peak = 6.3
EVENT : 1-JUN-98 23:00 to 2-JUN-98 4:30 (Time in hours)

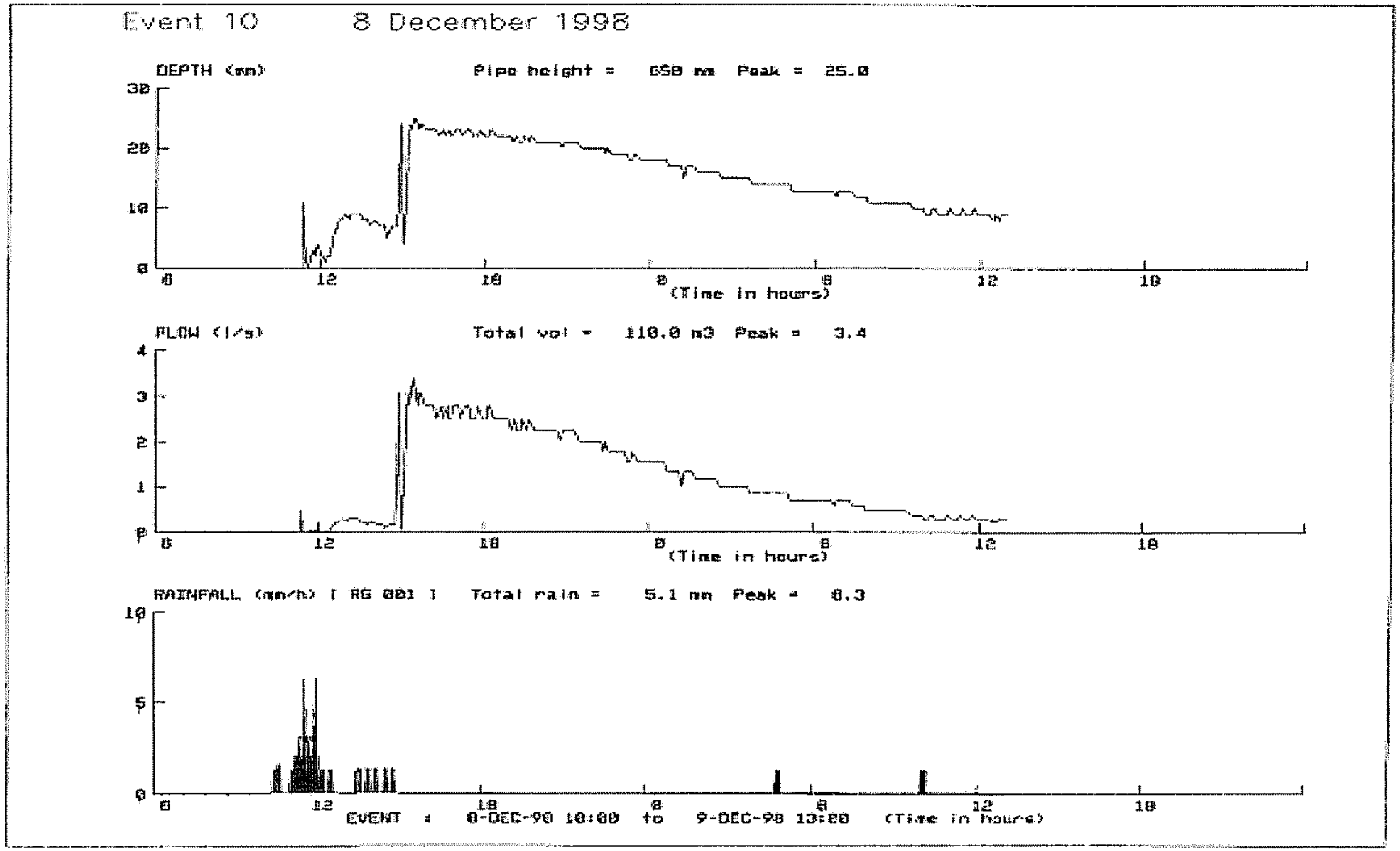


Event 6 25 June 1998
DEPTH (mm)
Pipe height = 650 mm Peak = 19.8
(Time in hours)
FLOW (l/s)
Total vol = 6.0 m3 Peak = 1.8
(Time in hours)
RAINFALL (mm/h) [RG 001] Total rain = 4.4 mm Peak = 18.9
EVENT : 25-JUN-98 16:00 to 25-JUN-98 21:30 (Time in hours)

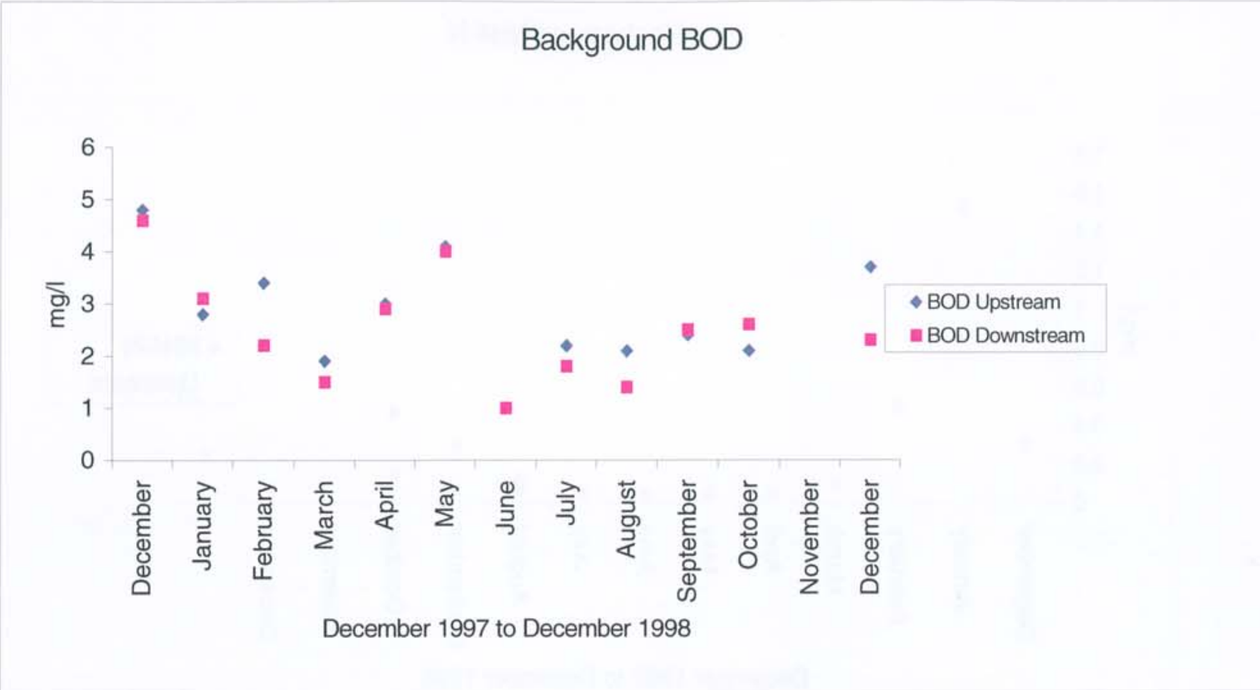

Event 7 11 July 1998
DEPTH (mm)
Pipe height = 650 mm Peak = 20.0
20
10
0
14
16
18
20
(Time in hours)
FLOW (l/s)
Total vol = 10.1 m3 Peak = 2.0
2
1
0
14
16
18
20
(Time in hours)
RAINFALL (mm/h) [RG 001] Total rain = 4.1 mm Peak = 12.0
15
10
5
0
14
16
18
20
EVENT : 11-JUL-98 14:00 to 11-JUL-98 19:15 (Time in hours)

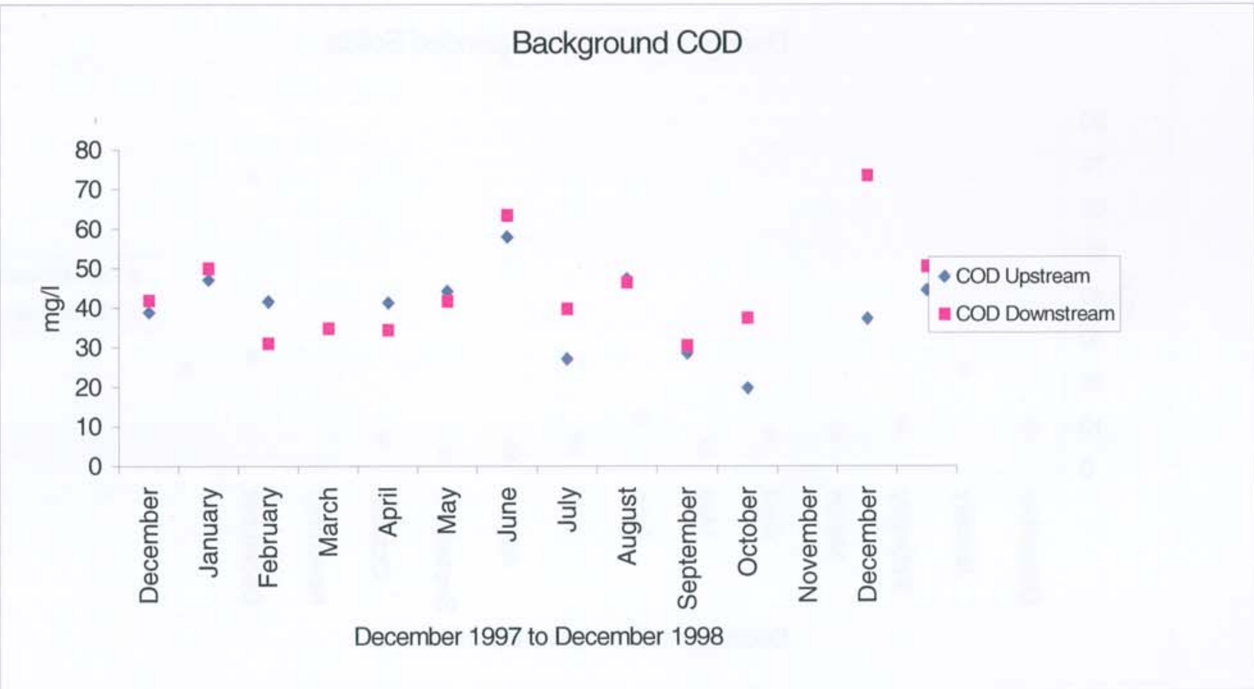

Event 8 9 September 1998
DEPTH (mm)
Pipe height = 650 mm Peak = 19.0
(Time in hours)
FLOW (l/s)
Total vol = 5.5 m3 Peak = 1.8
(Time in hours)
RAINFALL (mm/h) [RG 001] Total rain = 5.9 mm Peak = 18.9
EVENT : 9-SEP-98 5:00 to 9-SEP-98 8:20 (Time in hours)

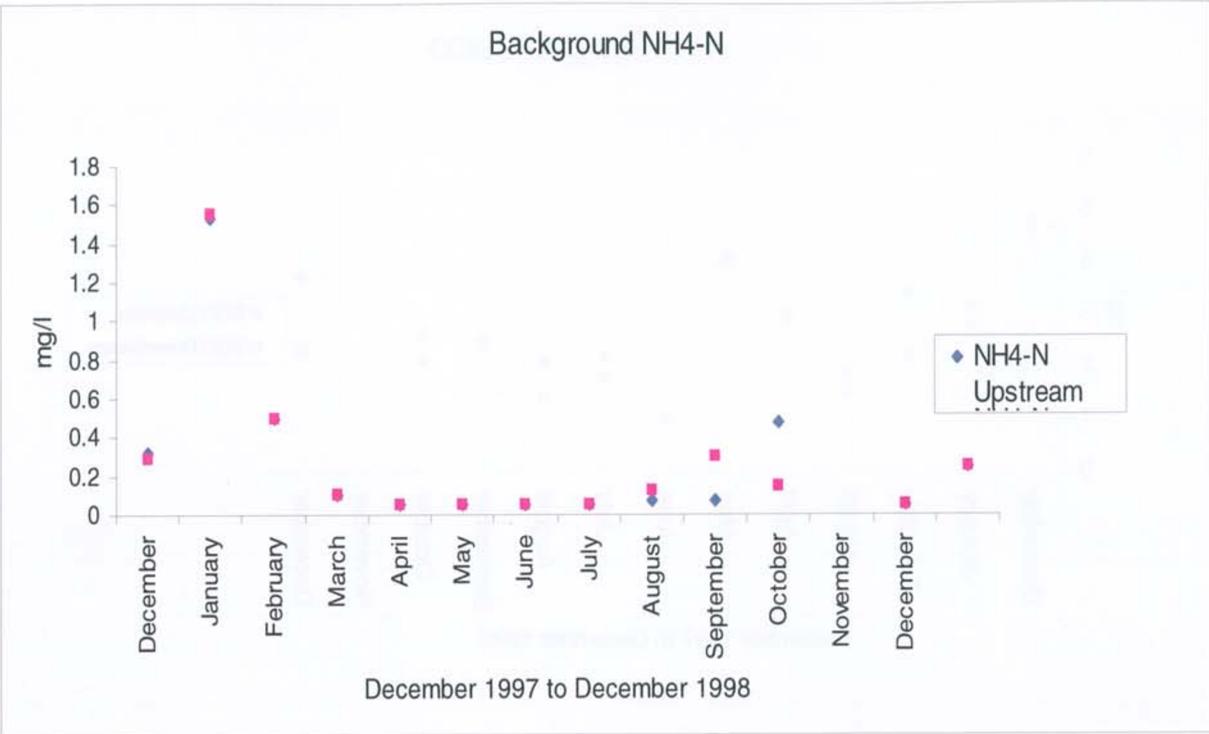

Event 9 12 November 1998
DEPTH (mm)
Pipe height = 850 mm Peak = 29.0
(Time in hours)
FLOW (l/s)
Total vol = 33.0 m3 Peak = 4.9
(Time in hours)
RAINFALL (mm/h) [RG 801] Total rain = 4.2 mm Peak = 6.3
EVENT : 12-NOV-98 0:00 to 12-NOV-98 5:00 (Time in hours)

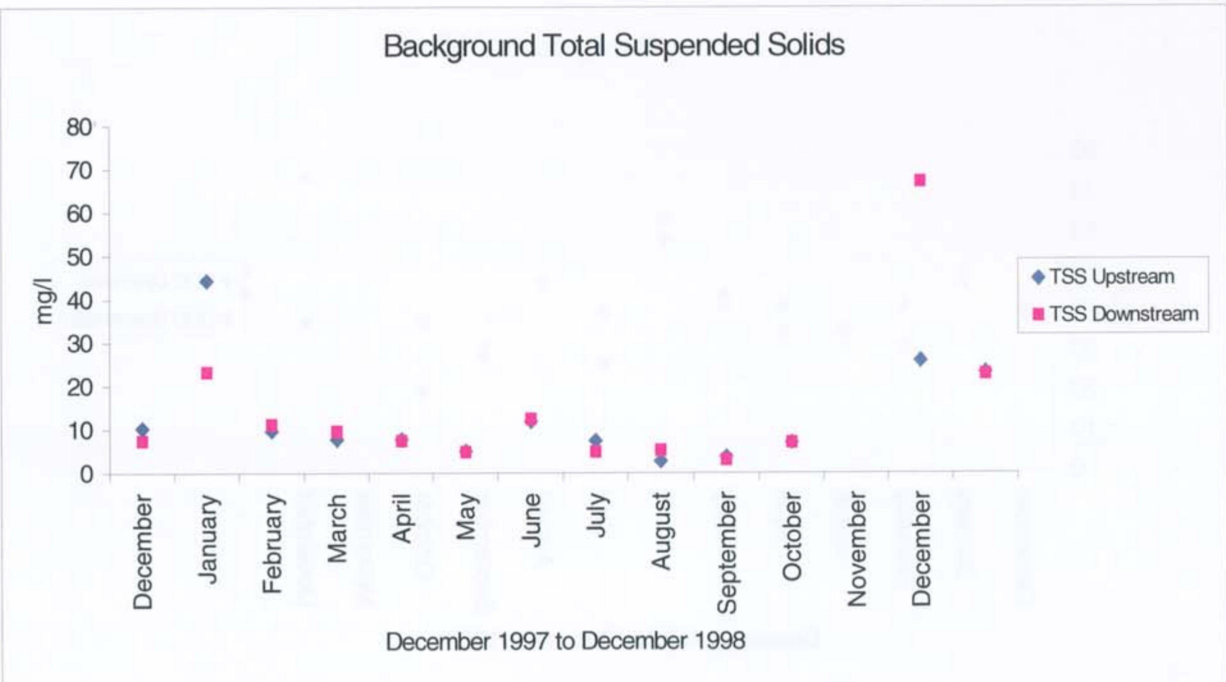

Event 10 8 December 1998
DEPTH (mm)
Pipe height = 650 mm Peak = 25.0
30
20
10
0
0 12 18 0 6 12 18
(Time in hours)
FLOW (l/s)
Total vol = 110.0 m3 Peak = 3.4
4
3
2
1
0
0 12 18 0 6 12 18
(Time in hours)
RAINFALL (mm/h) [RG 001] Total rain = 5.1 mm Peak = 6.3
10
5
0
0 12 18 0 6 12 18
EVENT : 8-DEC-98 10:00 to 9-DEC-98 13:00 (Time in hours)

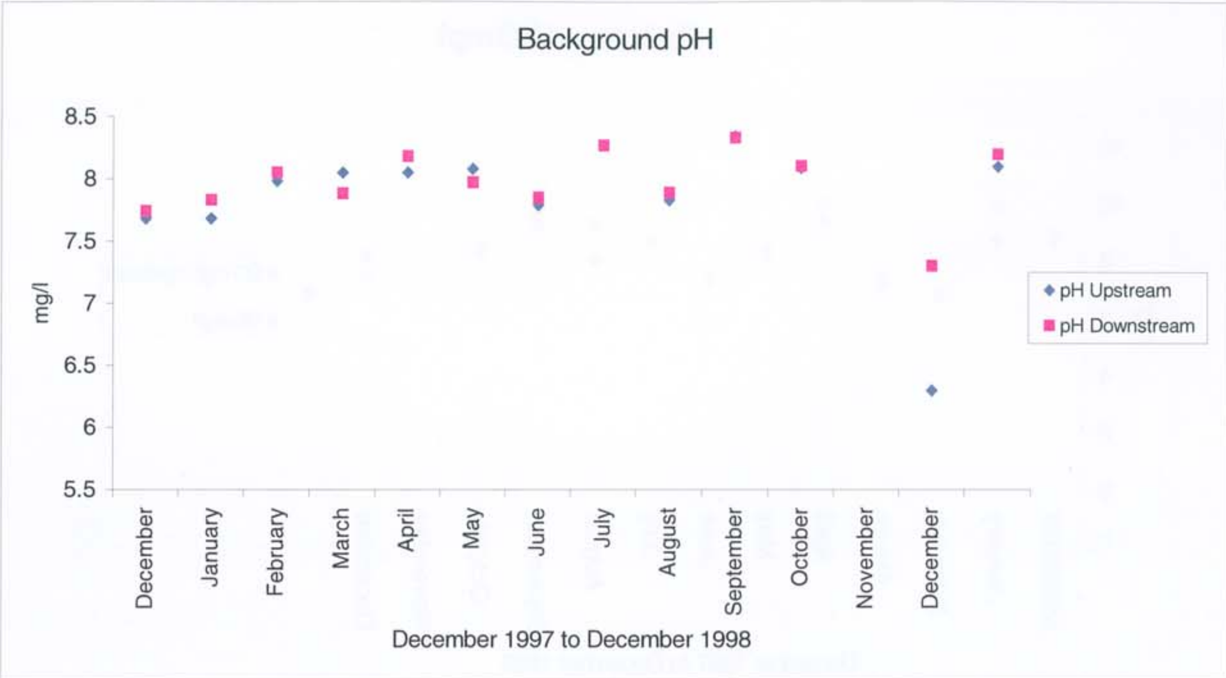
APPENDIX E GRAPHICAL PLOTS OF MONTHLY SAMPLE ANALYSIS RESULTS AND INSITU READINGS

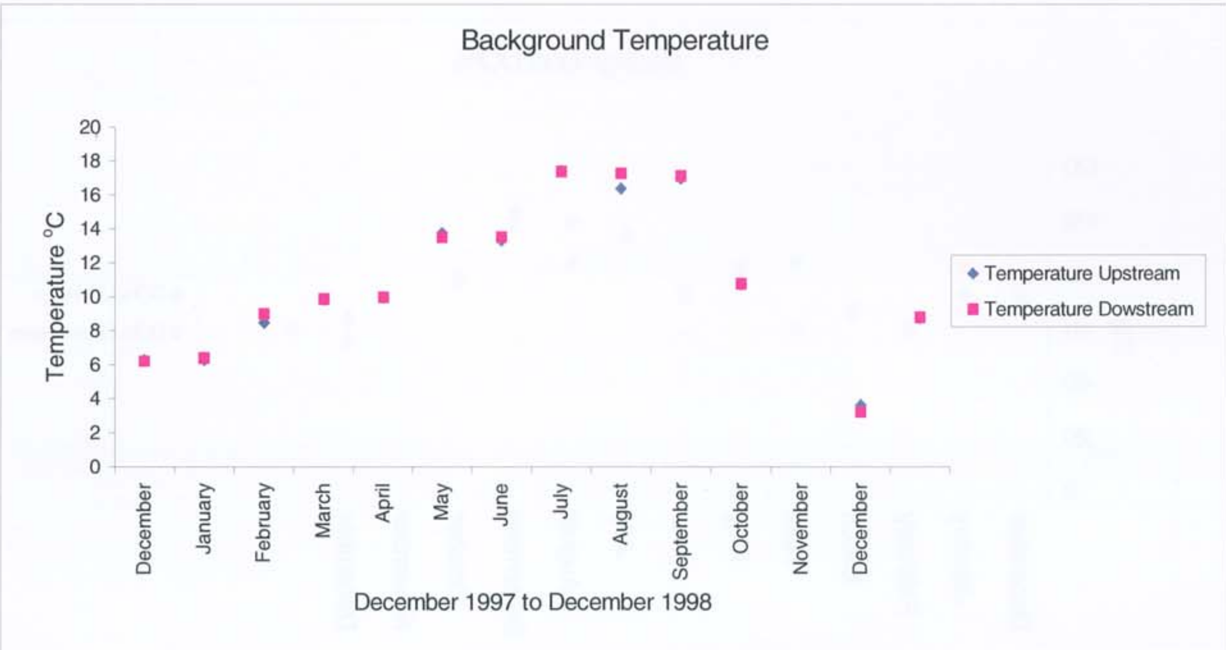

Background BOD
mg/l
6
5
4
3
2
1
0
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998
BOD Upstream
BOD Downstream

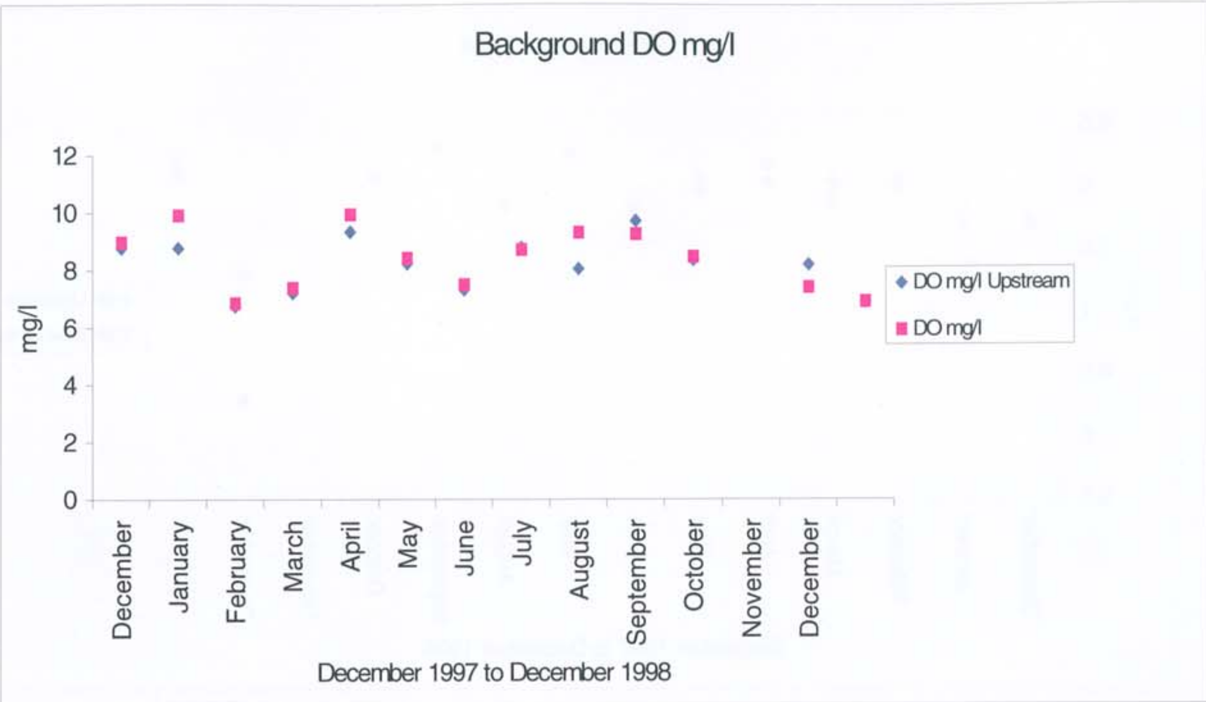

Background COD
mg/l
80
70
60
50
40
30
20
10
0
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998
COD Upstream
COD Downstream

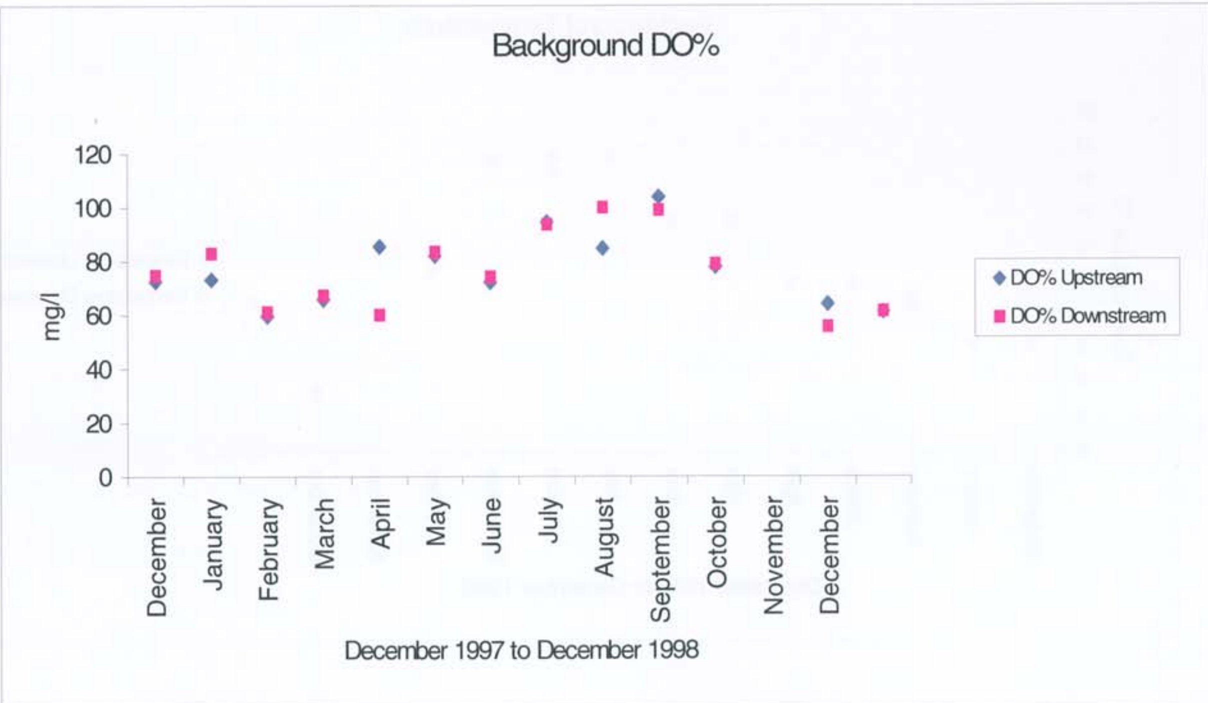

Background NH4-N
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
mg/l
NH4-N Upstream
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998

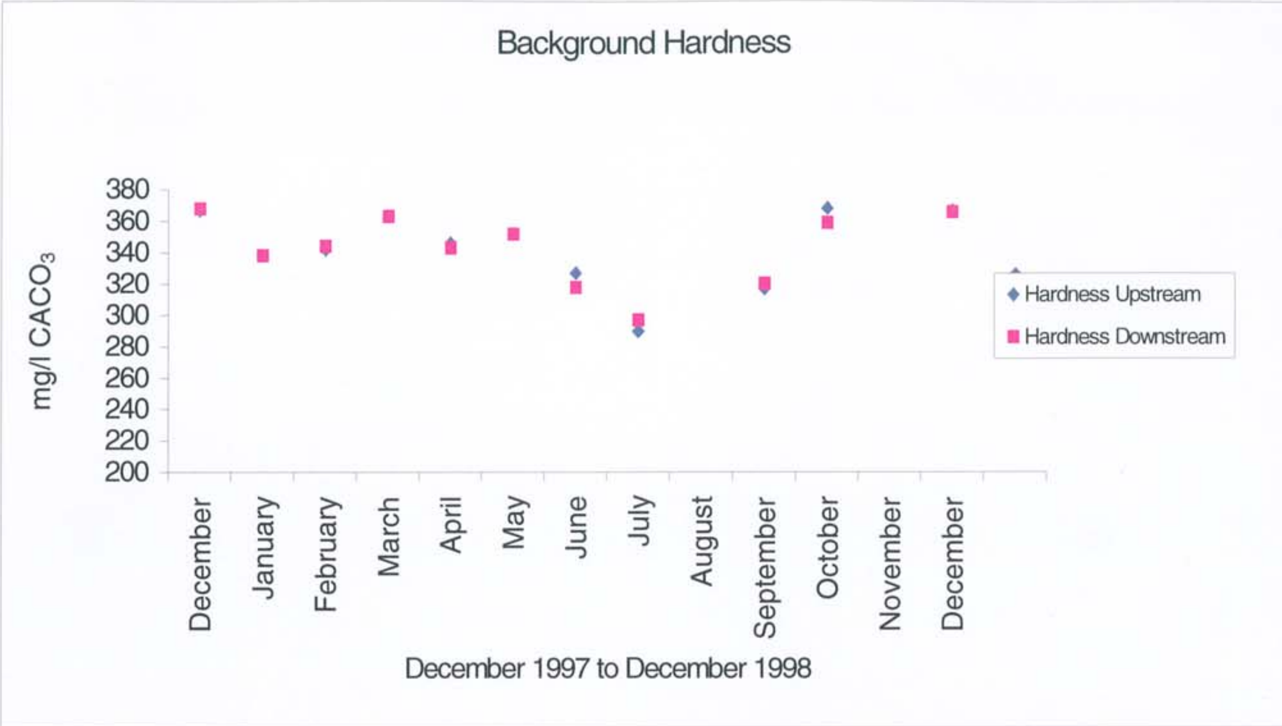

Background Total Suspended Solids
80
70
60
50
40
30
20
10
0
mg/l
TSS Upstream
TSS Downstream
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998


Background pH
8.5
8
7.5
7
6.5
6
5.5
mg/l
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998
pH Upstream
pH Downstream

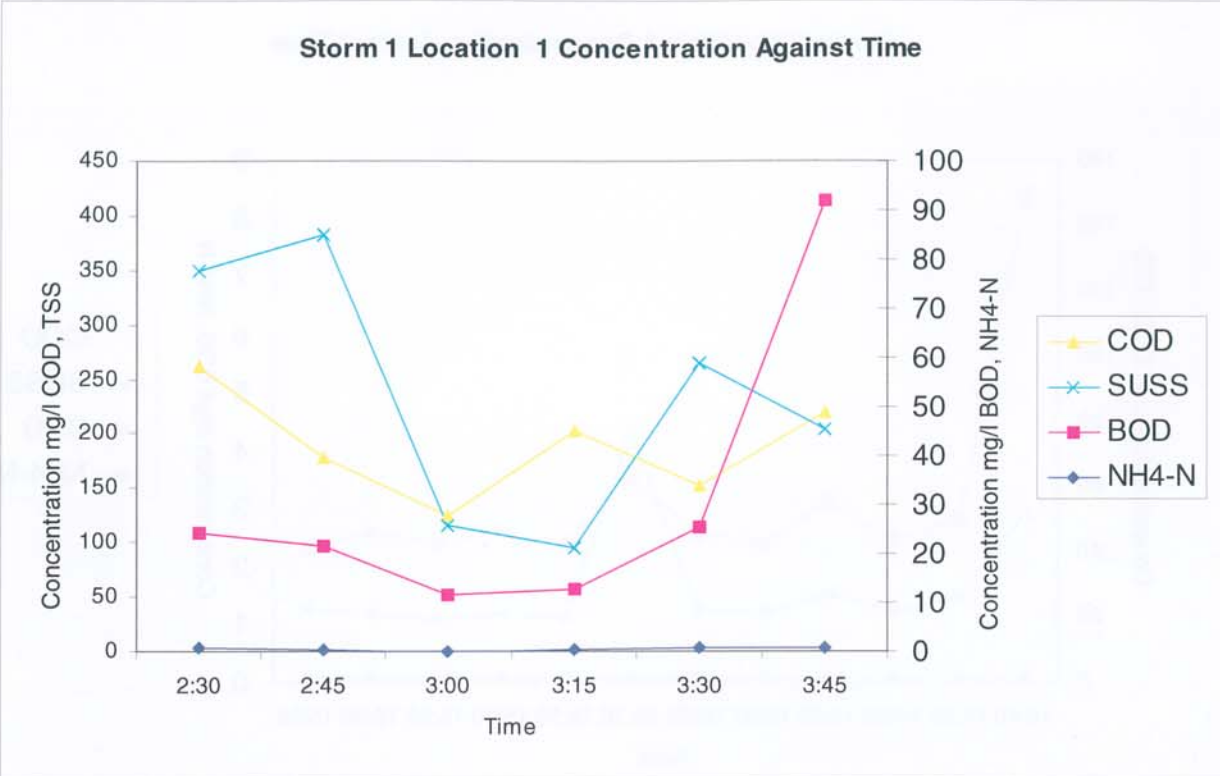

Background Temperature
20
18
16
14
12
10
8
6
4
2
0
Temperature °C
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998
Temperature Upstream
Temperature Dowstream

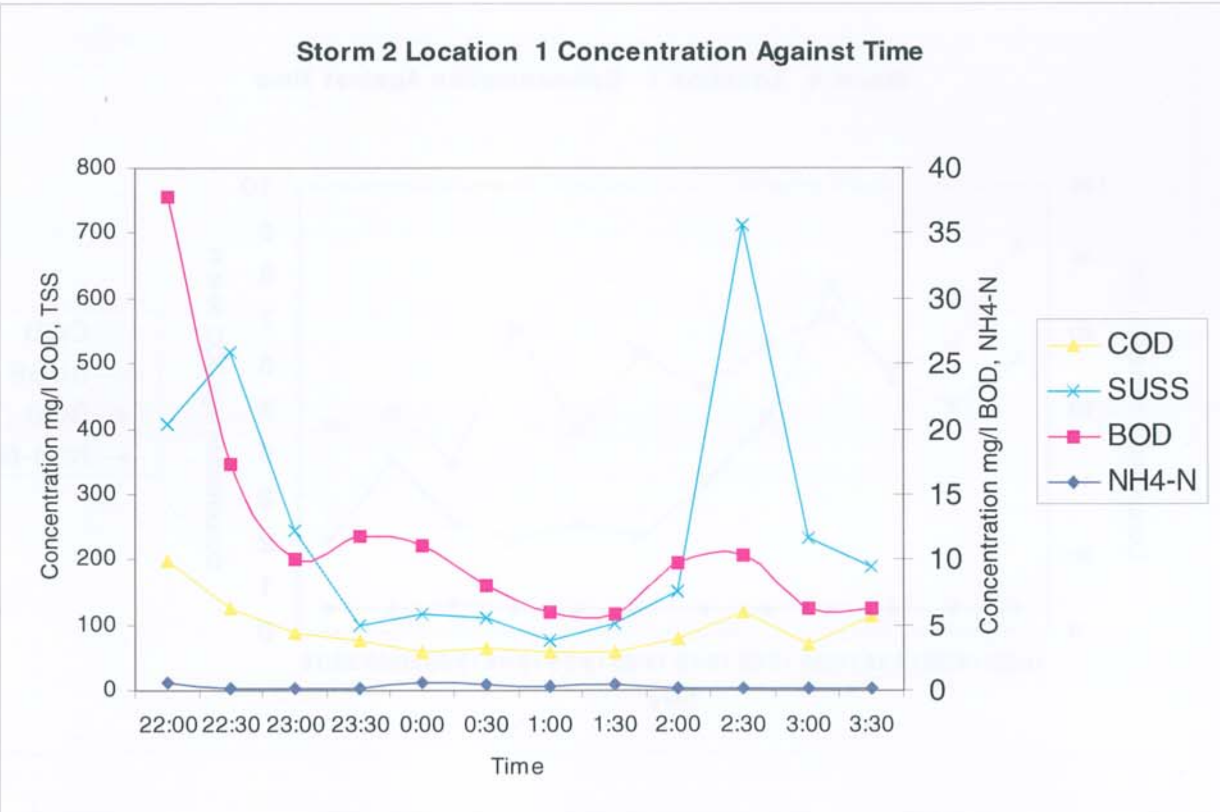

Background DO mg/l
12
10
8
6
4
2
0
mg/l
DO mg/l Upstream
DO mg/l
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998


Background DO%
120
100
80
60
40
20
0
mg/l
DO% Upstream
DO% Downstream
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998


Background Hardness
mg/l CACO3
380
360
340
320
300
280
260
240
220
200
December
January
February
March
April
May
June
July
August
September
October
November
December
December 1997 to December 1998
Hardness Upstream
Hardness Downstream

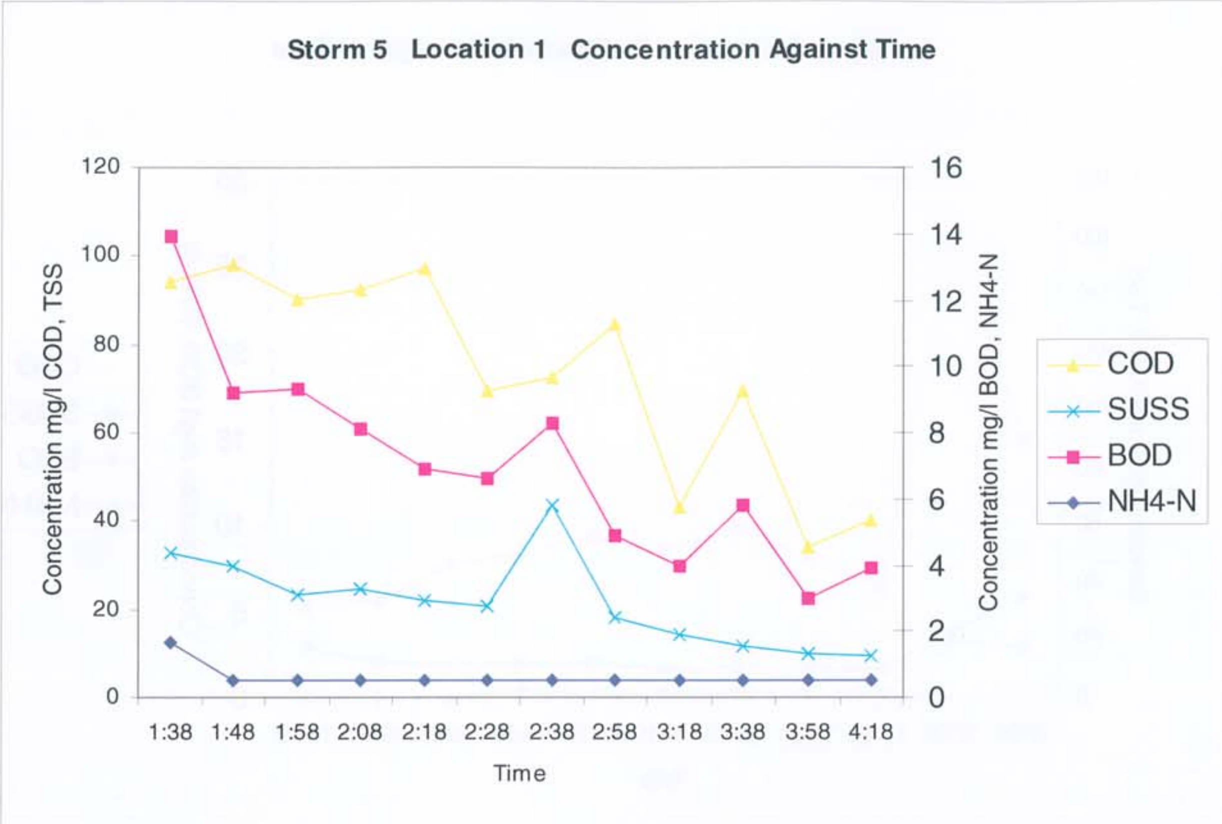
APPENDIX F GRAPHICAL PLOTS OF STORM EVENT DISCRETE SAMPLE ANALYSIS RESULTS


Storm 1 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
450
400
350
300
250
200
150
100
50
0
100
90
80
70
60
50
40
30
20
10
0
Concentration mg/l BOD, NH4-N
2:30
2:45
3:00
3:15
3:30
3:45
Time
COD
SUSS
BOD
NH4-N

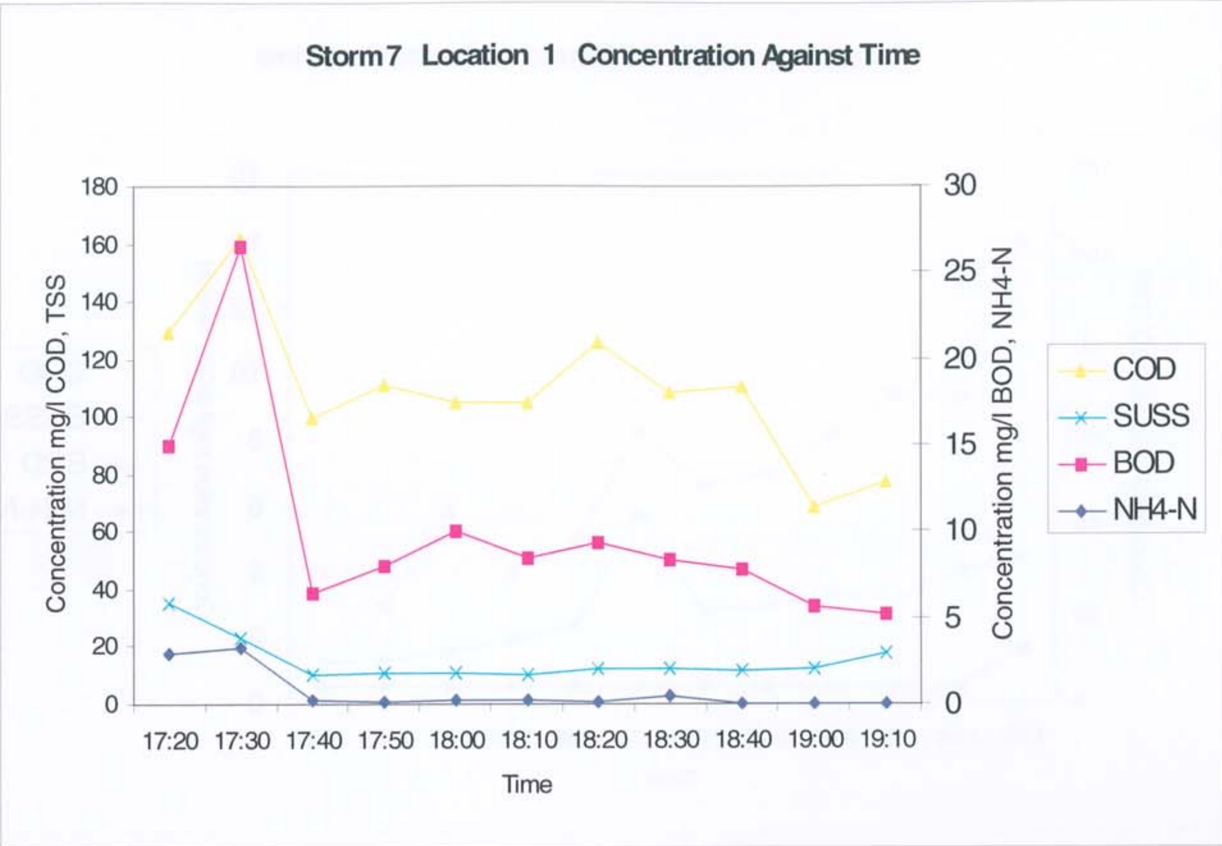

Storm 2 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
800
700
600
500
400
300
200
100
0
40
35
30
25
20
15
10
5
0
Concentration mg/l BOD, NH4-N
22:00
22:30
23:00
23:30
0:00
0:30
1:00
1:30
2:00
2:30
3:00
3:30
Time
COD
SUSS
BOD
NH4-N


Storm 3 Location 1 Concentration Against Time
Concentrationmug/l COD, TSS
Concentration mg/l BOD, NH4-N
160
140
120
100
80
60
40
20
0
9
8
7
6
5
4
3
2
1
0
14:40 14:45 14:50 14:55 15:00 15:05 15:10 15:15 15:20 15:25 15:30 15:35
Time
COD
SUSS
BOD
NH4-N

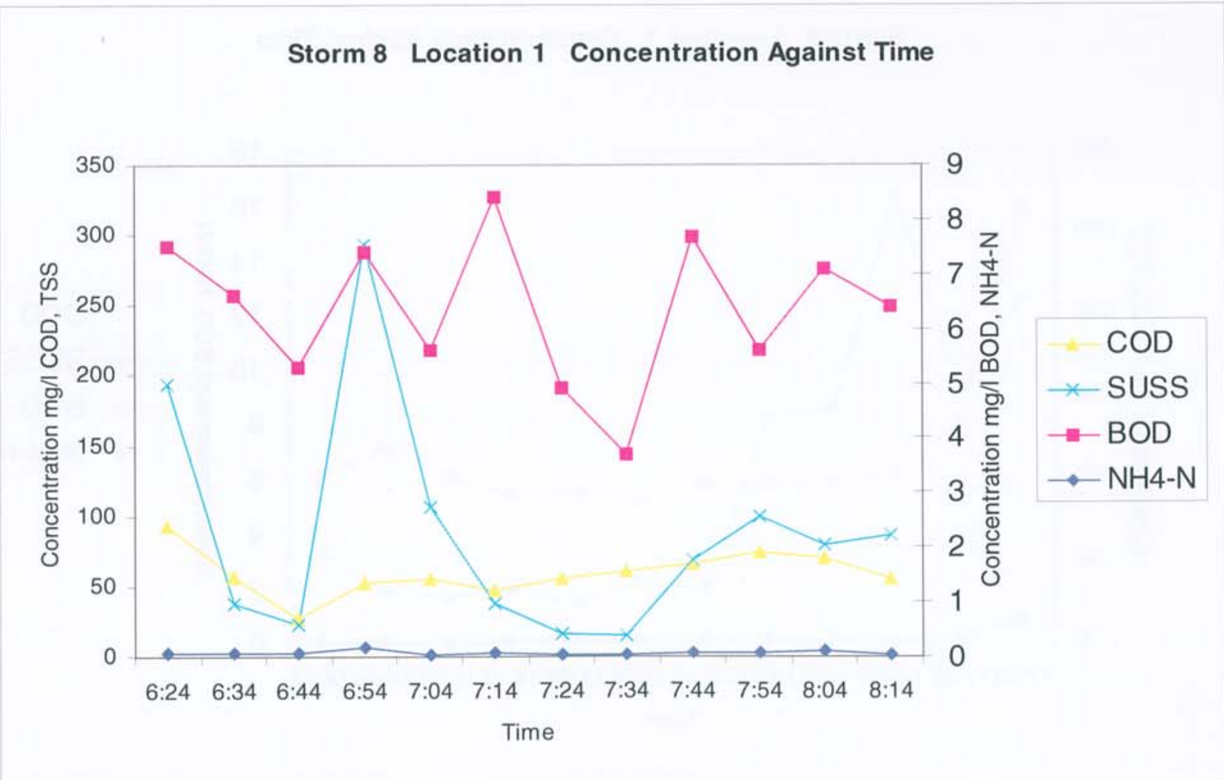

Storm 4 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
Concentration mg/l BOD, NH4-N
120
100
80
60
40
20
0
10
9
8
7
6
5
4
3
2
1
0
18:28 18:38 18:48 18:58 19:08 19:18 19:28 19:38 19:48 19:58 20:08 20:18
Time
COD
SUSS
BOD
NH4-N


Storm 5 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
Concentration mg/l BOD, NH4-N
0
20
40
60
80
100
120
0
2
4
6
8
10
12
14
16
1:38 1:48 1:58 2:08 2:18 2:28 2:38 2:58 3:18 3:38 3:58 4:18
Time
COD
SUSS
BOD
NH4-N

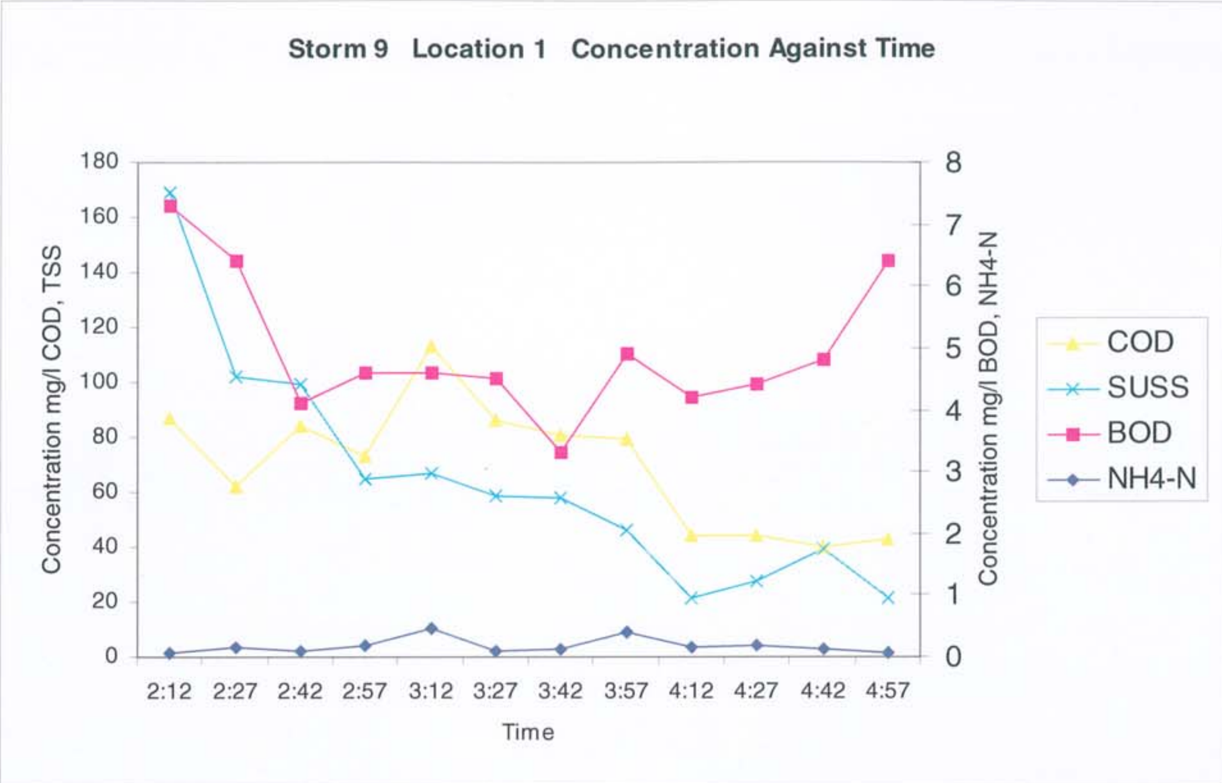

Storm 6 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
Concentration mg/l BOD, NH4-N
0
50
100
150
200
250
300
0
2
4
6
8
10
12
14
16
18
17:28 17:38 17:48 17:58 18:08 18:18 18:28 18:38 18:48 18:58 19:08 19:18
Time
COD
SUSS
BOD
NH4-N

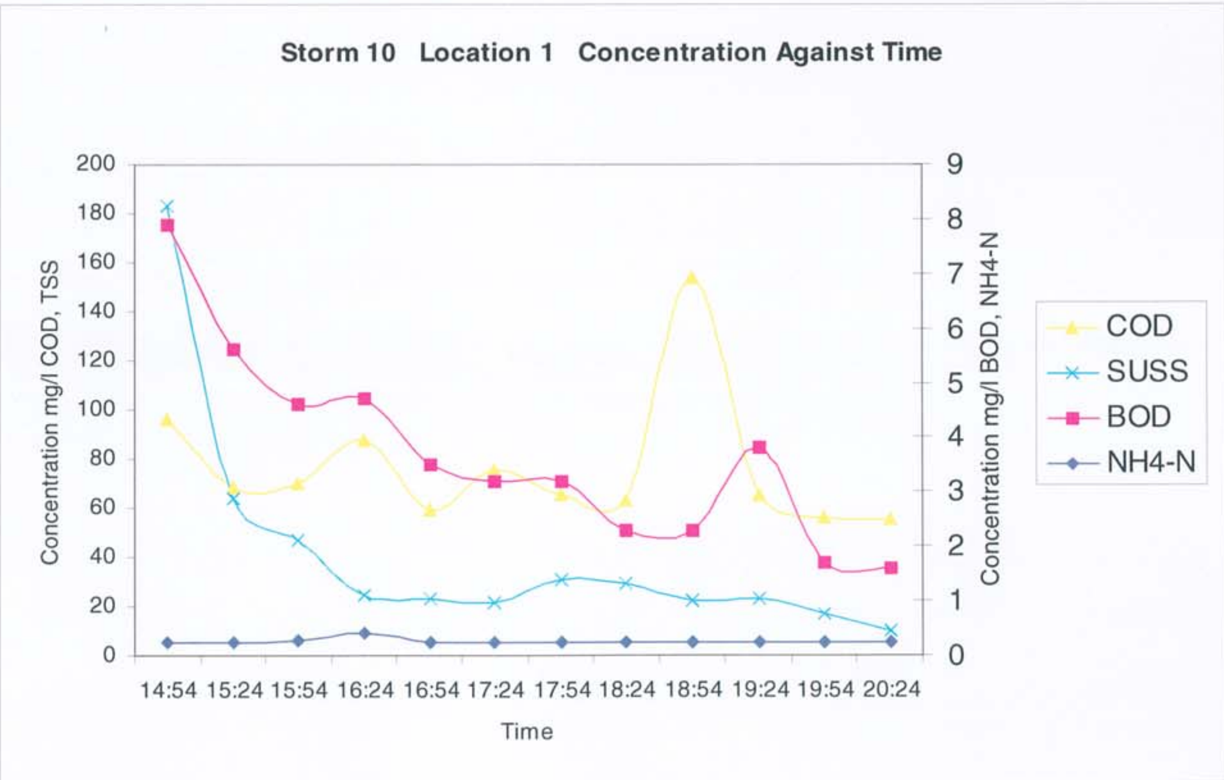


Storm 7 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
Concentration mg/l BOD, NH4-N
Time
17:20 17:30 17:40 17:50 18:00 18:10 18:20 18:30 18:40 19:00 19:10
COD
SUSS
BOD
NH4-N

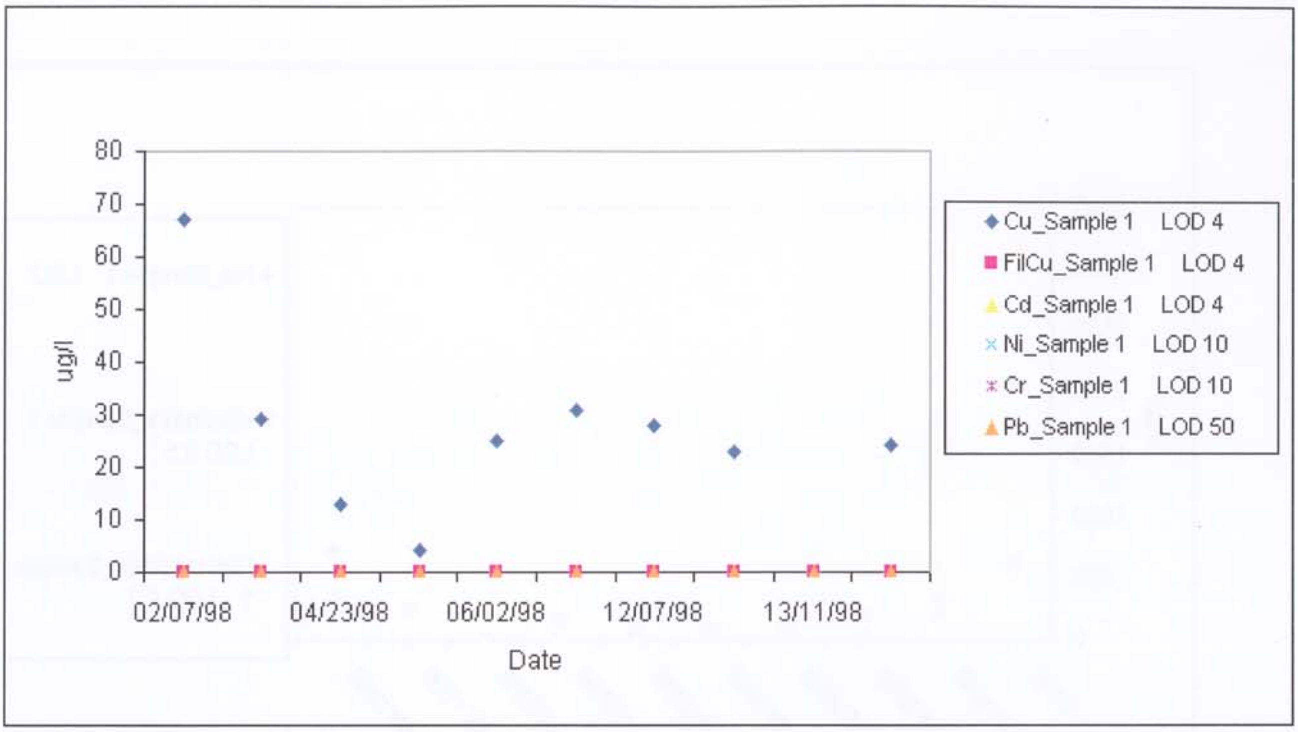


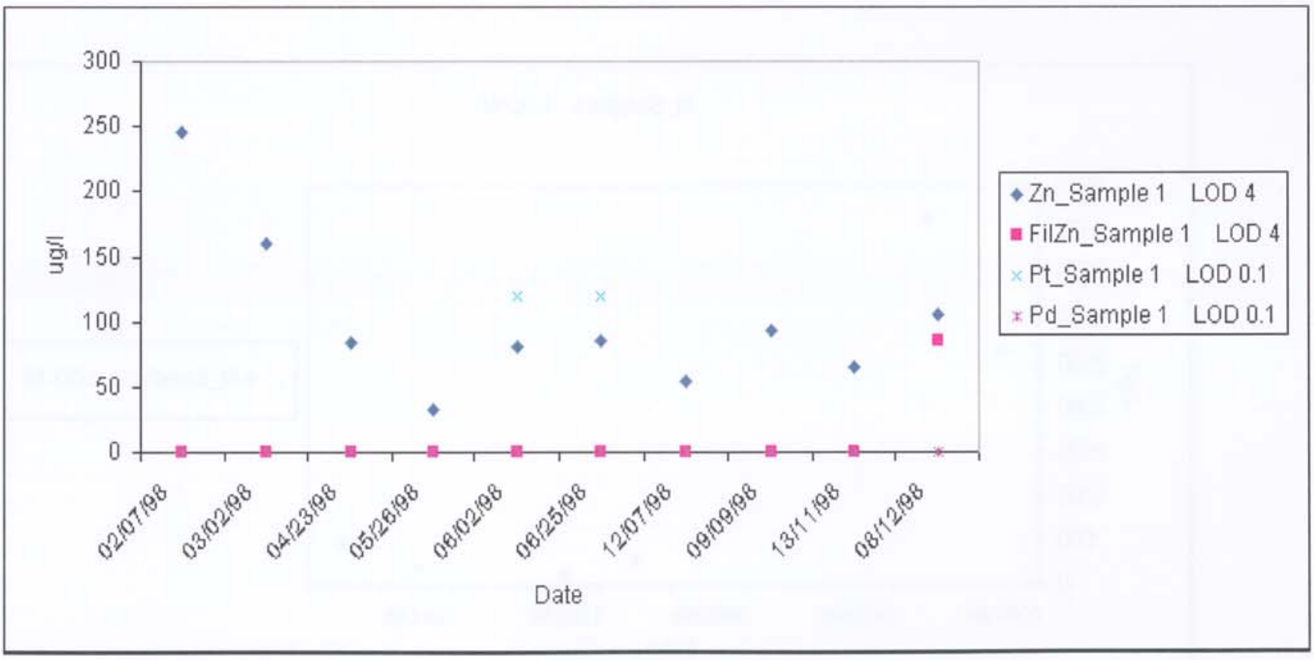
Storm 8 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
Concentration mg/l BOD, NH4-N
Time
6:24 6:34 6:44 6:54 7:04 7:14 7:24 7:34 7:44 7:54 8:04 8:14
COD
SUSS
BOD
NH4-N

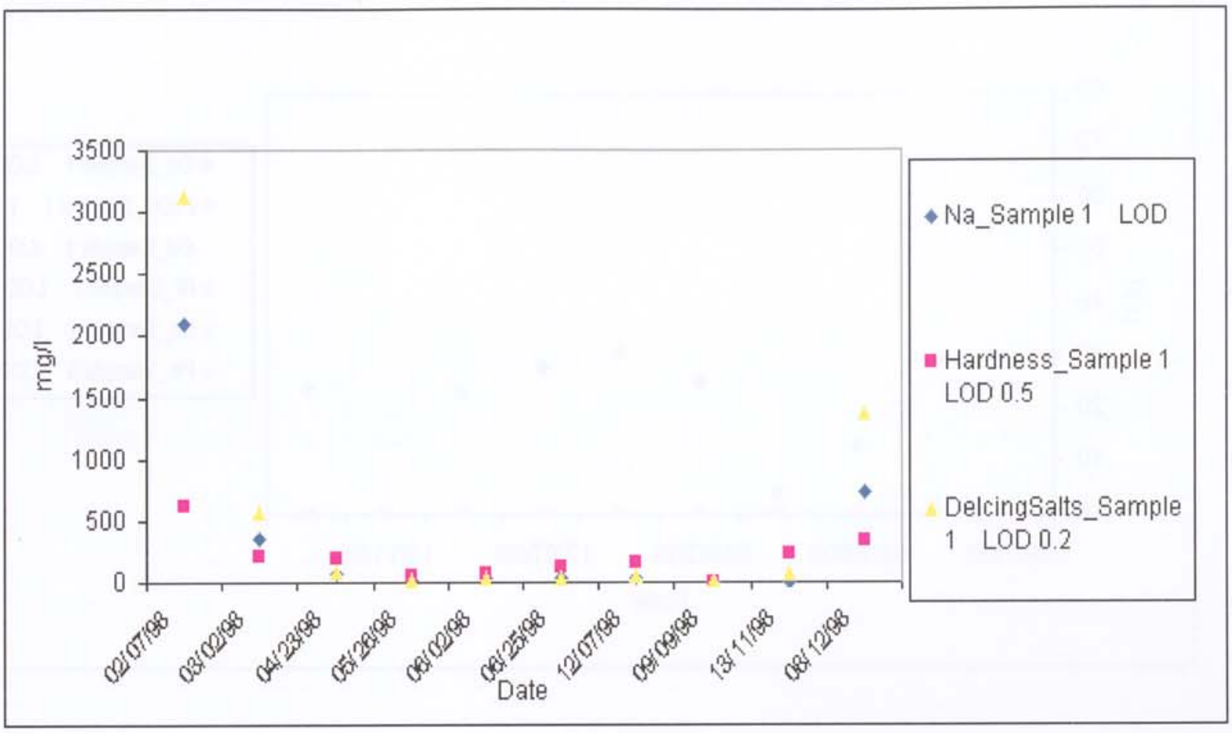

Storm 9 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
Concentration mg/l BOD, NH4-N
180
160
140
120
100
80
60
40
20
0
8
7
6
5
4
3
2
1
0
2:12 2:27 2:42 2:57 3:12 3:27 3:42 3:57 4:12 4:27 4:42 4:57
Time
COD
SUSS
BOD
NH4-N

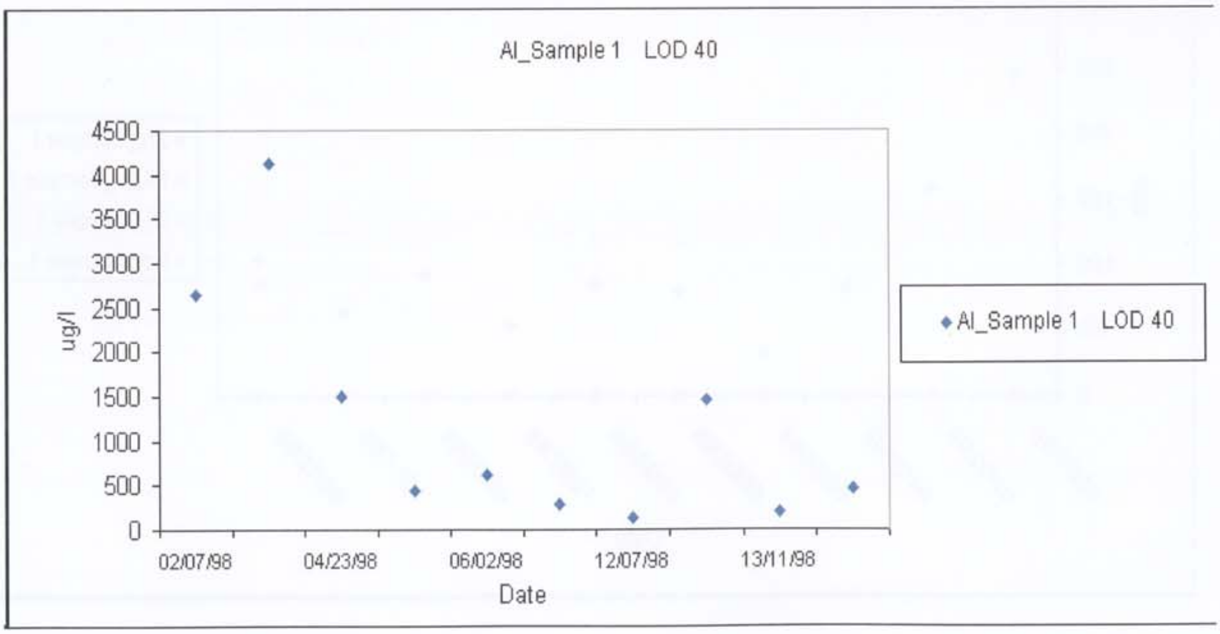

Storm 10 Location 1 Concentration Against Time
Concentration mg/l COD, TSS
Concentration mg/l BOD, NH4-N
200
180
160
140
120
100
80
60
40
20
0
9
8
7
6
5
4
3
2
1
0
14:54 15:24 15:54 16:24 16:54 17:24 17:54 18:24 18:54 19:24 19:54 20:24
Time
COD
SUSS
BOD
NH4-N

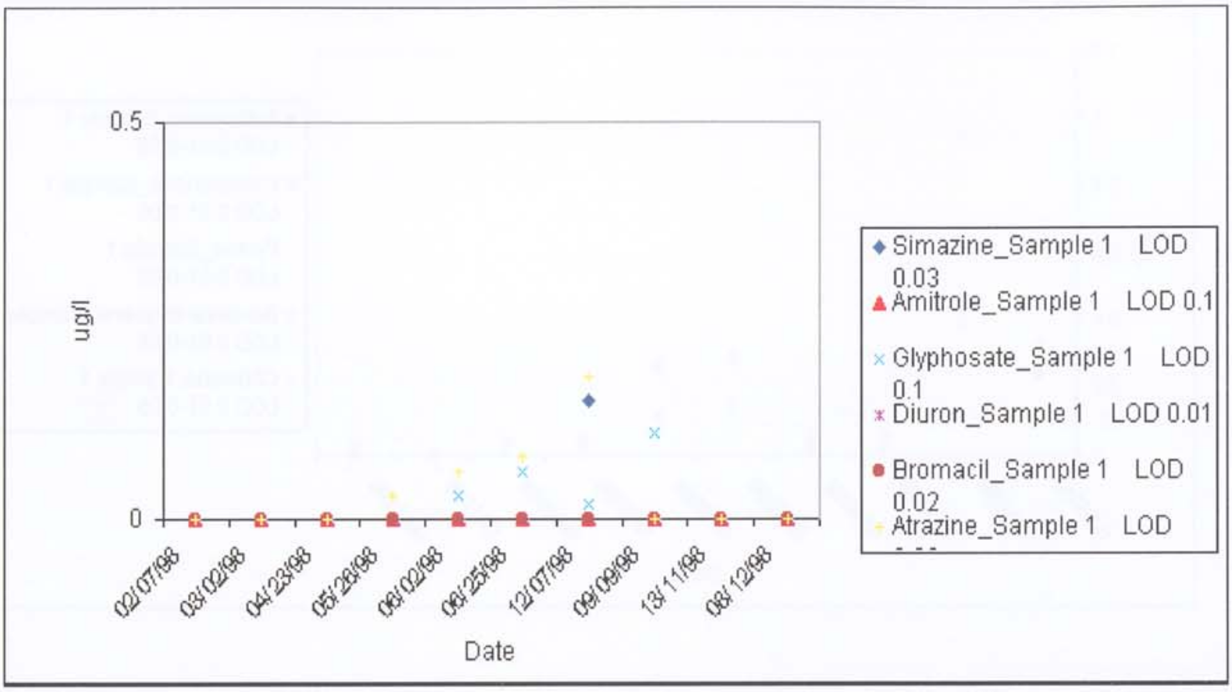
APPENDIX G GRAPHICAL PLOTS OF STORM EVENT COMPOSITE SAMPLE ANALYSIS RESULTS


80
70
60
50
40
30
20
10
0
ug/l
02/07/98
04/23/98
06/02/98
12/07/98
13/11/98
Date
Cu_Sample 1 LOD 4
FilCu_Sample 1 LOD 4
Cd_Sample 1 LOD 4
Ni_Sample 1 LOD 10
Cr_Sample 1 LOD 10
Pb_Sample 1 LOD 50

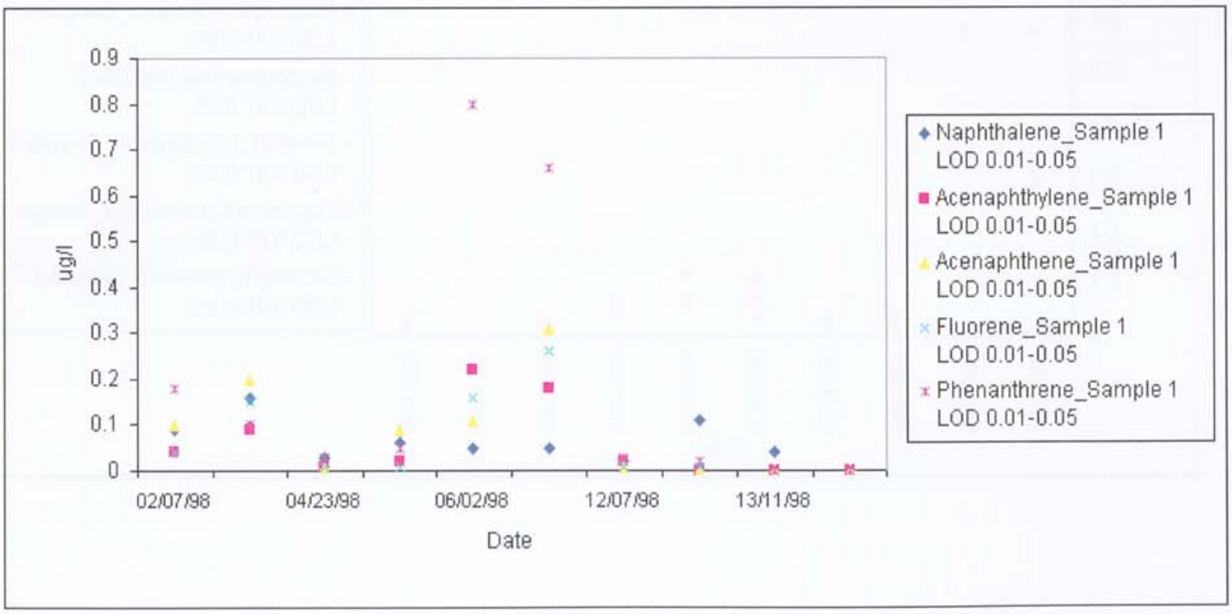

300
250
200
150
100
50
0
ug/l
02/07/98
03/02/98
04/23/98
05/26/98
06/02/98
06/25/98
12/07/98
09/09/98
13/11/98
08/12/98
Date
Zn_Sample 1 LOD 4
FilZn_Sample 1 LOD 4
Pt_Sample 1 LOD 0.1
Pd_Sample 1 LOD 0.1


3500
3000
2500
2000
1500
1000
500
0
mg/l
02/07/98
03/02/98
04/23/98
05/26/98
06/02/98
06/25/98
12/07/98
09/09/98
13/11/98
08/12/98
Date
Na_Sample 1 LOD
Hardness_Sample 1 LOD 0.5
DeIcingSalts_Sample 1 LOD 0.2

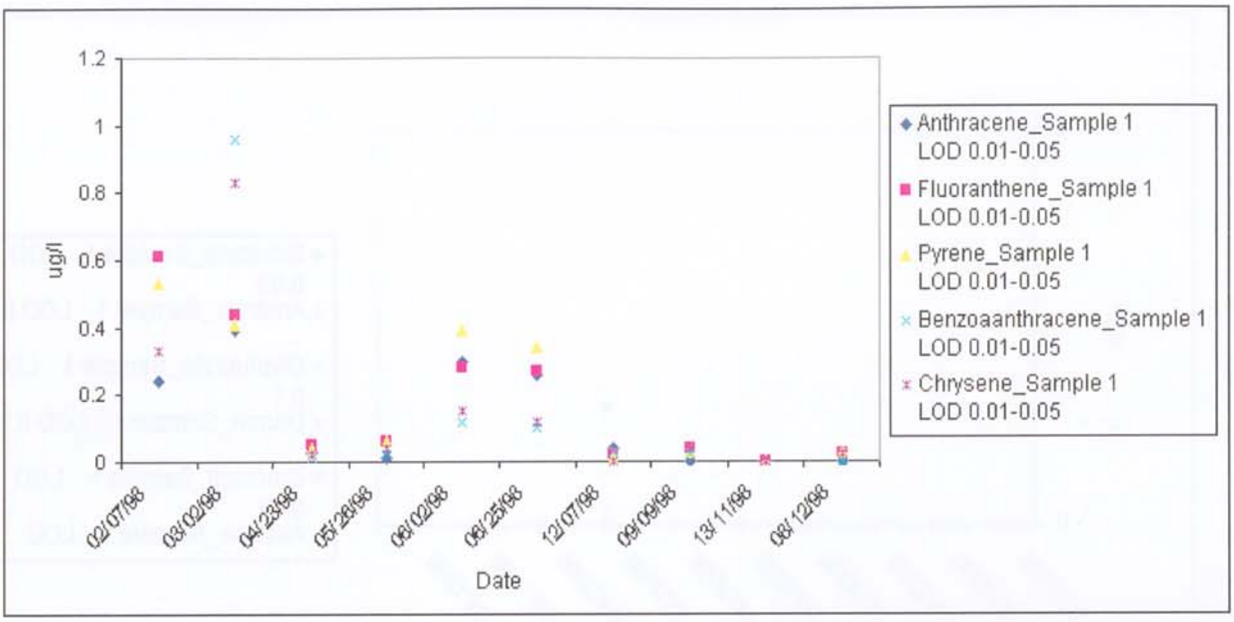

Al_Sample 1 LOD 40
4500
4000
3500
3000
2500
2000
1500
1000
500
0
ug/l
02/07/98
04/23/98
06/02/98
12/07/98
13/11/98
Date
Al_Sample 1 LOD 40



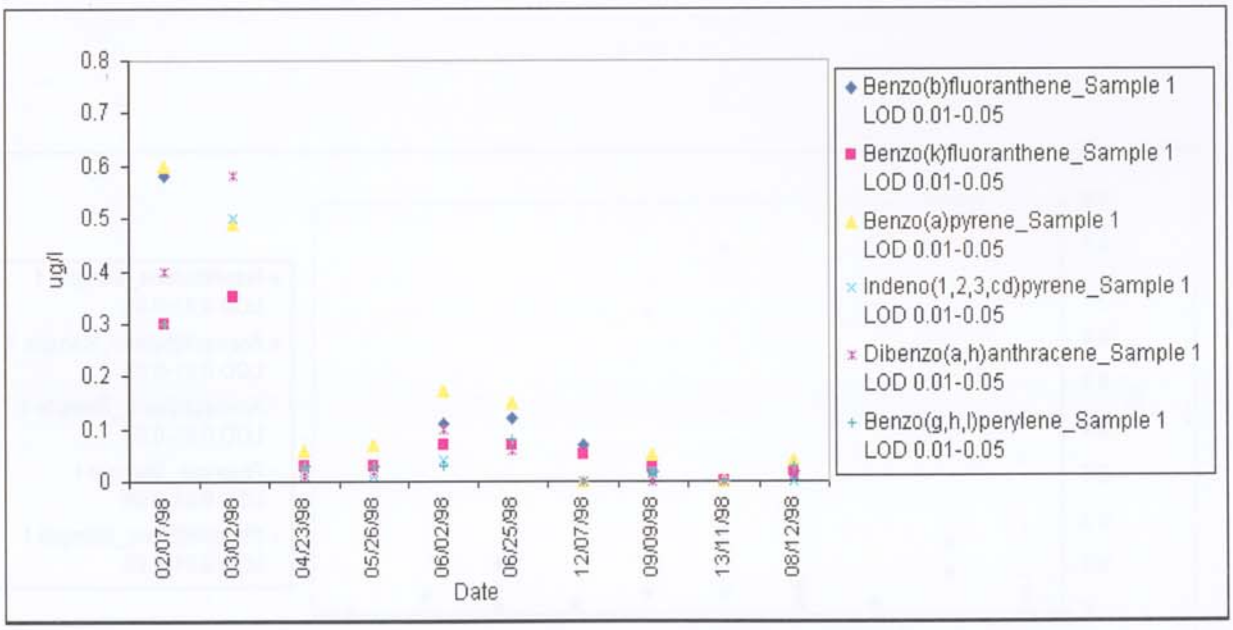
0.5
0
ug/l
02/07/98
03/02/98
04/23/98
05/26/98
06/02/98
06/25/98
12/07/98
09/09/98
13/11/98
08/12/98
Date
Simazine_Sample 1 LOD 0.03
Amitrole_Sample 1 LOD 0.1
Glyphosate_Sample 1 LOD 0.1
Diuron_Sample 1 LOD 0.01
Bromacil_Sample 1 LOD 0.02
Atrazine_Sample 1 LOD



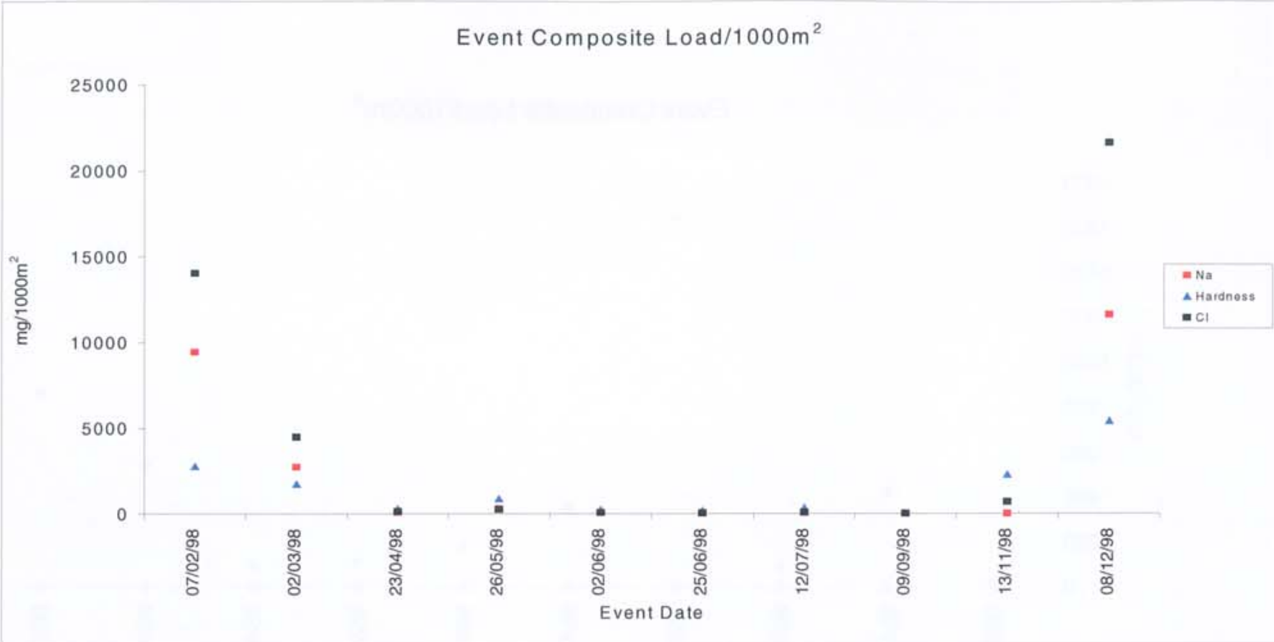
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ug/l
02/07/98
04/23/98
06/02/98
12/07/98
13/11/98
Date
Naphthalene_Sample 1 LOD 0.01-0.05
Acenaphthylene_Sample 1 LOD 0.01-0.05
Acenaphthene_Sample 1 LOD 0.01-0.05
Fluorene_Sample 1 LOD 0.01-0.05
Phenanthrene_Sample 1 LOD 0.01-0.05

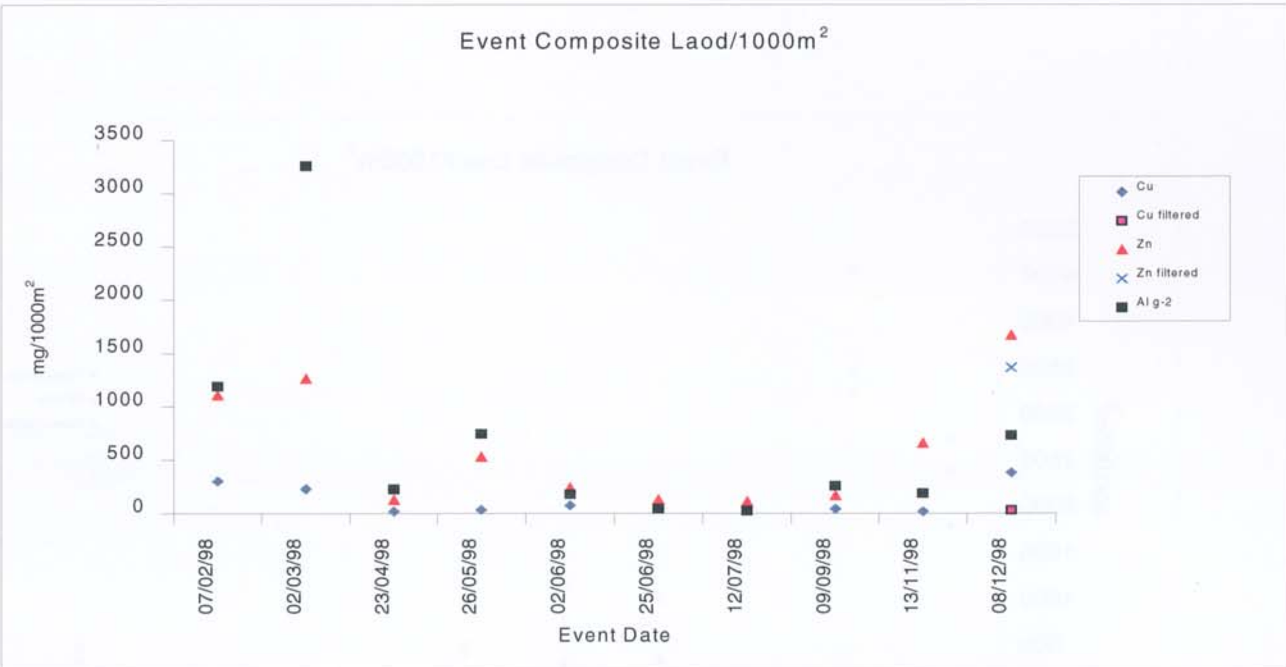


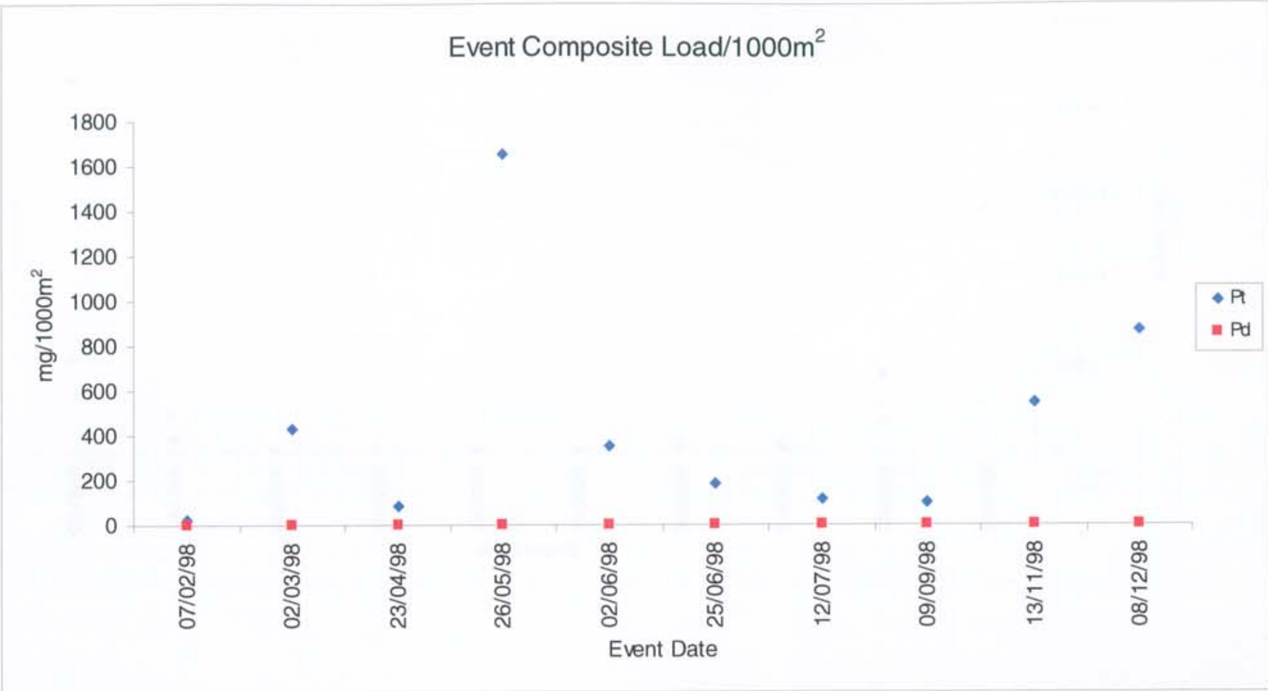
1.2
1
0.8
0.6
0.4
0.2
0
ug/l
02/07/98
03/02/98
04/23/98
05/26/98
06/02/98
06/25/98
12/07/98
09/09/98
13/11/98
08/12/98
Date
Anthracene_Sample 1 LOD 0.01-0.05
Fluoranthene_Sample 1 LOD 0.01-0.05
Pyrene_Sample 1 LOD 0.01-0.05
Benzoaanthracene_Sample 1 LOD 0.01-0.05
Chrysene_Sample 1 LOD 0.01-0.05

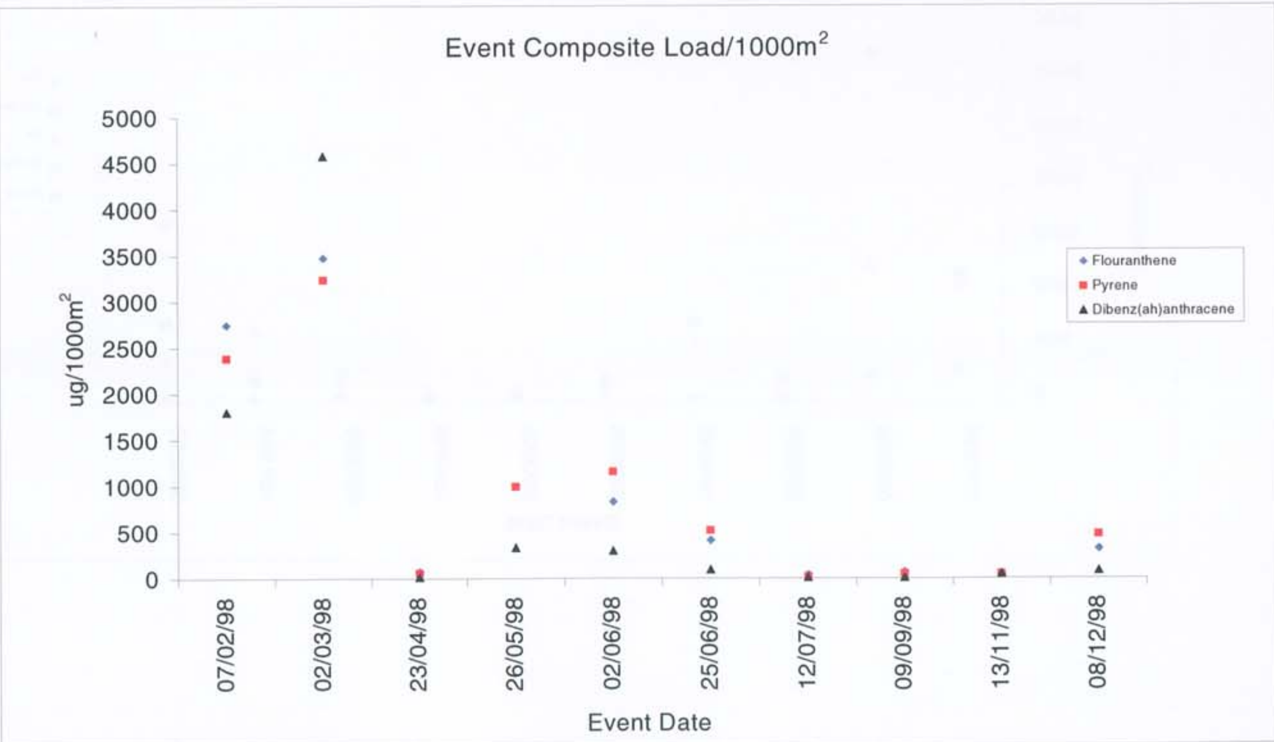


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ug/l
02/07/98
03/02/98
04/23/98
05/26/98
06/02/98
06/25/98
12/07/98
09/09/98
13/11/98
08/12/98
Date
Benzo(b)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(k)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(a)pyrene_Sample 1 LOD 0.01-0.05
Indeno(1,2,3,cd)pyrene_Sample 1 LOD 0.01-0.05
Dibenzo(a,h)anthracene_Sample 1 LOD 0.01-0.05
Benzo(g,h,l)perylene_Sample 1 LOD 0.01-0.05

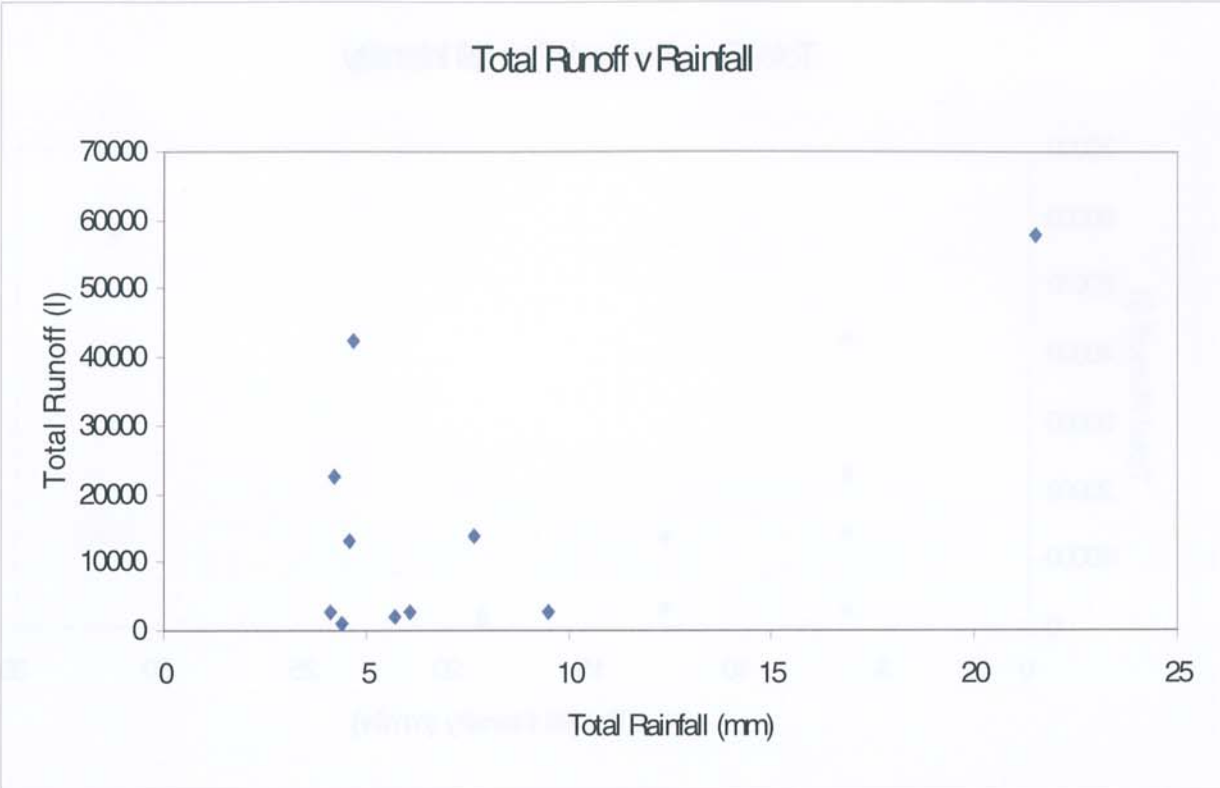

Event Composite Load/1000m2
25000
20000
15000
10000
5000
0
mg/1000m2
07/02/98
02/03/98
23/04/98
26/05/98
02/06/98
25/06/98
12/07/98
09/09/98
13/11/98
08/12/98
Event Date
Na
Hardness
Cl

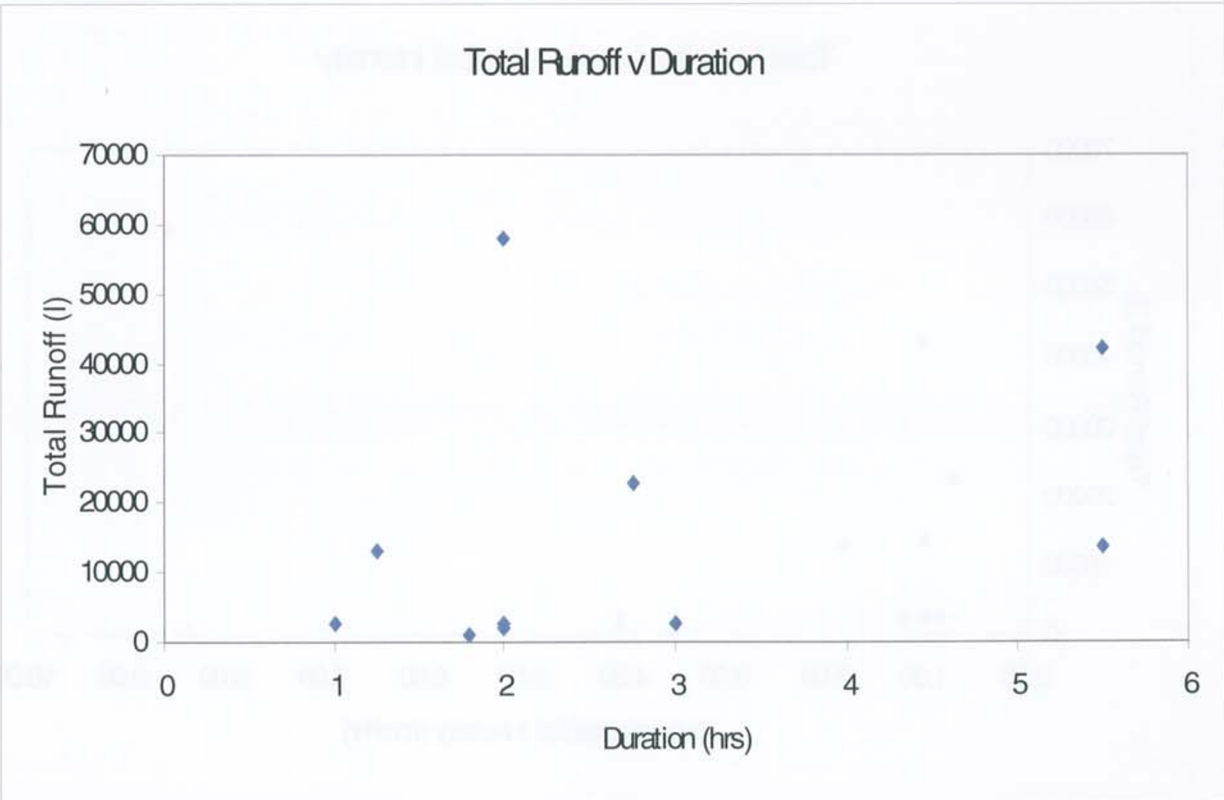

Event Composite Laod/1000m2
3500
3000
2500
2000
1500
1000
500
0
mg/1000m2
07/02/98
02/03/98
23/04/98
26/05/98
02/06/98
25/06/98
12/07/98
09/09/98
13/11/98
08/12/98
Event Date
Cu
Cu filtered
Zn
Zn filtered
Al g-2

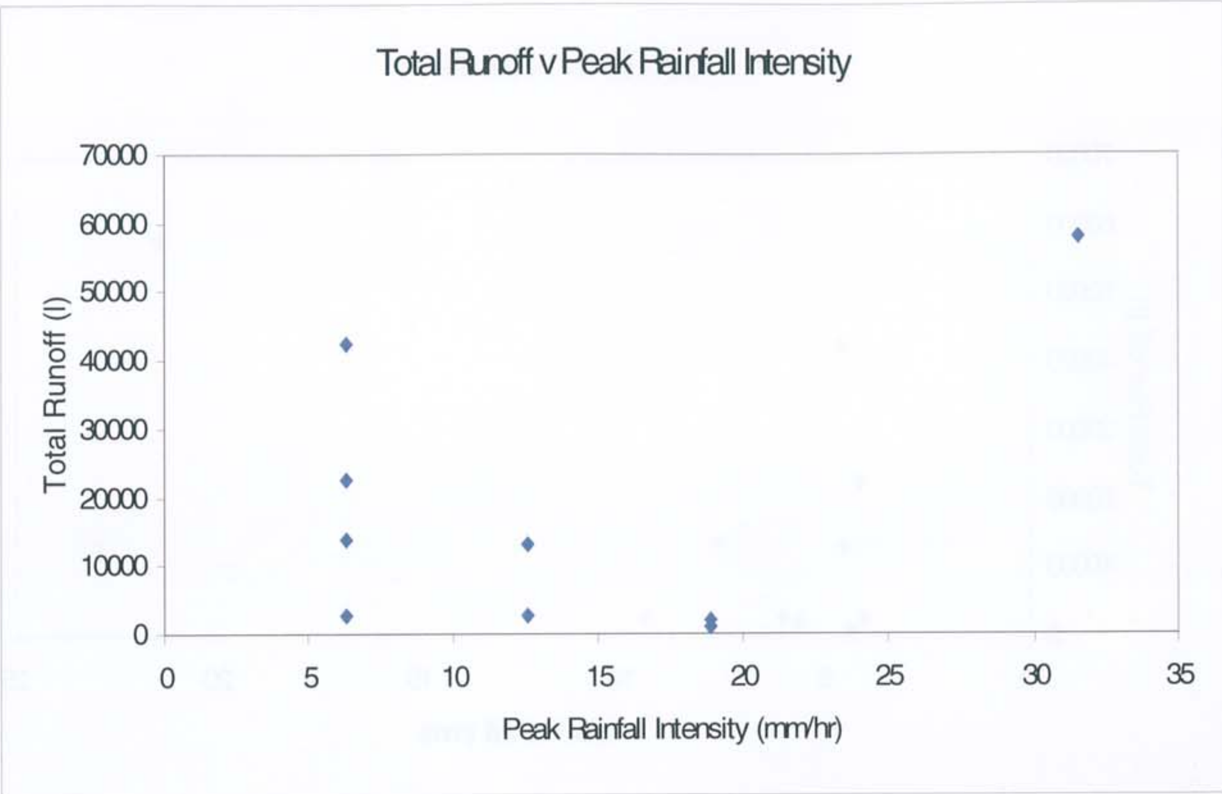

Event Composite Load/1000m2
mg/1000m2
1800
1600
1400
1200
1000
800
600
400
200
0
07/02/98
02/03/98
23/04/98
26/05/98
02/06/98
25/06/98
12/07/98
09/09/98
13/11/98
08/12/98
Event Date
Pt
Pd

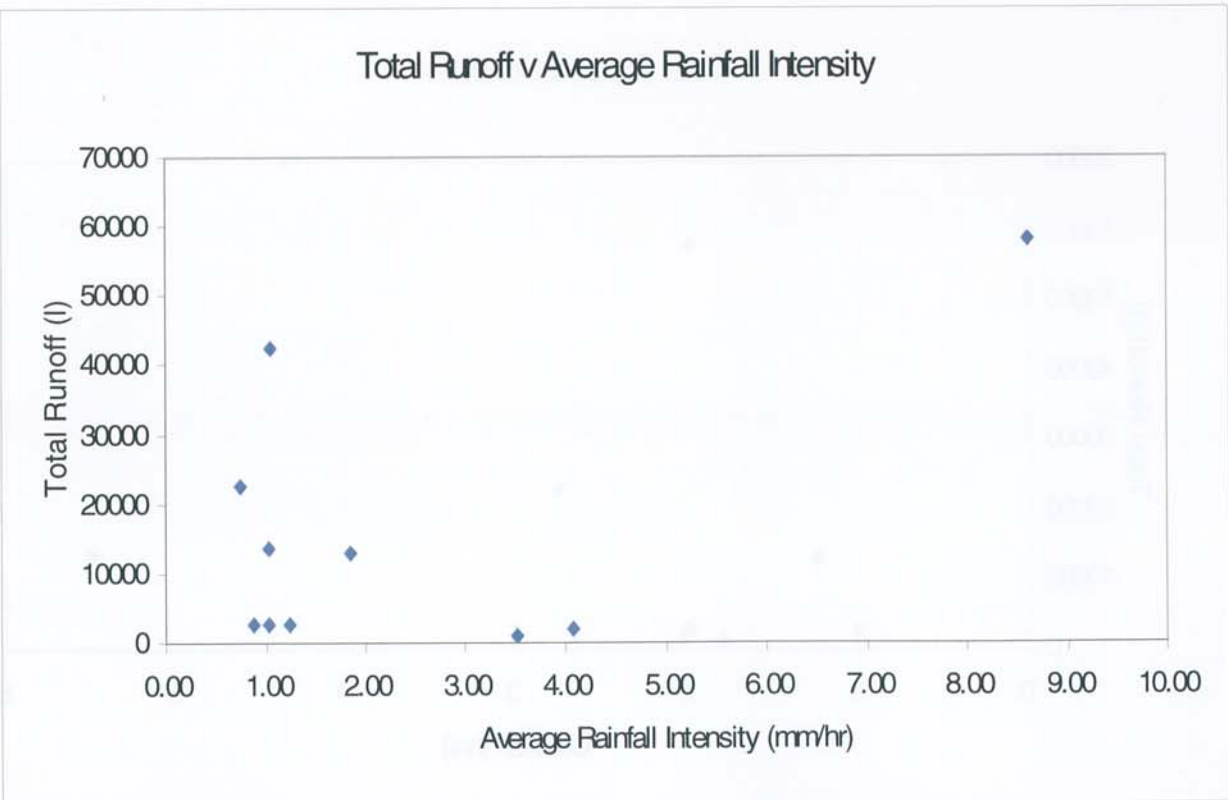

Event Composite Load/1000m2
ug/1000m2
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
07/02/98
02/03/98
23/04/98
26/05/98
02/06/98
25/06/98
12/07/98
09/09/98
13/11/98
08/12/98
Event Date
Flouranthene
Pyrene
Dibenz(ah)anthracene

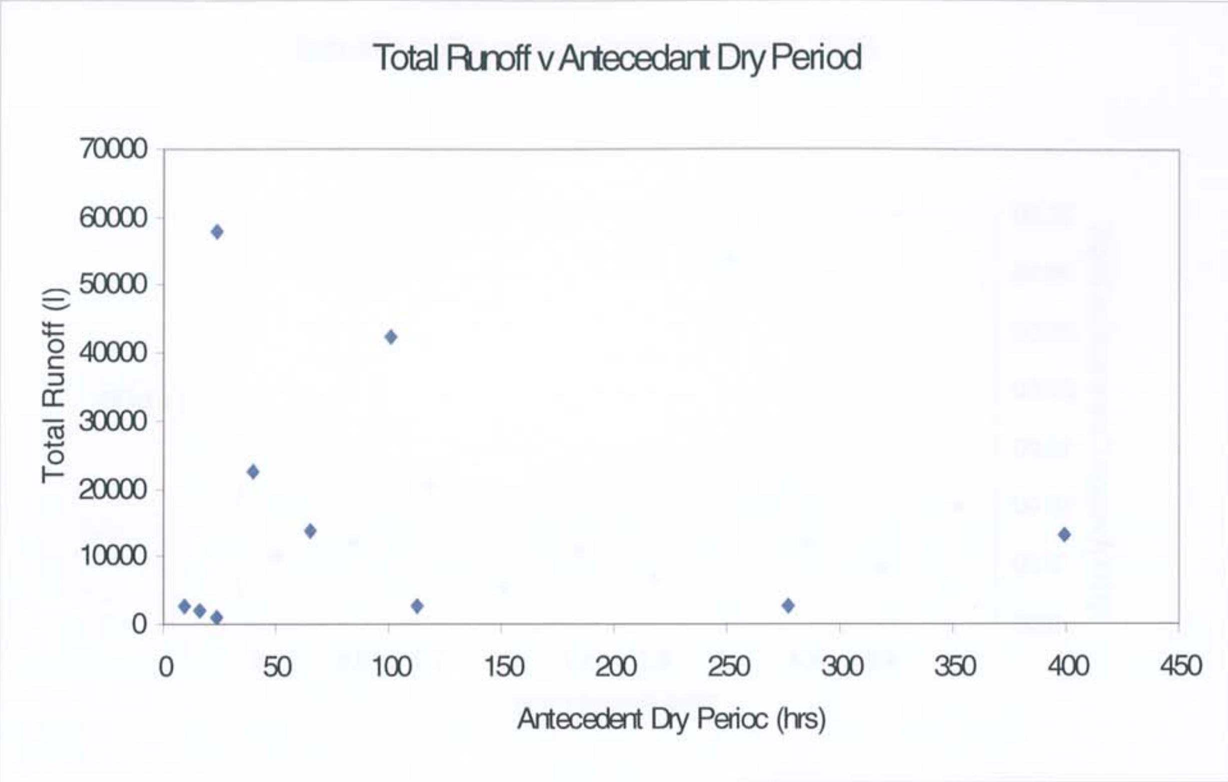
APPENDIX H GRAPHICAL PLOTS OF STORM EVENT DISCRETE SAMPLE ANALYSIS RESULTS AGAINST EVENT PARAMETERS

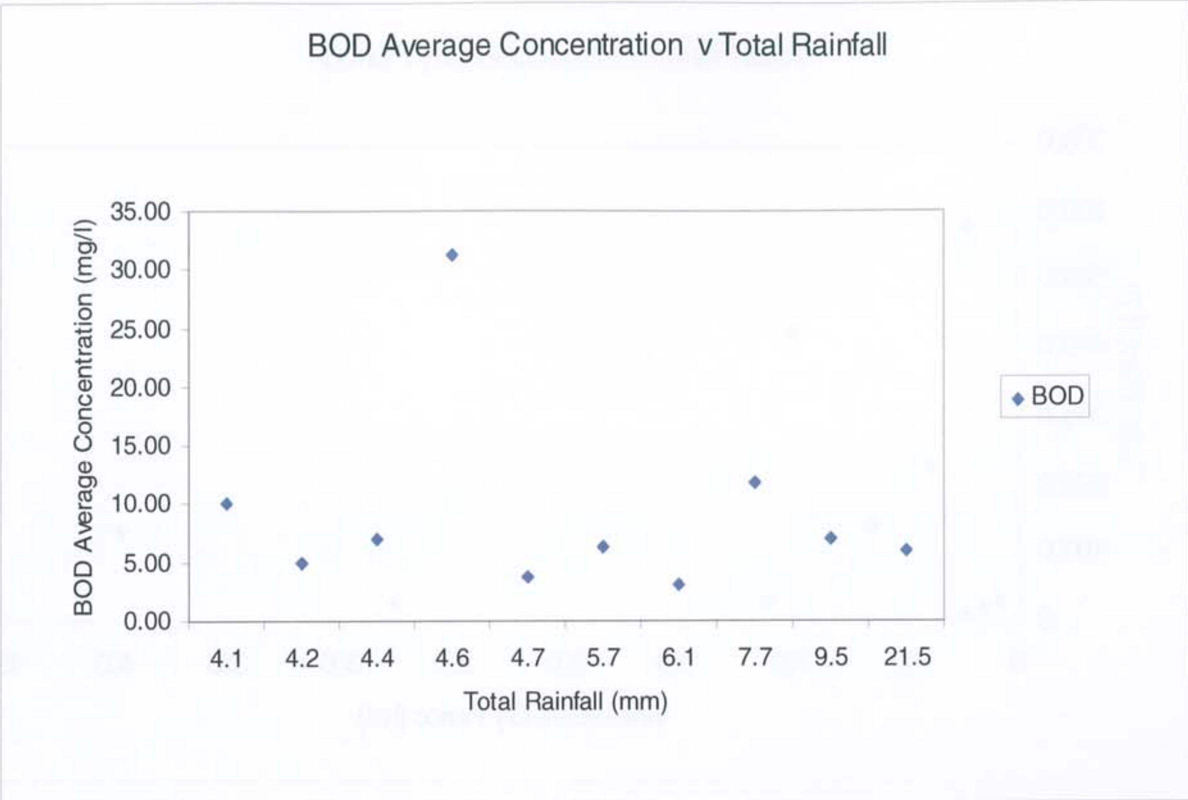

Total Runoff v Rainfall
Total Runoff (l)
70000
60000
50000
40000
30000
20000
10000
0
0
5
10
15
20
25
Total Rainfall (mm)

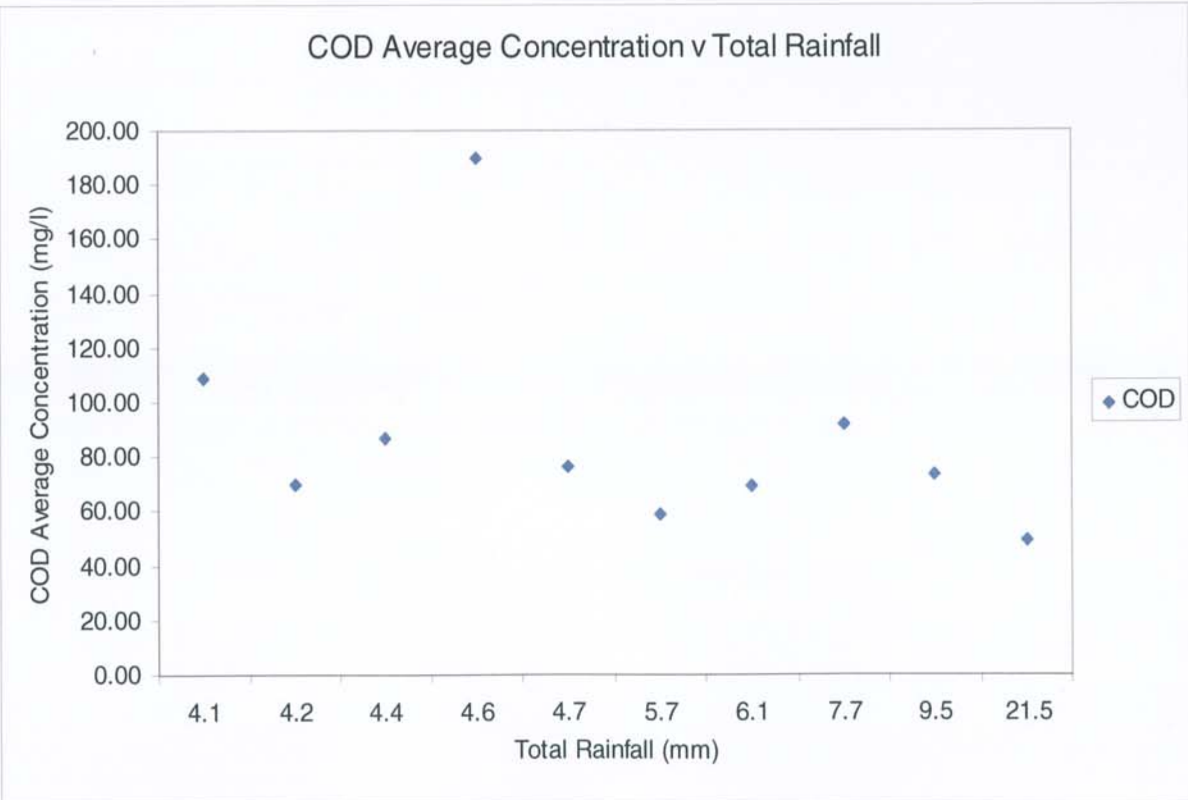

Total Runoff v Duration
Total Runoff (l)
70000
60000
50000
40000
30000
20000
10000
0
0
1
2
3
4
5
6
Duration (hrs)

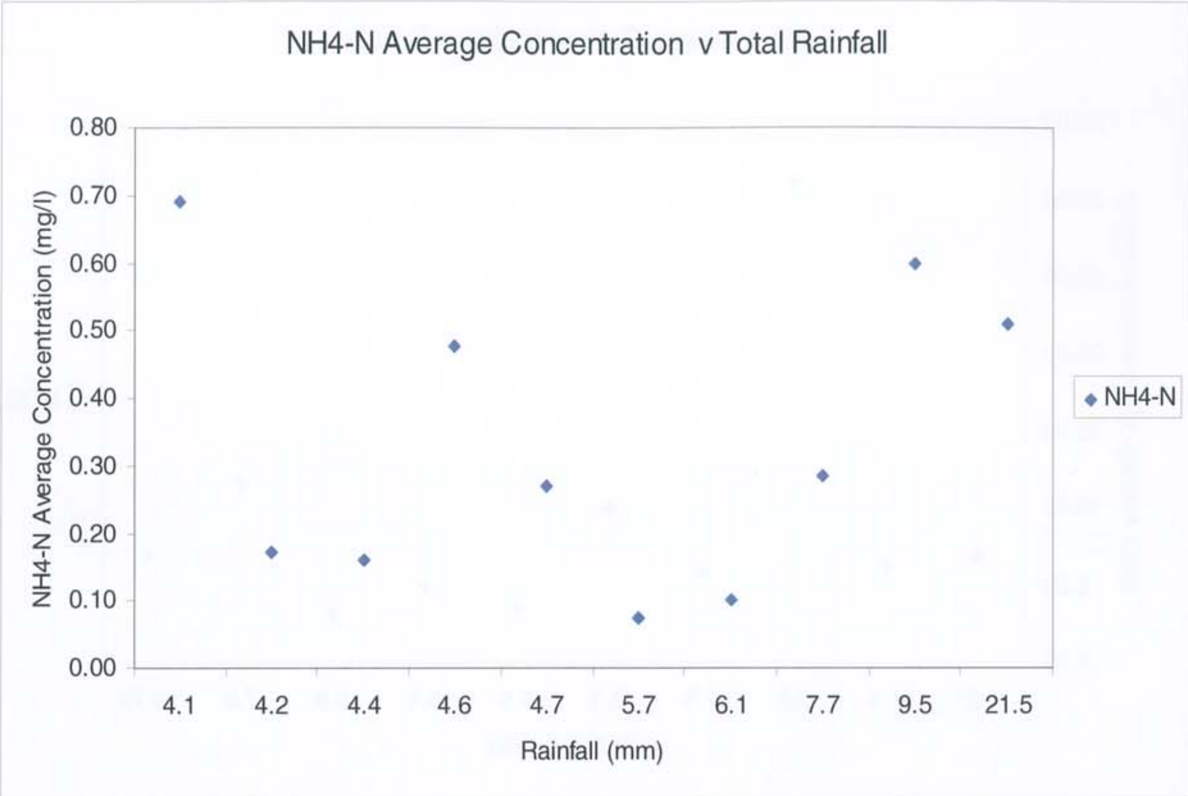

Total Runoff v Peak Rainfall Intensity
Total Runoff (l)
70000
60000
50000
40000
30000
20000
10000
0
0
5
10
15
20
25
30
35
Peak Rainfall Intensity (mm/hr)

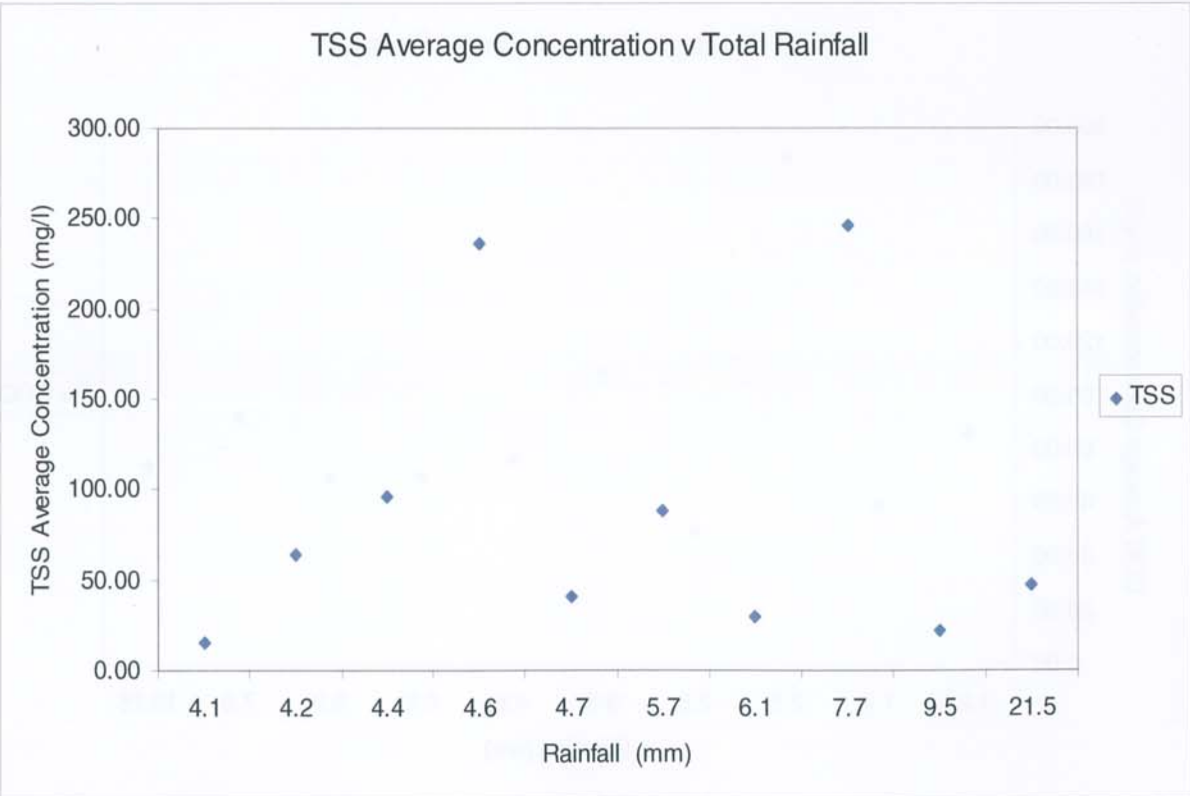

Total Runoff v Average Rainfall Intensity
Total Runoff (l)
70000
60000
50000
40000
30000
20000
10000
0
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Average Rainfall Intensity (mm/hr)

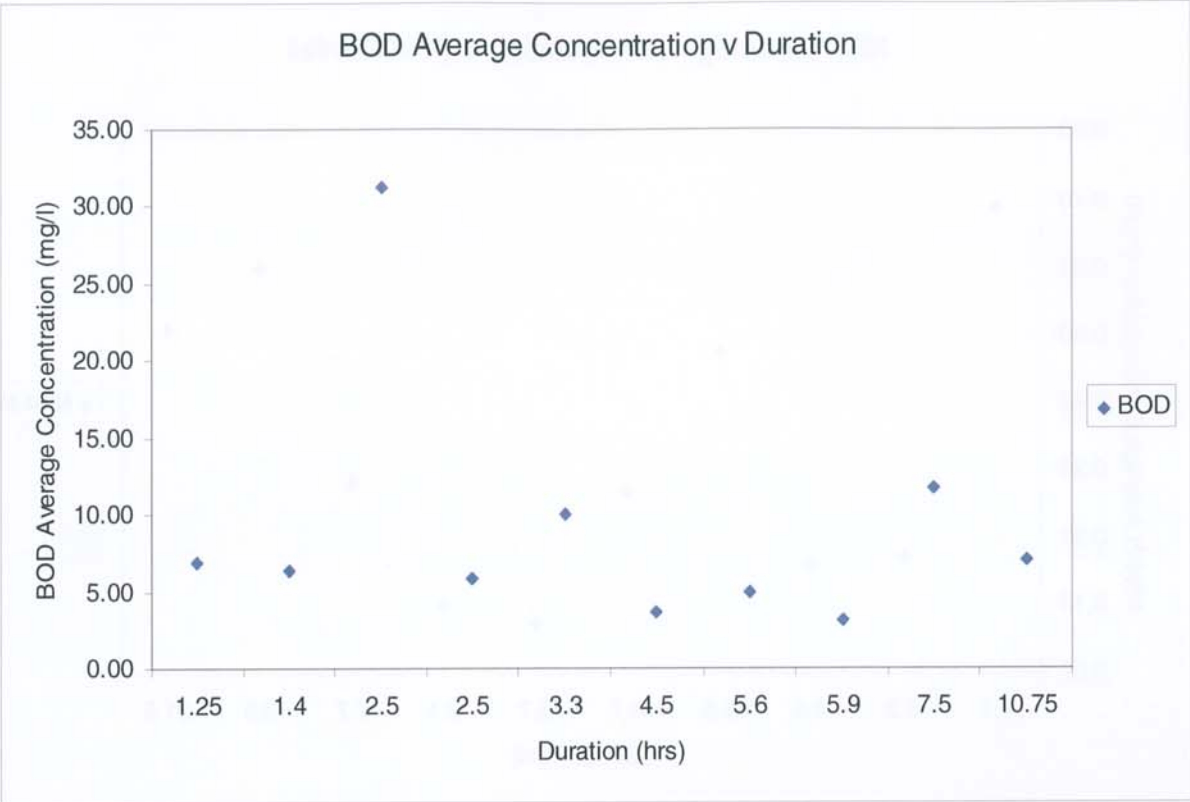

Total Runoff v Antecedant Dry Period
70000
60000
50000
40000
30000
20000
10000
0
Total Runoff (l)
0
50
100
150
200
250
300
350
400
450
Antecedent Dry Perioc (hrs)

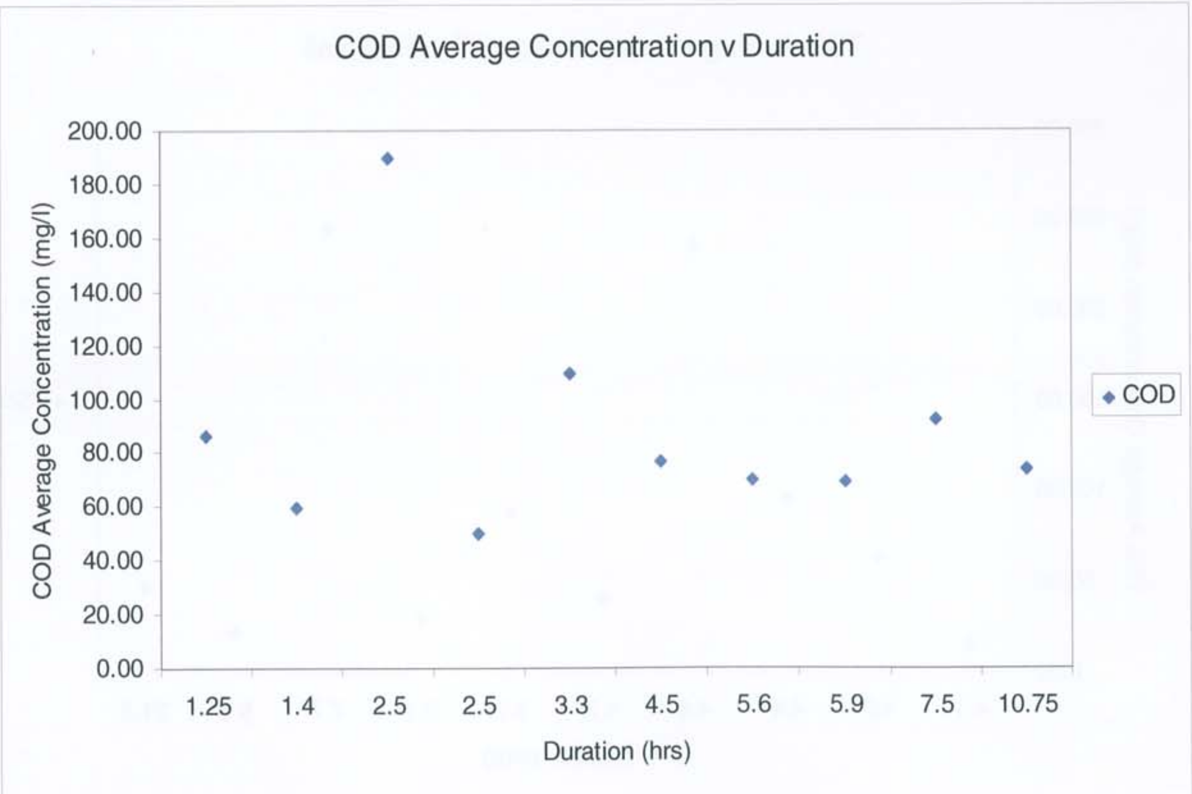

BOD Average Concentration v Total Rainfall
BOD Average Concentration (mg/l)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
4.1
4.2
4.4
4.6
4.7
5.7
6.1
7.7
9.5
21.5
Total Rainfall (mm)
BOD

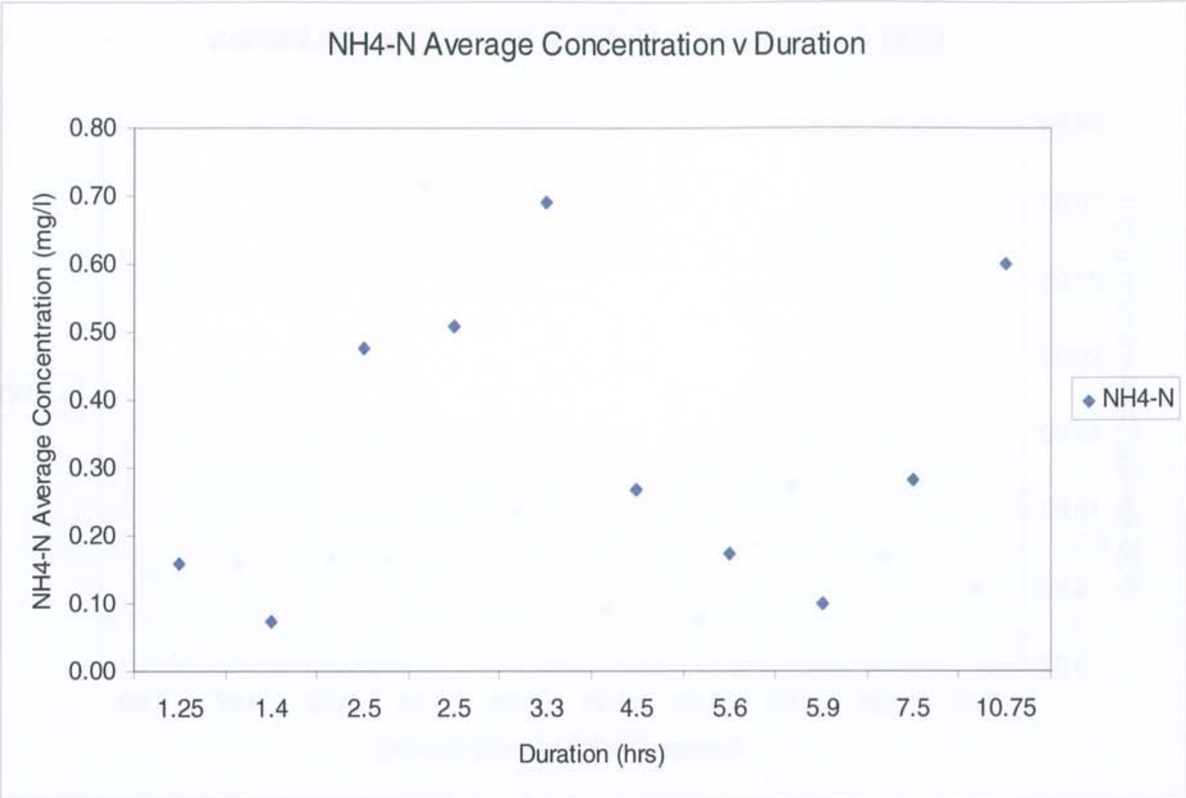

COD Average Concentration v Total Rainfall
COD Average Concentration (mg/l)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
4.1
4.2
4.4
4.6
4.7
5.7
6.1
7.7
9.5
21.5
Total Rainfall (mm)
COD

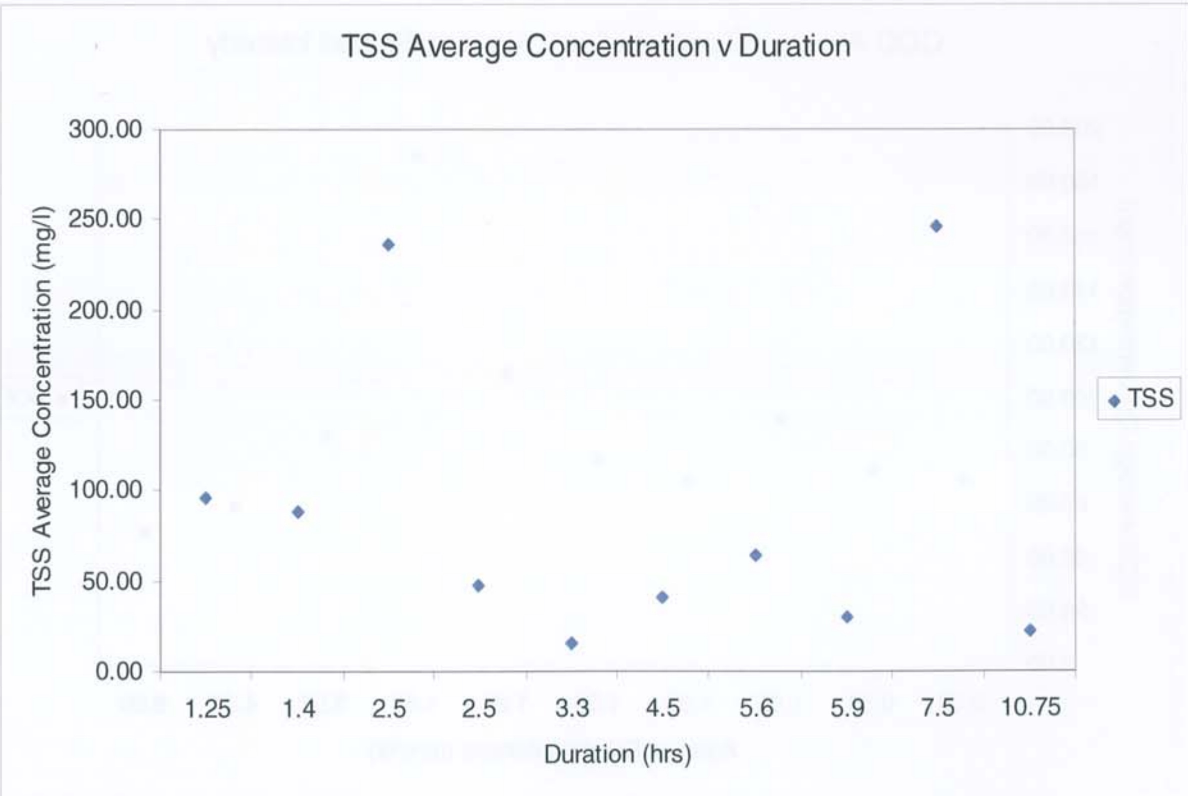

NH4-N Average Concentration v Total Rainfall
NH4-N Average Concentration (mg/l)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
4.1
4.2
4.4
4.6
4.7
5.7
6.1
7.7
9.5
21.5
Rainfall (mm)
NH4-N

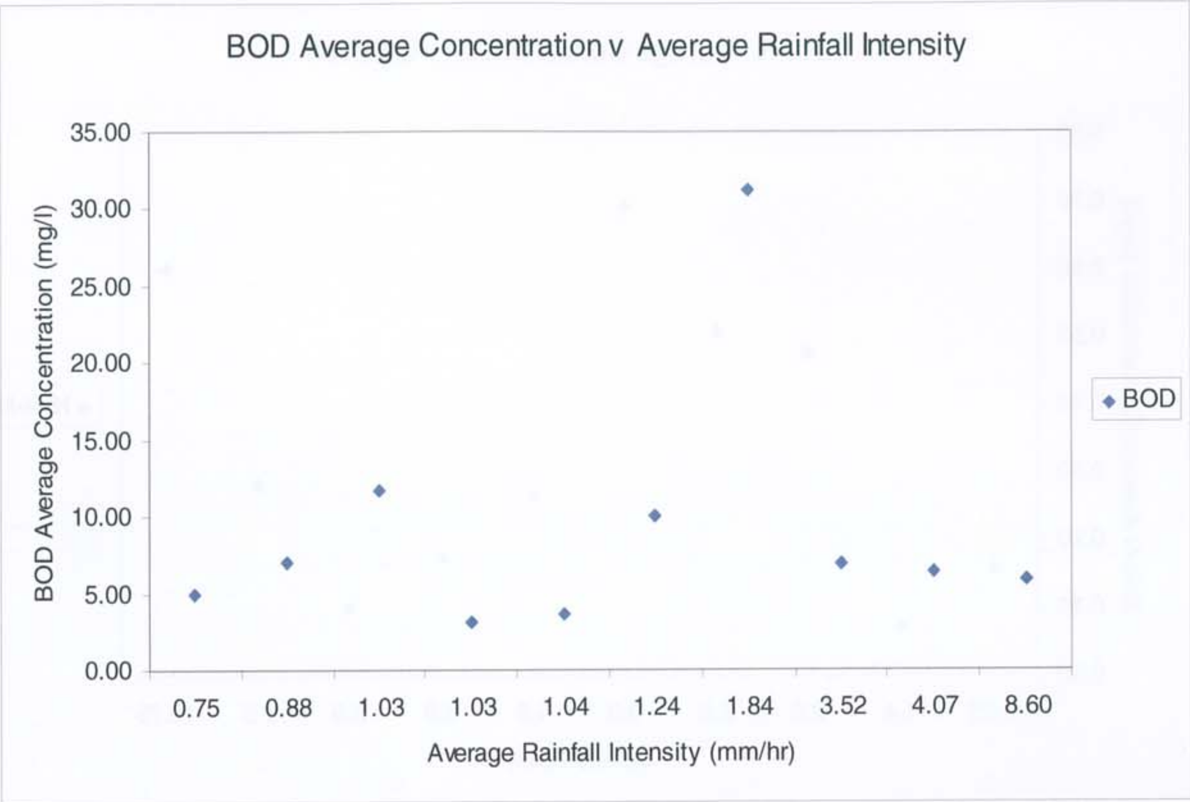

TSS Average Concentration v Total Rainfall
TSS Average Concentration (mg/l)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
4.1
4.2
4.4
4.6
4.7
5.7
6.1
7.7
9.5
21.5
Rainfall (mm)
TSS

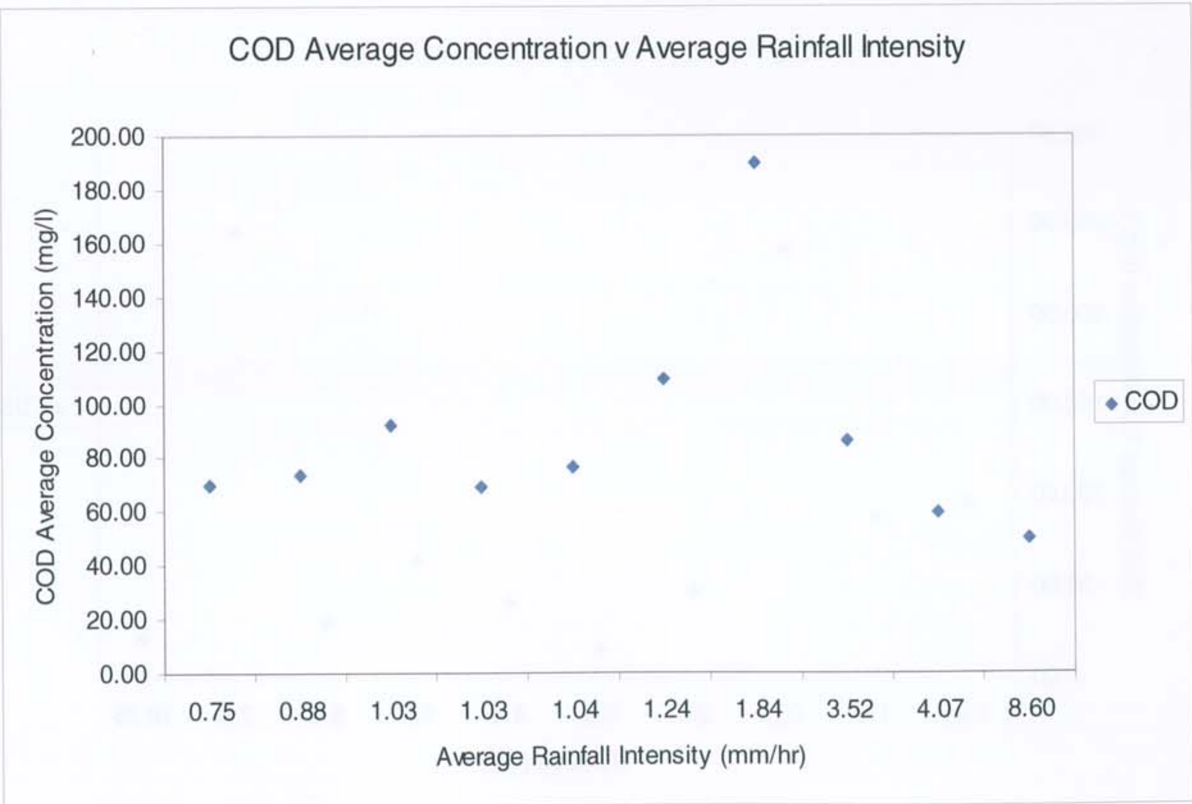

BOD Average Concentration v Duration
BOD Average Concentration (mg/l)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1.25
1.4
2.5
2.5
3.3
4.5
5.6
5.9
7.5
10.75
Duration (hrs)
BOD

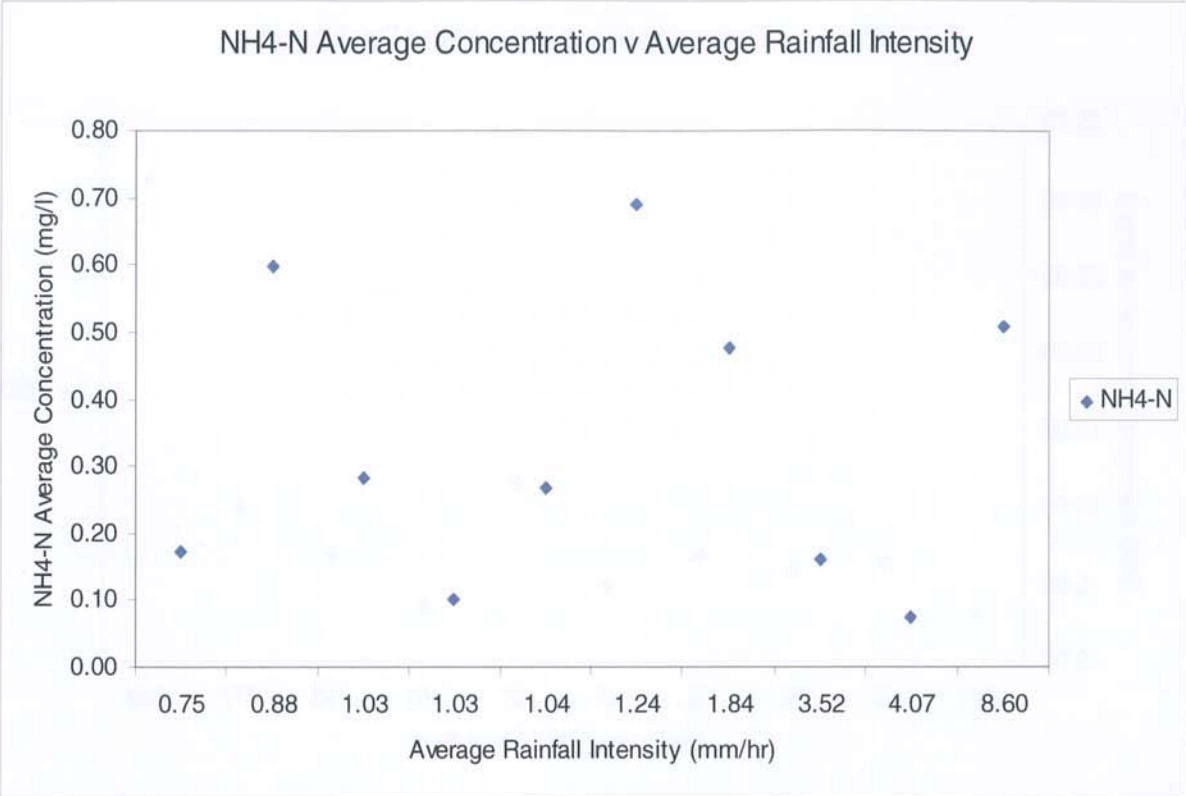

COD Average Concentration v Duration
COD Average Concentration (mg/l)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
1.25
1.4
2.5
2.5
3.3
4.5
5.6
5.9
7.5
10.75
Duration (hrs)
COD

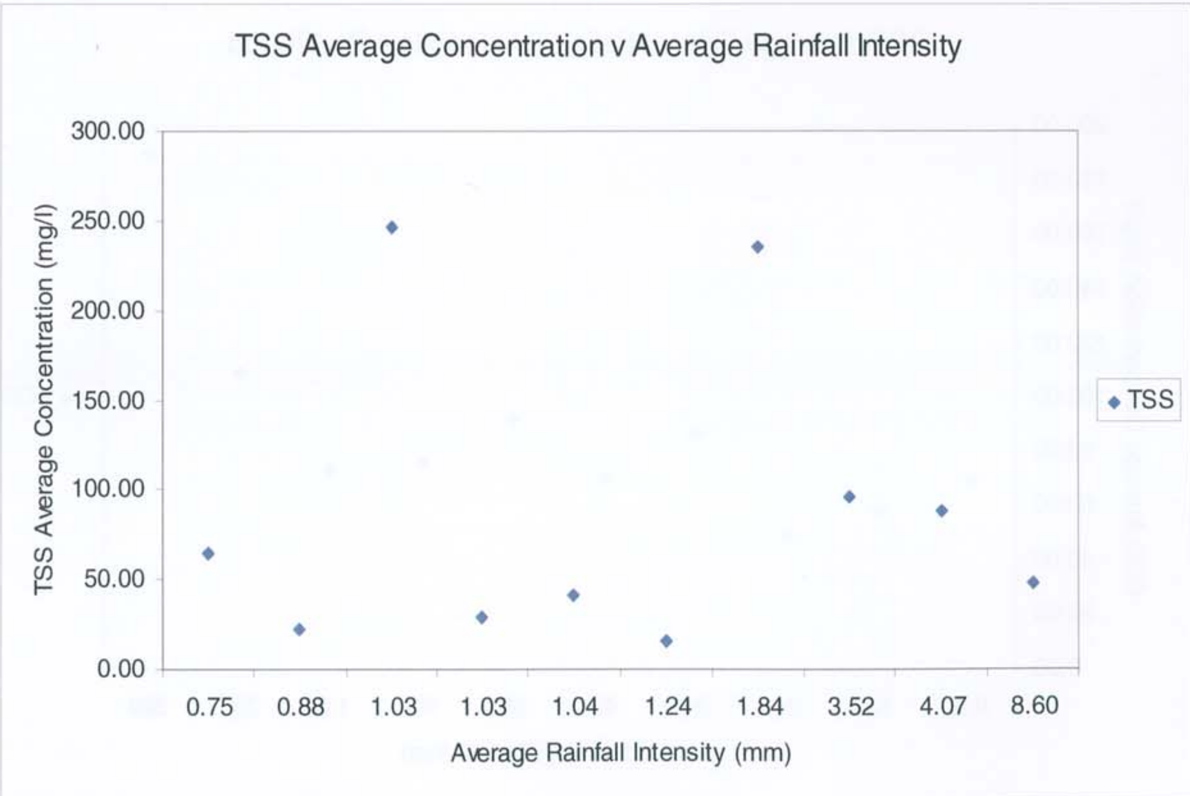

NH4-N Average Concentration v Duration
NH4-N Average Concentration (mg/l)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1.25
1.4
2.5
2.5
3.3
4.5
5.6
5.9
7.5
10.75
Duration (hrs)
NH4-N

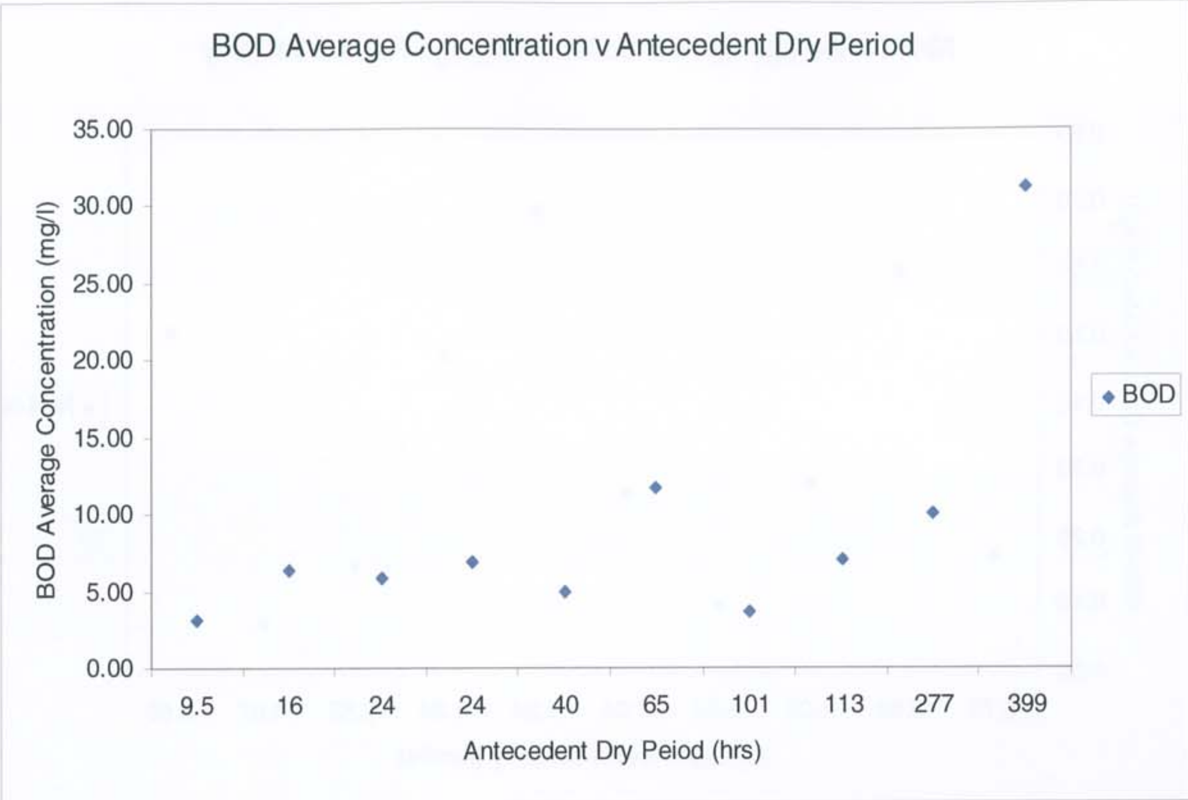

TSS Average Concentration v Duration
TSS Average Concentration (mg/l)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
1.25
1.4
2.5
2.5
3.3
4.5
5.6
5.9
7.5
10.75
Duration (hrs)
TSS

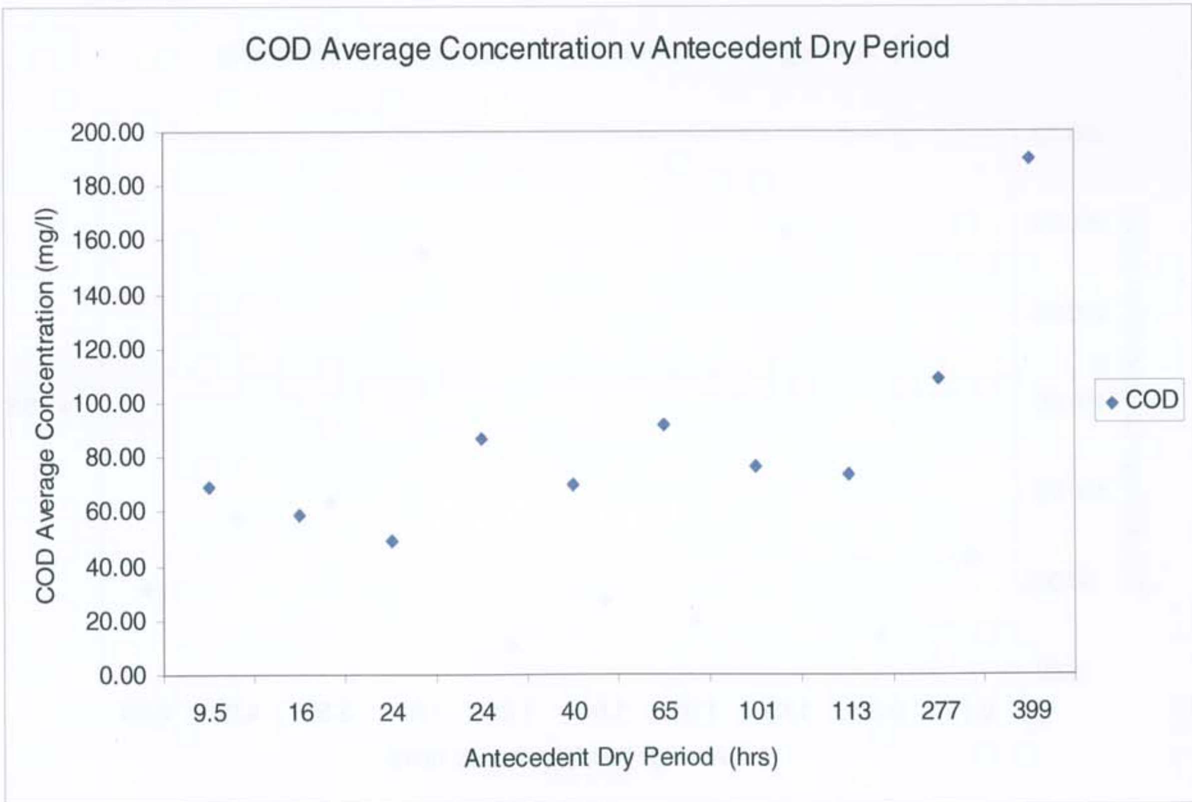

BOD Average Concentration v Average Rainfall Intensity
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
BOD Average Concentration (mg/l)
0.75
0.88
1.03
1.03
1.04
1.24
1.84
3.52
4.07
8.60
Average Rainfall Intensity (mm/hr)
BOD

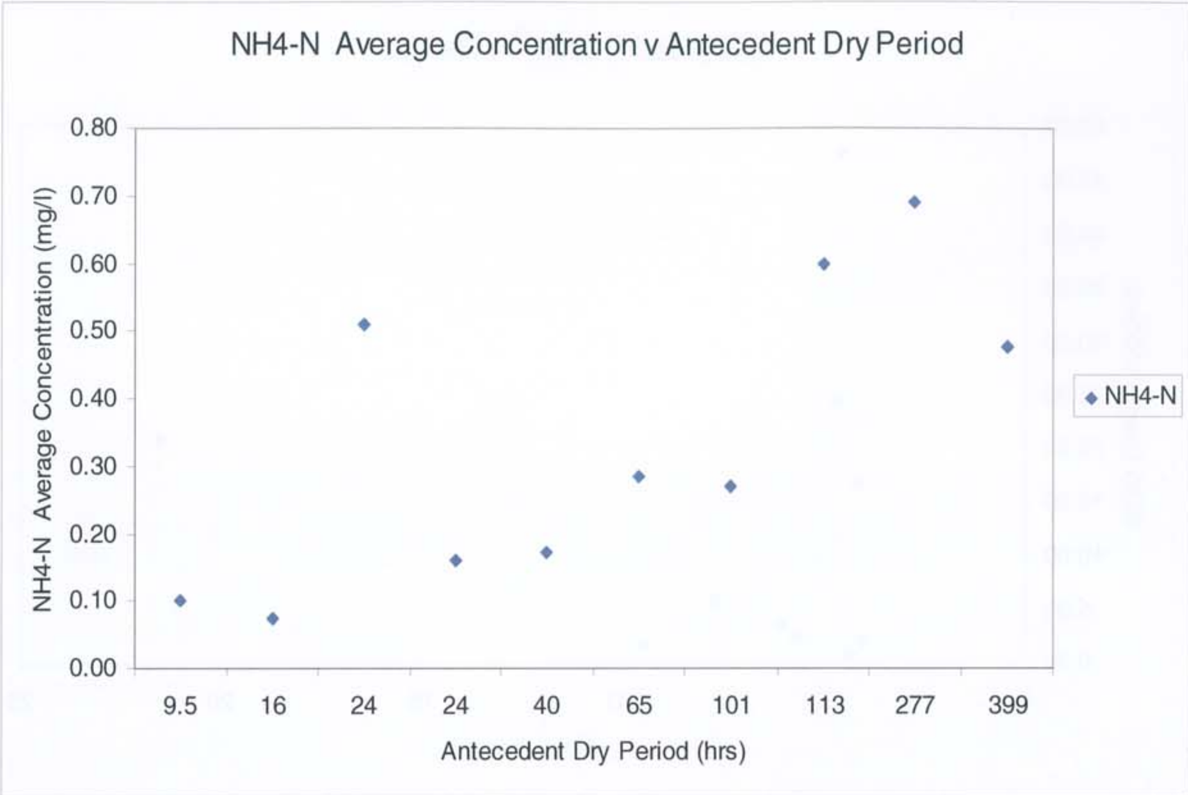

COD Average Concentration v Average Rainfall Intensity
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
COD Average Concentration (mg/l)
0.75
0.88
1.03
1.03
1.04
1.24
1.84
3.52
4.07
8.60
Average Rainfall Intensity (mm/hr)
COD

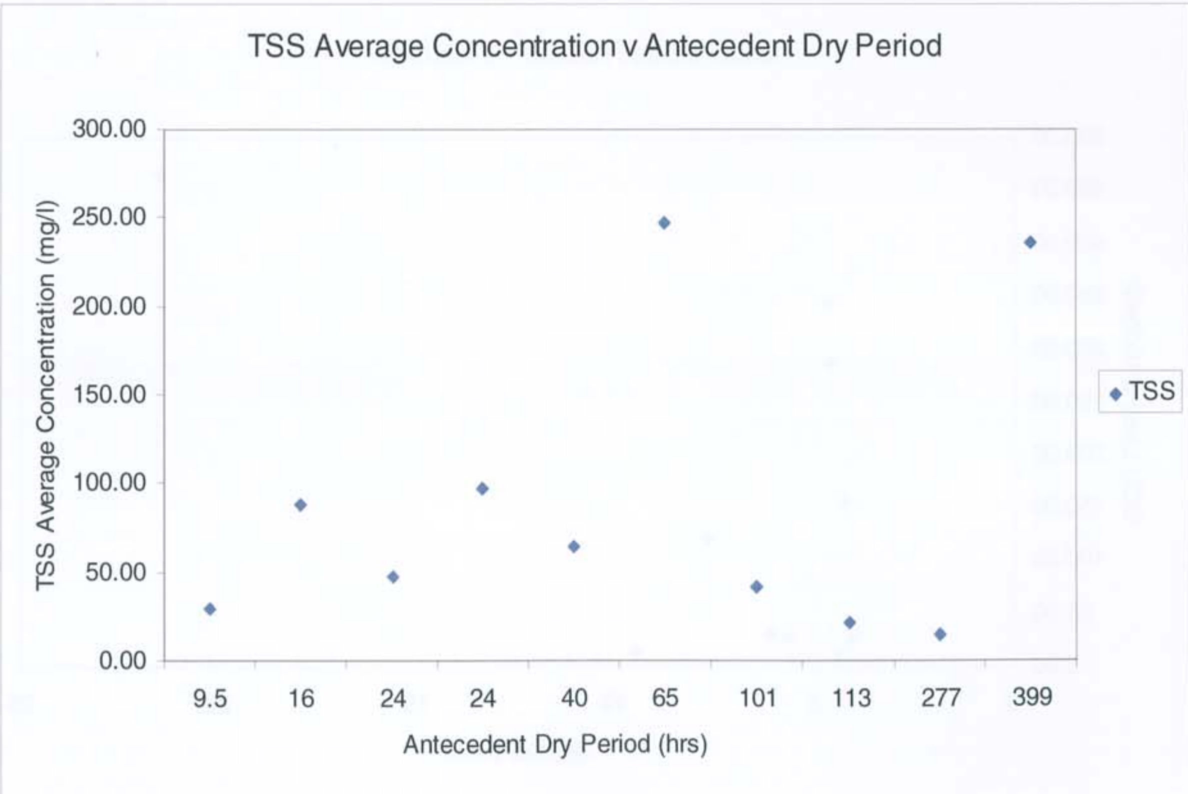

NH4-N Average Concentration v Average Rainfall Intensity
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
NH4-N Average Concentration (mg/l)
0.75
0.88
1.03
1.03
1.04
1.24
1.84
3.52
4.07
8.60
Average Rainfall Intensity (mm/hr)
NH4-N

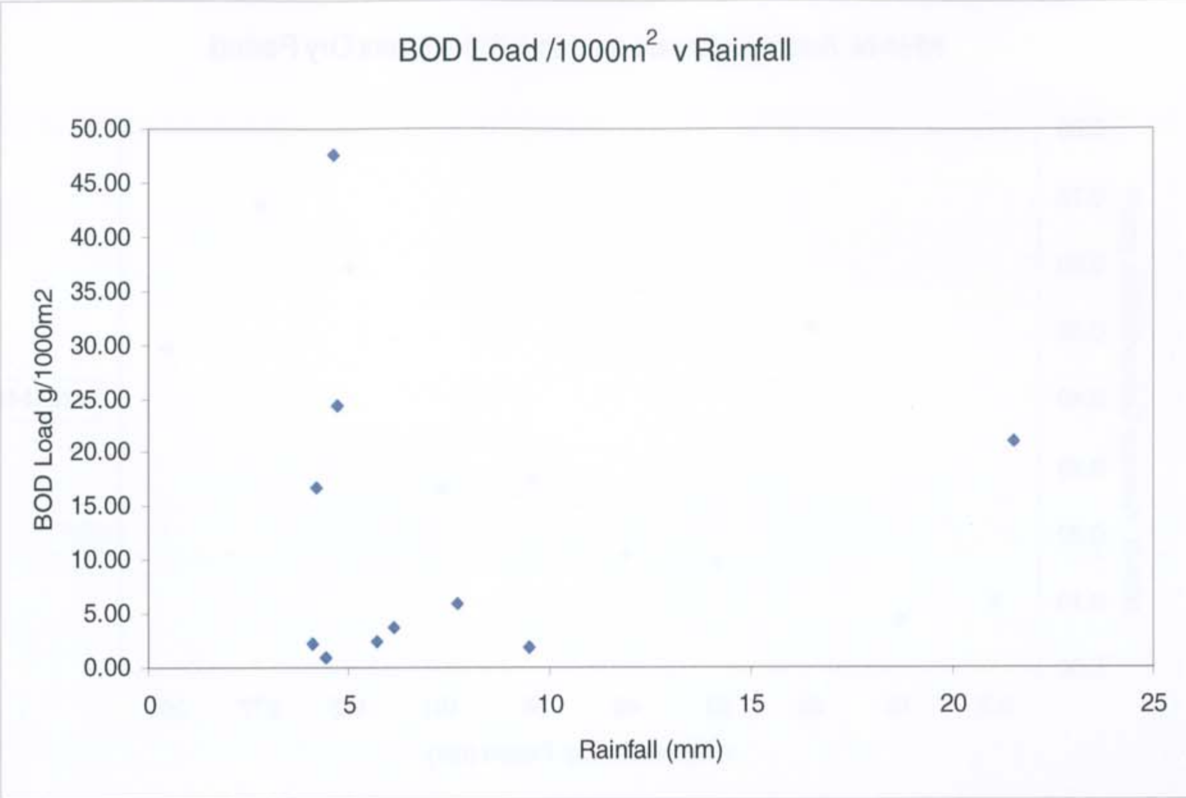

TSS Average Concentration v Average Rainfall Intensity
300.00
250.00
200.00
150.00
100.00
50.00
0.00
TSS Average Concentration (mg/l)
0.75
0.88
1.03
1.03
1.04
1.24
1.84
3.52
4.07
8.60
Average Rainfall Intensity (mm)
TSS

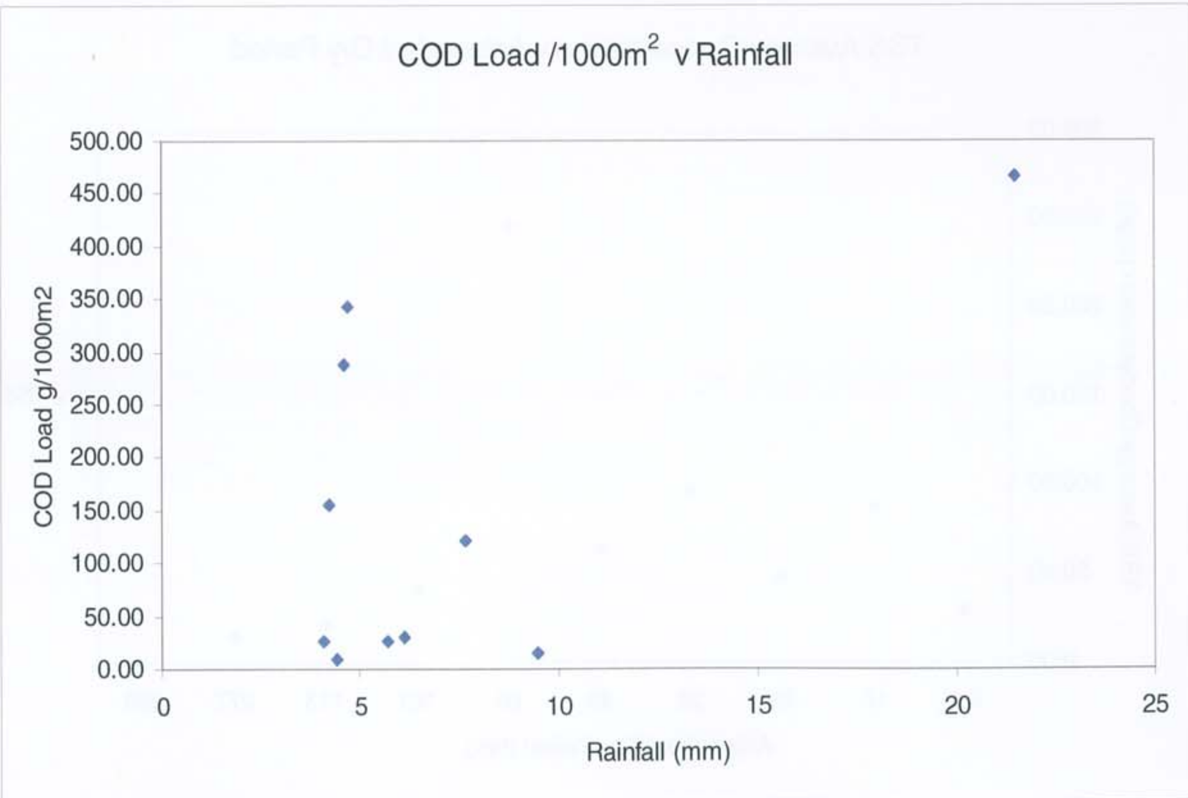

BOD Average Concentration v Antecedent Dry Period
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
BOD Average Concentration (mg/l)
9.5
16
24
24
40
65
101
113
277
399
Antecedent Dry Peiod (hrs)
BOD

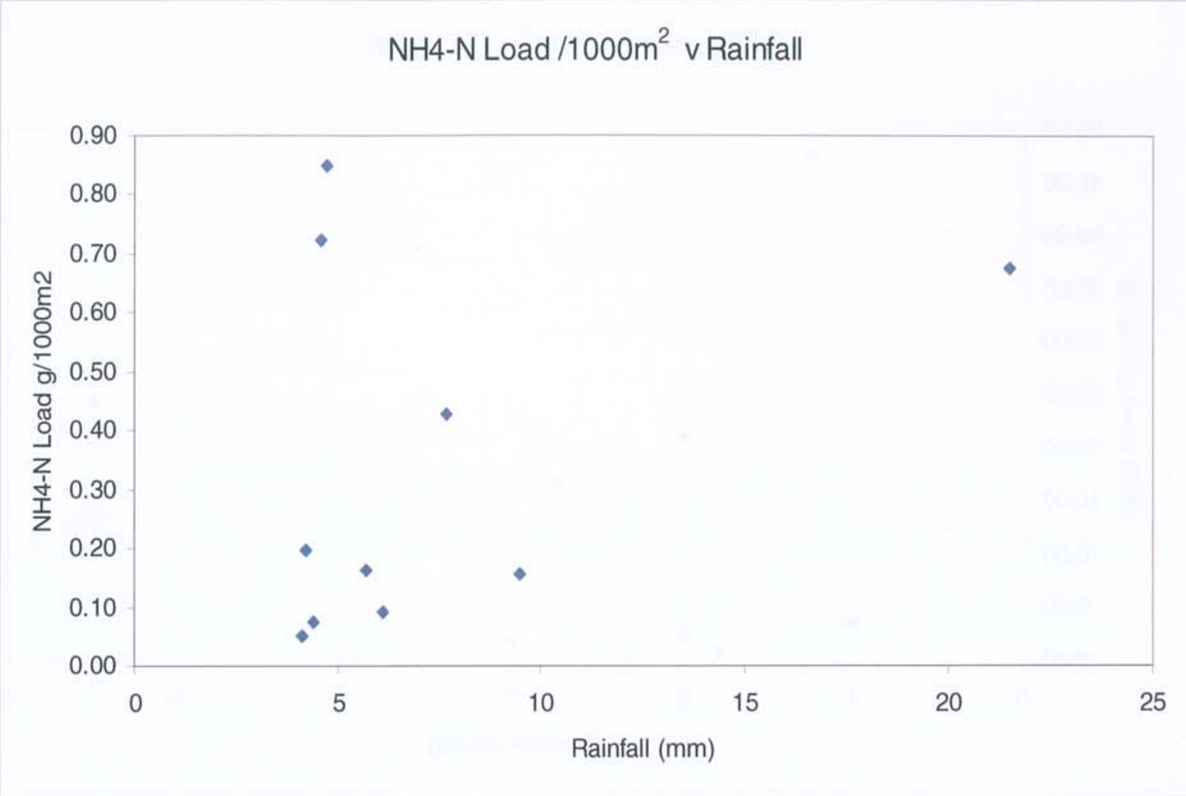

COD Average Concentration v Antecedent Dry Period
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
COD Average Concentration (mg/l)
9.5
16
24
24
40
65
101
113
277
399
Antecedent Dry Period (hrs)
COD

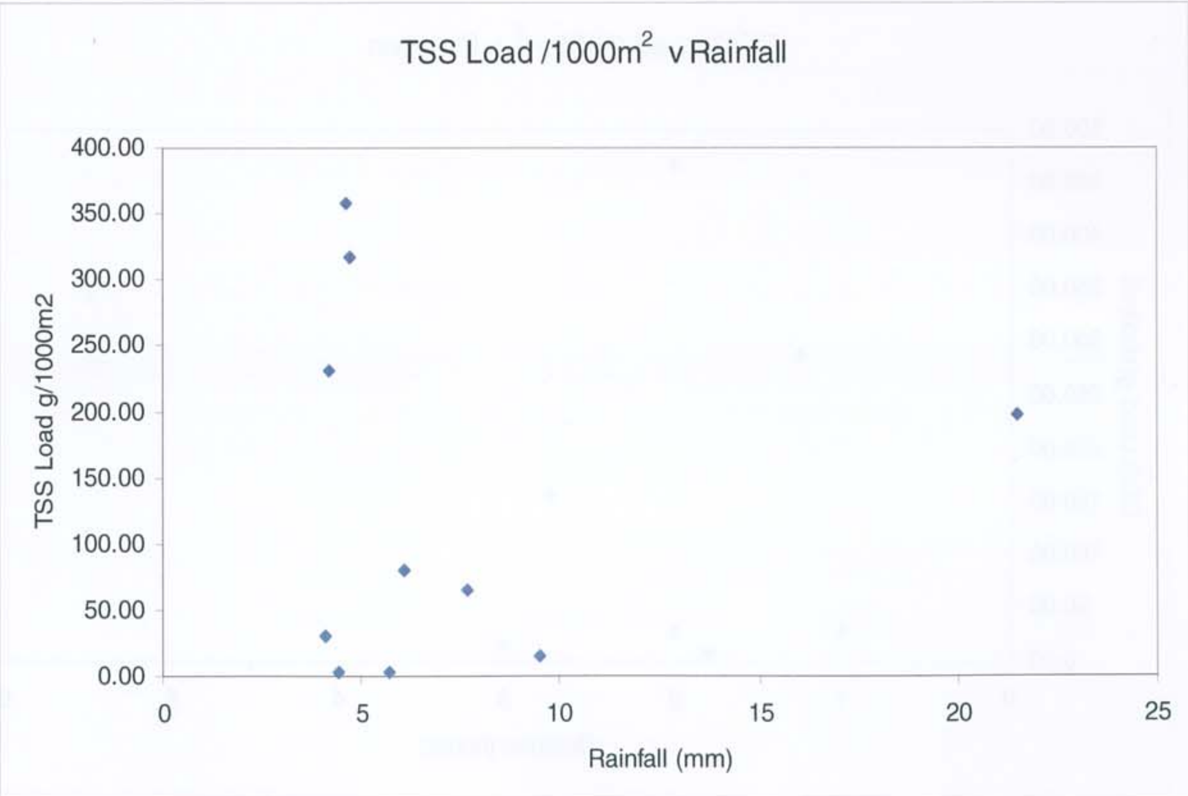

NH4-N Average Concentration v Antecedent Dry Period
NH4-N Average Concentration (mg/l)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
9.5
16
24
24
40
65
101
113
277
399
Antecedent Dry Period (hrs)
NH4-N

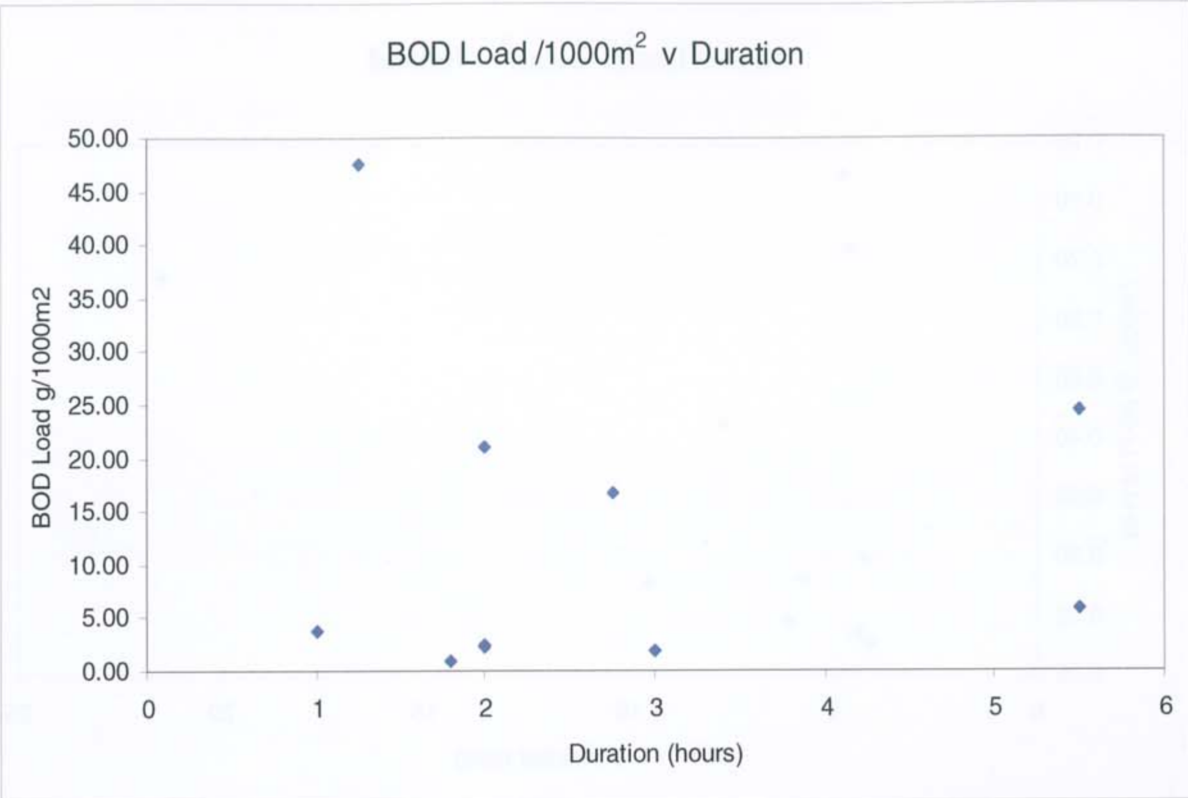

TSS Average Concentration v Antecedent Dry Period
TSS Average Concentration (mg/l)
300.00
250.00
200.00
150.00
100.00
50.00
0.00
9.5
16
24
24
40
65
101
113
277
399
Antecedent Dry Period (hrs)
TSS

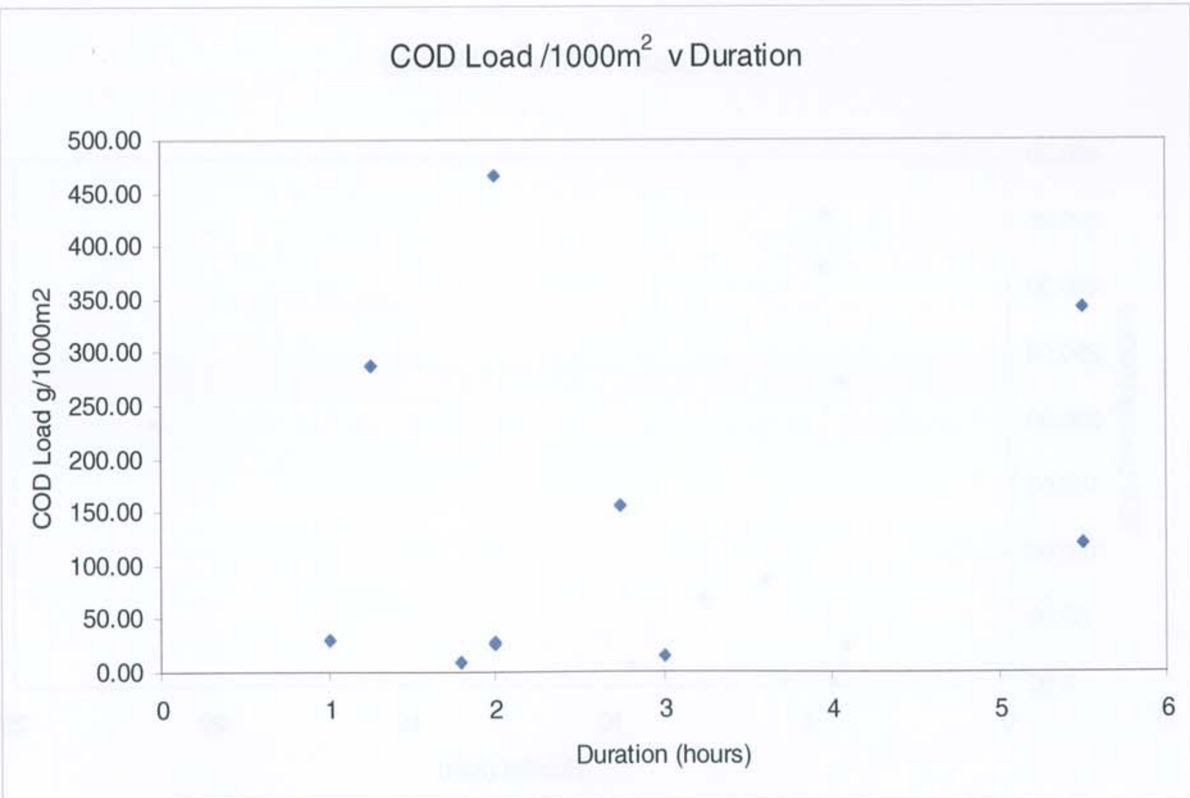

BOD Load /1000m2 v Rainfall
BOD Load g/1000m2
Rainfall (mm)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
5
10
15
20
25

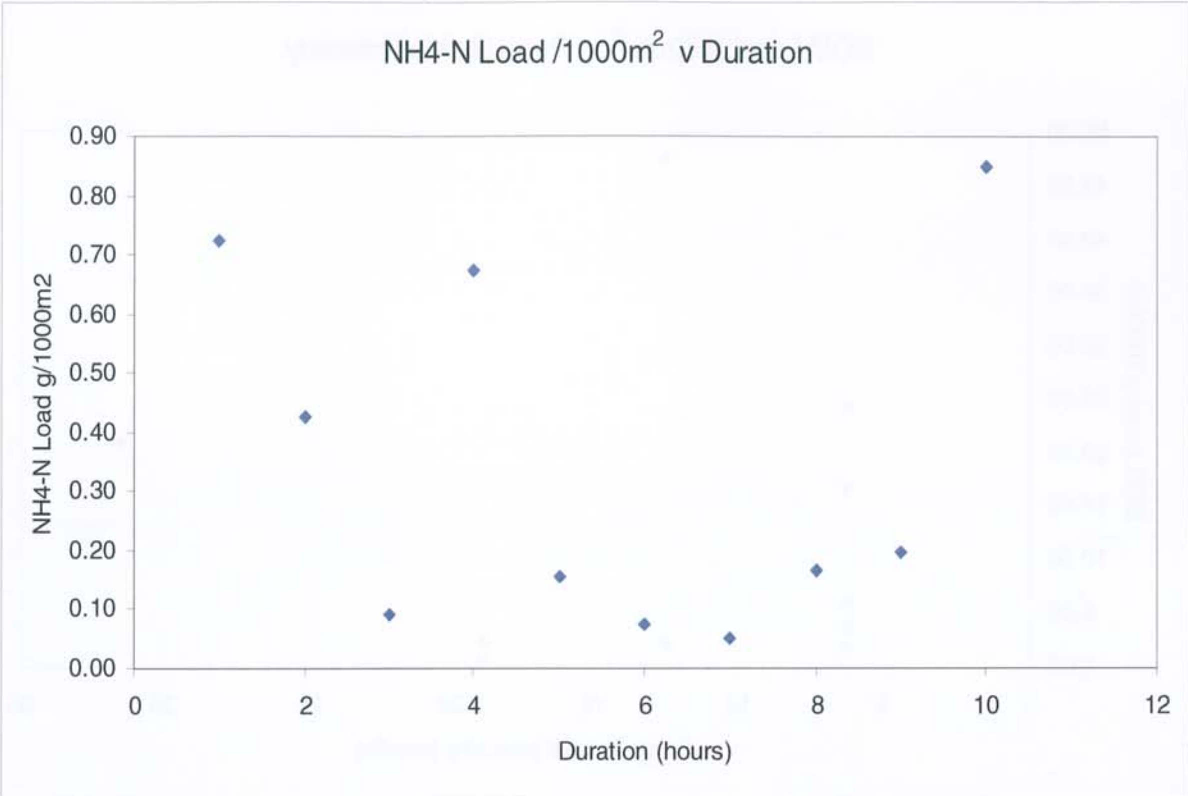

COD Load /1000m2 v Rainfall
COD Load g/1000m2
Rainfall (mm)
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
5
10
15
20
25

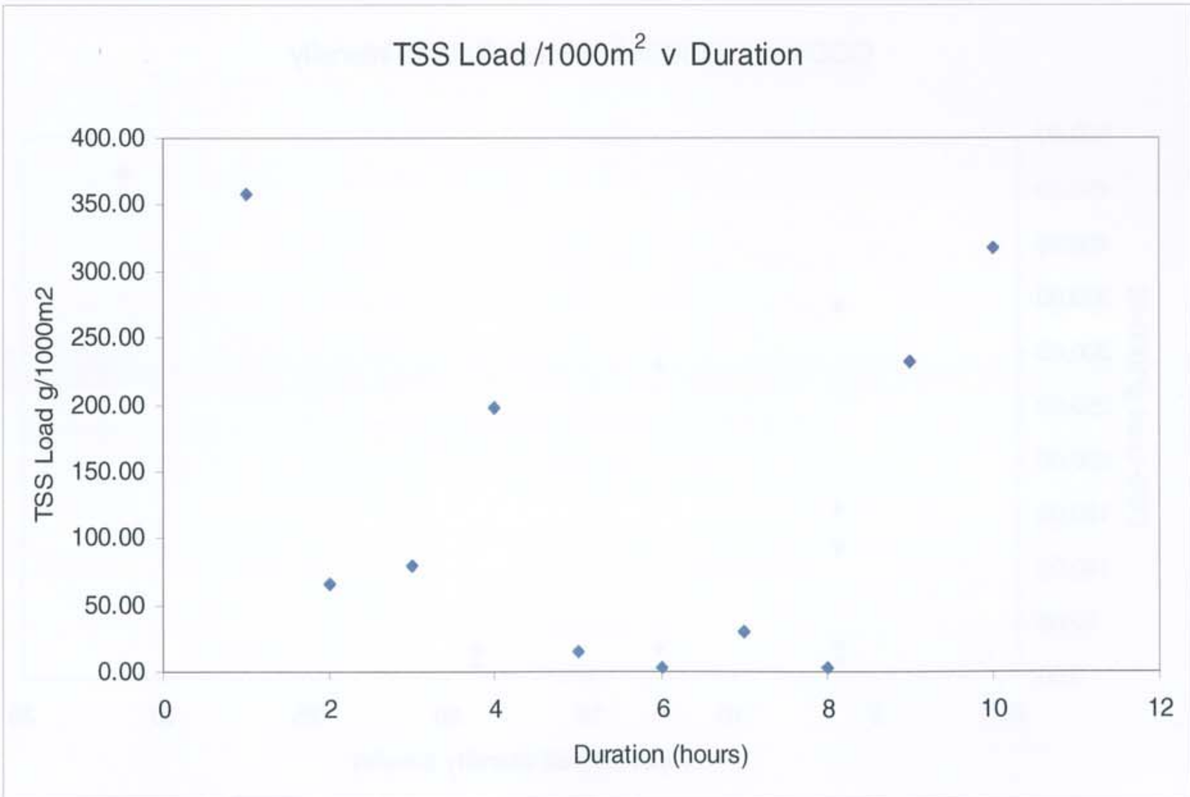

NH4-N Load /1000m2 v Rainfall
NH4-N Load g/1000m2
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
5
10
15
20
25
Rainfall (mm)

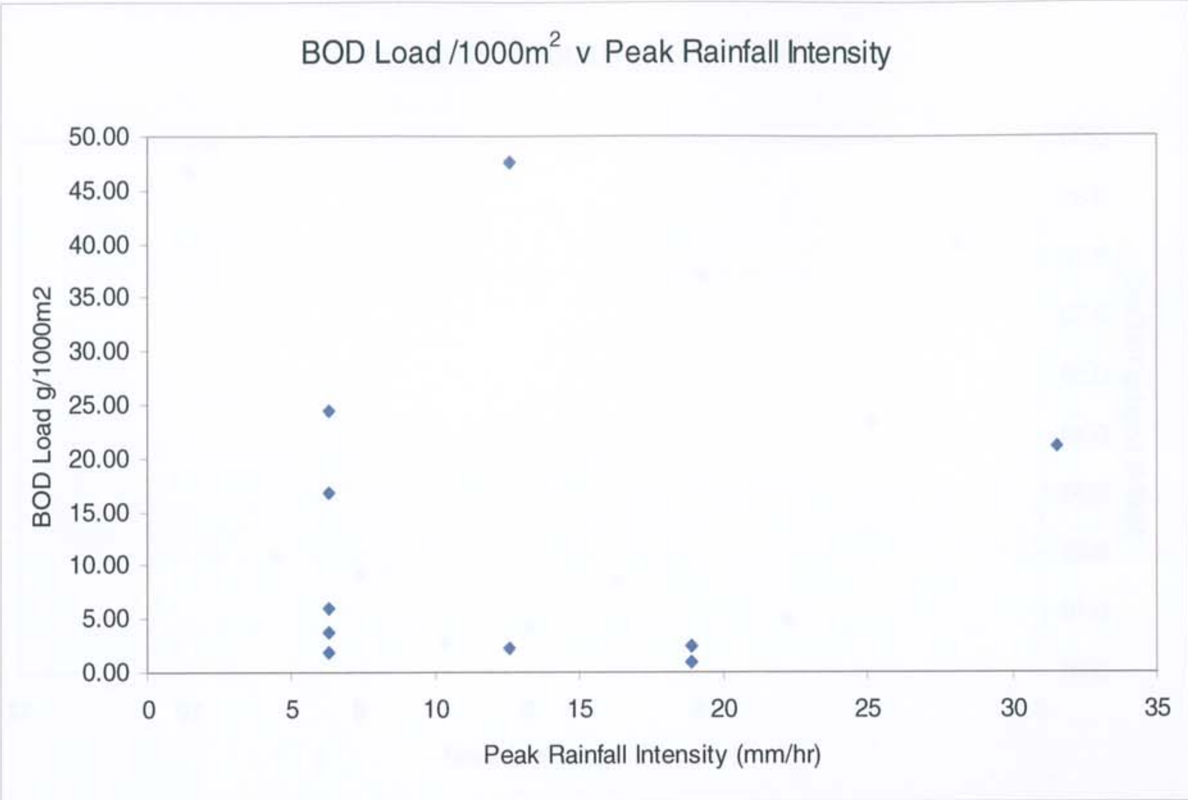

TSS Load /1000m2 v Rainfall
TSS Load g/1000m2
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
5
10
15
20
25
Rainfall (mm)

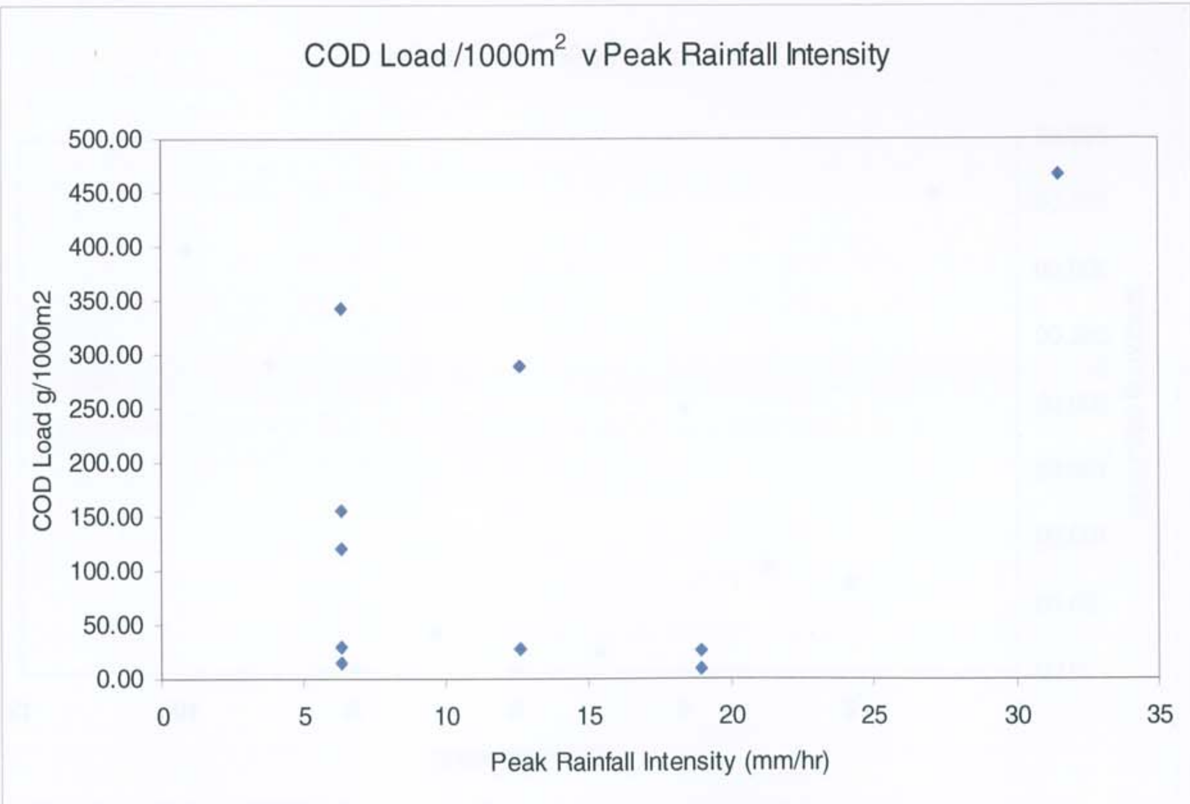

BOD Load /1000m2 v Duration
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
BOD Load g/1000m2
0
1
2
3
4
5
6
Duration (hours)

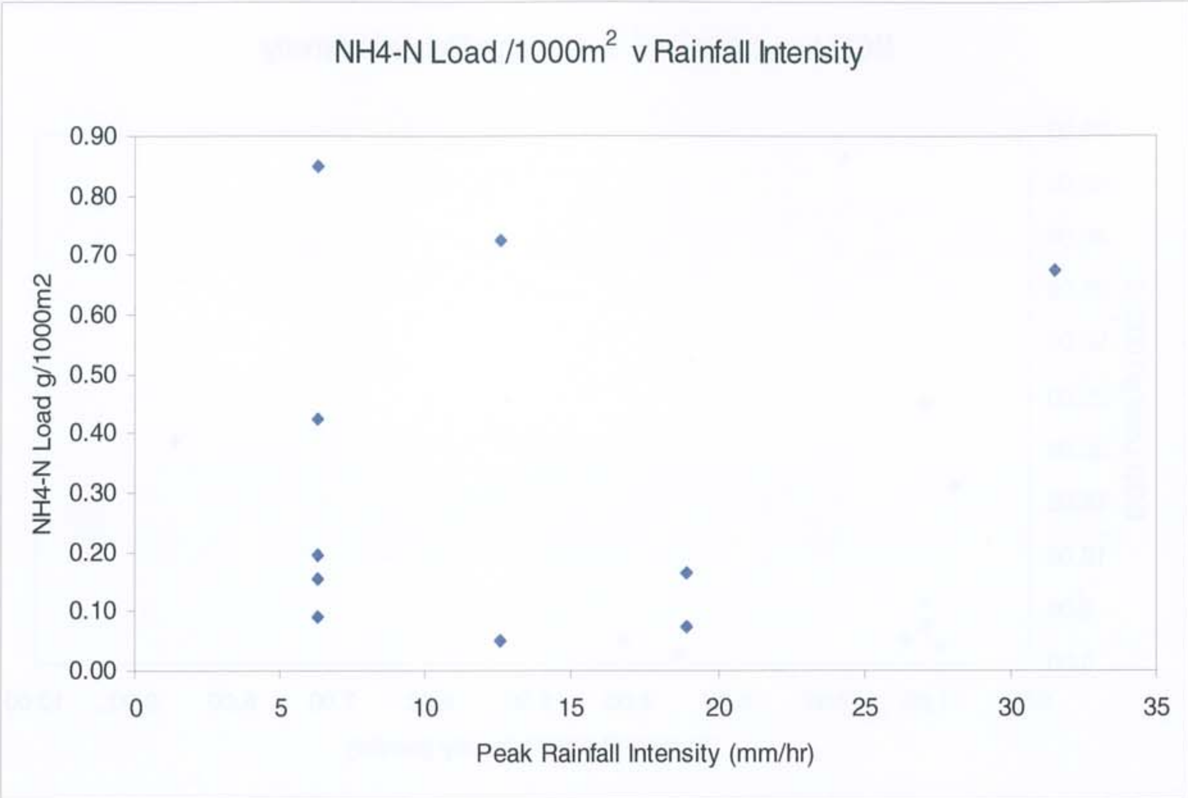

COD Load /1000m2 v Duration
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
COD Load g/1000m2
0
1
2
3
4
5
6
Duration (hours)

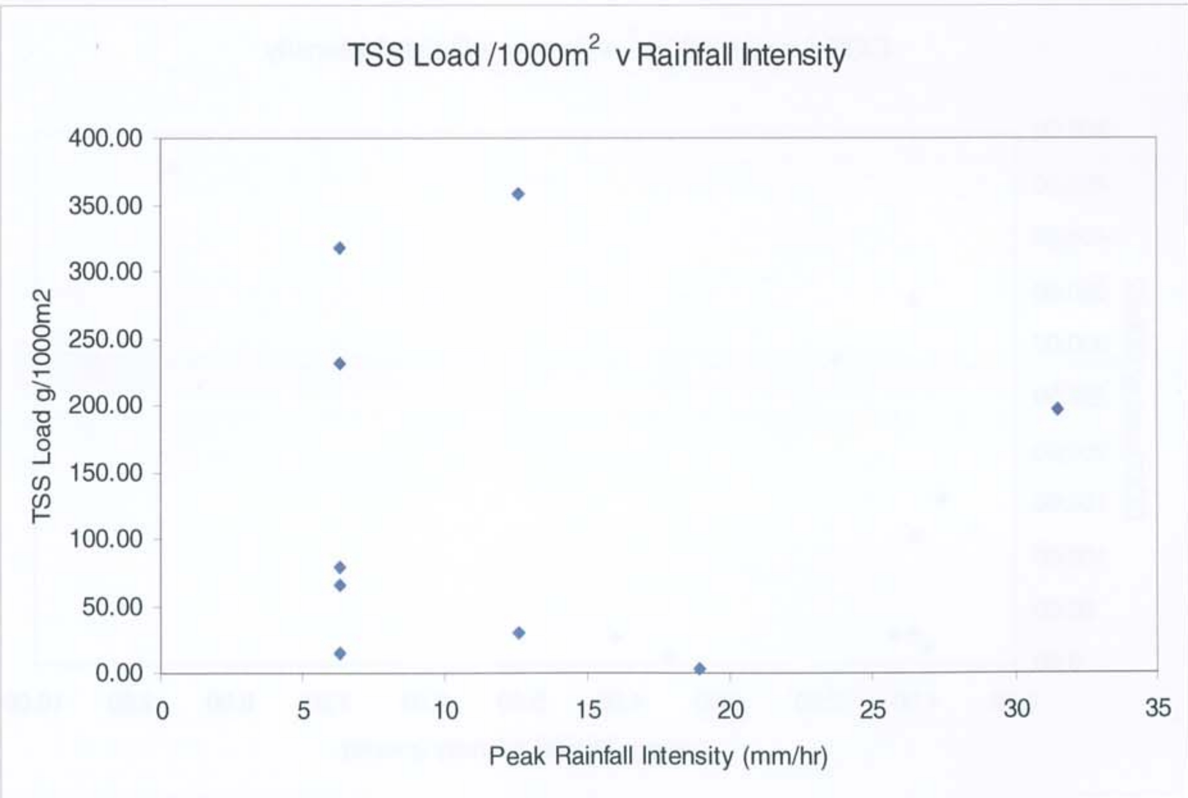

NH4-N Load /1000m2 v Duration
NH4-N Load g/1000m2
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
2
4
6
8
10
12
Duration (hours)

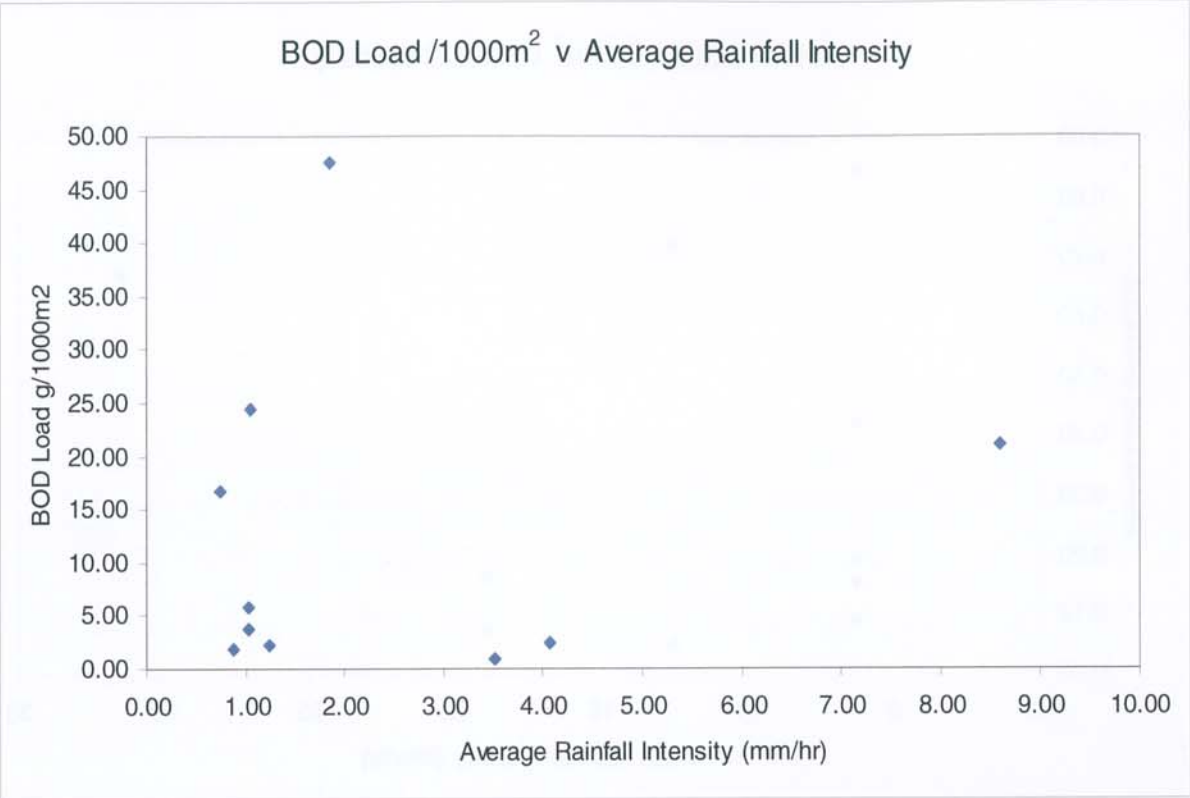

TSS Load /1000m2 v Duration
TSS Load g/1000m2
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
2
4
6
8
10
12
Duration (hours)


BOD Load /1000m2 v Peak Rainfall Intensity
BOD Load g/1000m2
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
5
10
15
20
25
30
35
Peak Rainfall Intensity (mm/hr)

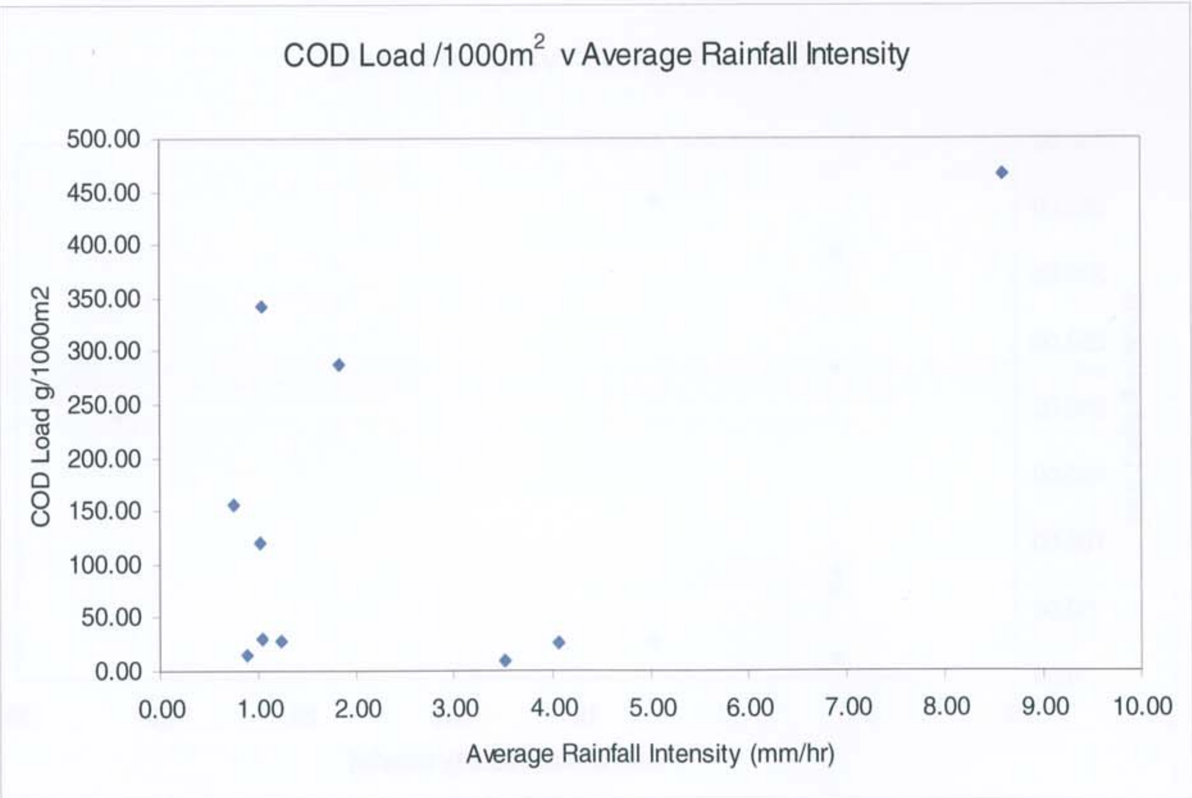

COD Load /1000m2 v Peak Rainfall Intensity
COD Load g/1000m2
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
5
10
15
20
25
30
35
Peak Rainfall Intensity (mm/hr)


NH4-N Load /1000m2 v Rainfall Intensity
NH4-N Load g/1000m2
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
5
10
15
20
25
30
35
Peak Rainfall Intensity (mm/hr)

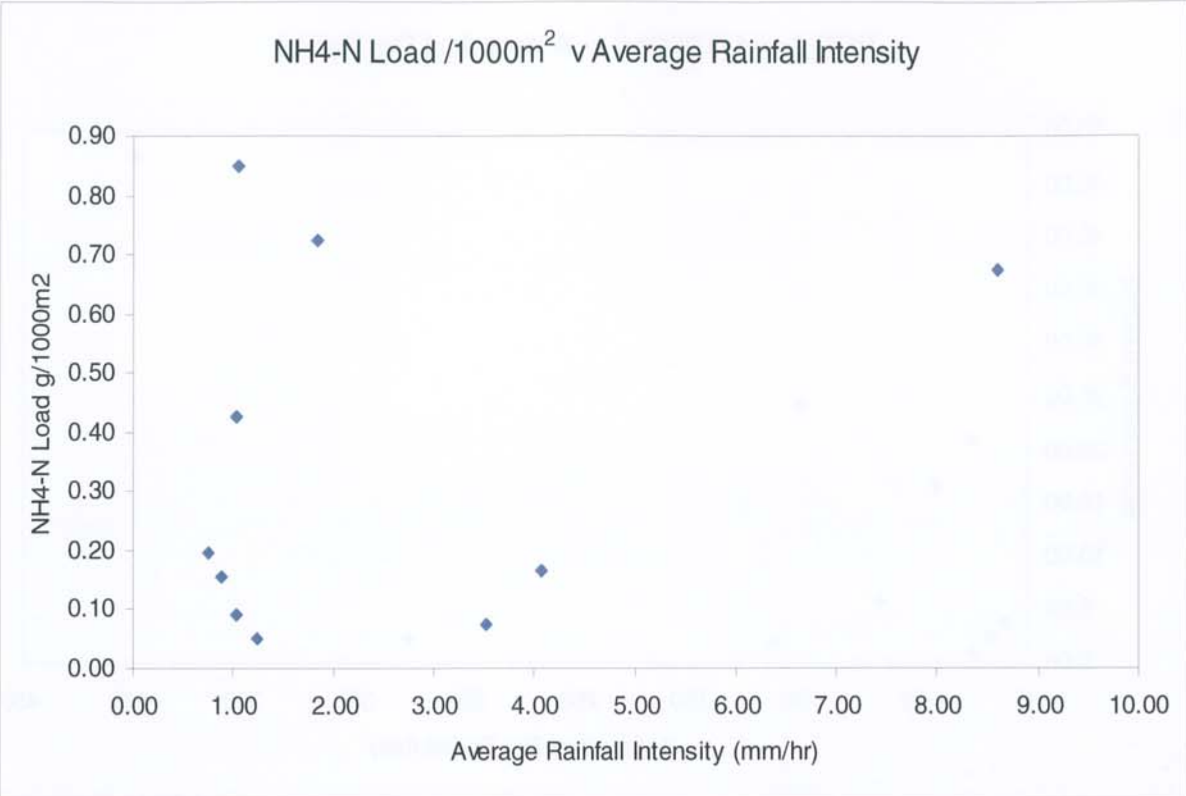

TSS Load /1000m2 v Rainfall Intensity
TSS Load g/1000m2
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
5
10
15
20
25
30
35
Peak Rainfall Intensity (mm/hr)



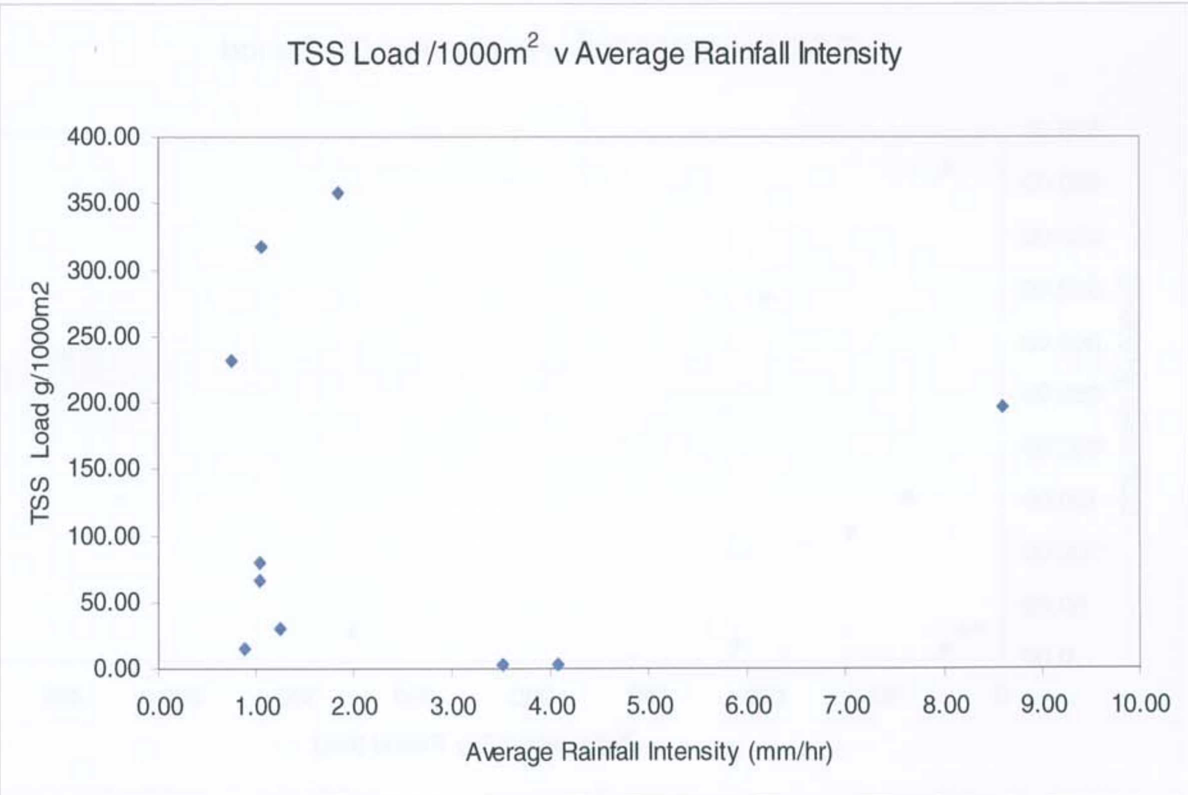
BOD Load /1000m2 v Average Rainfall Intensity
BOD Load g/1000m2
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Average Rainfall Intensity (mm/hr)



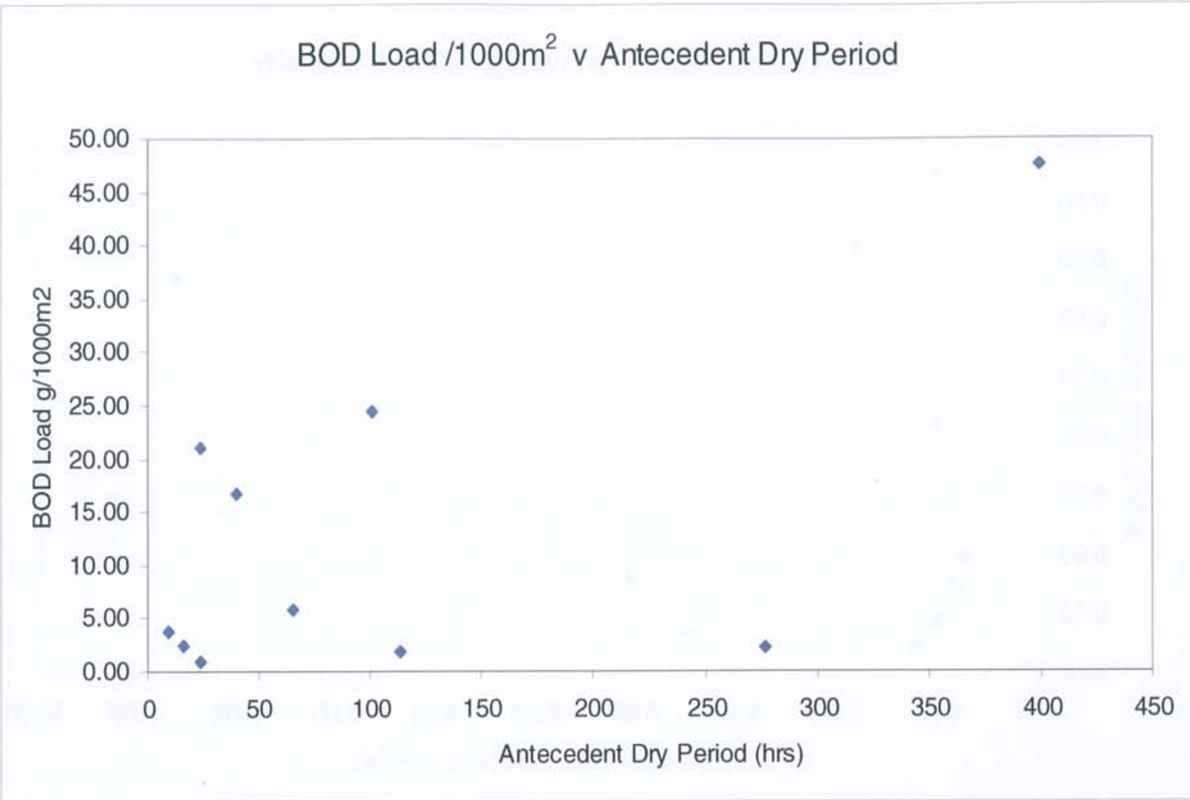
COD Load /1000m2 v Average Rainfall Intensity
COD Load g/1000m2
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Average Rainfall Intensity (mm/hr)

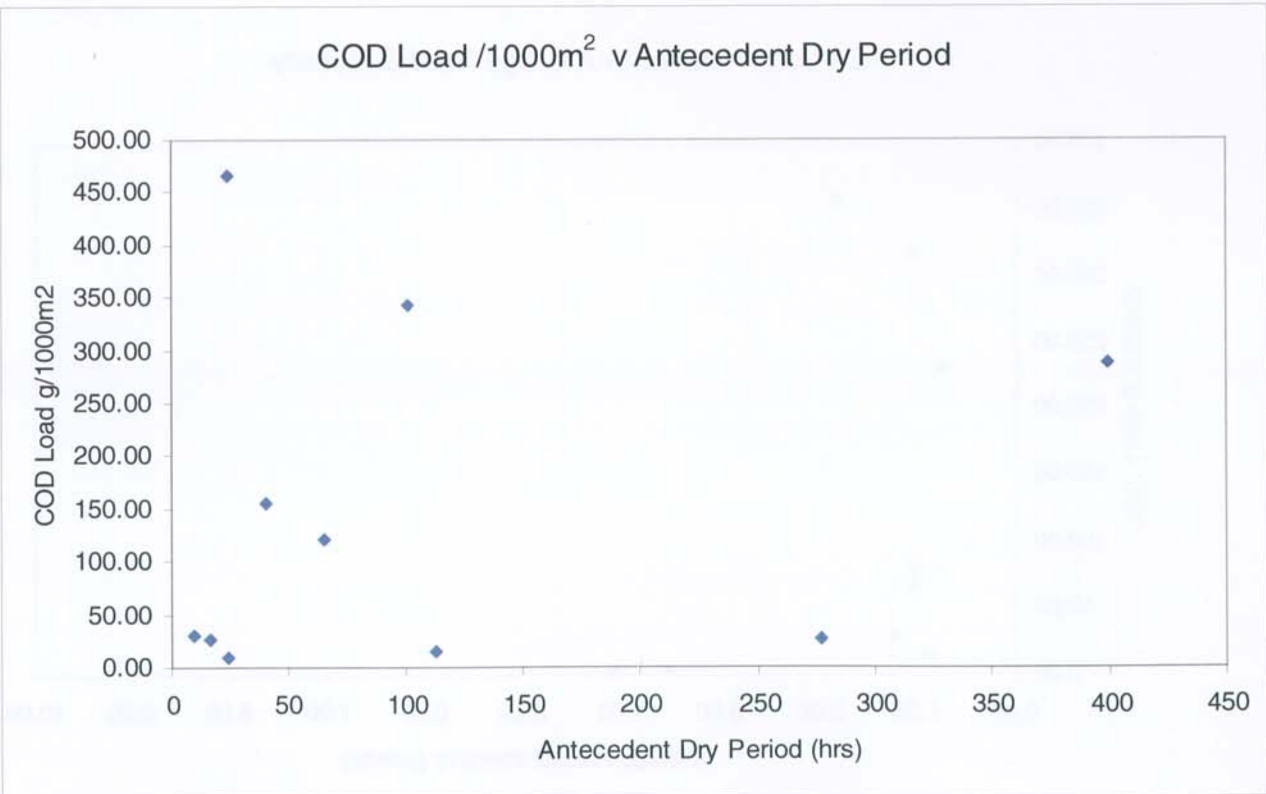


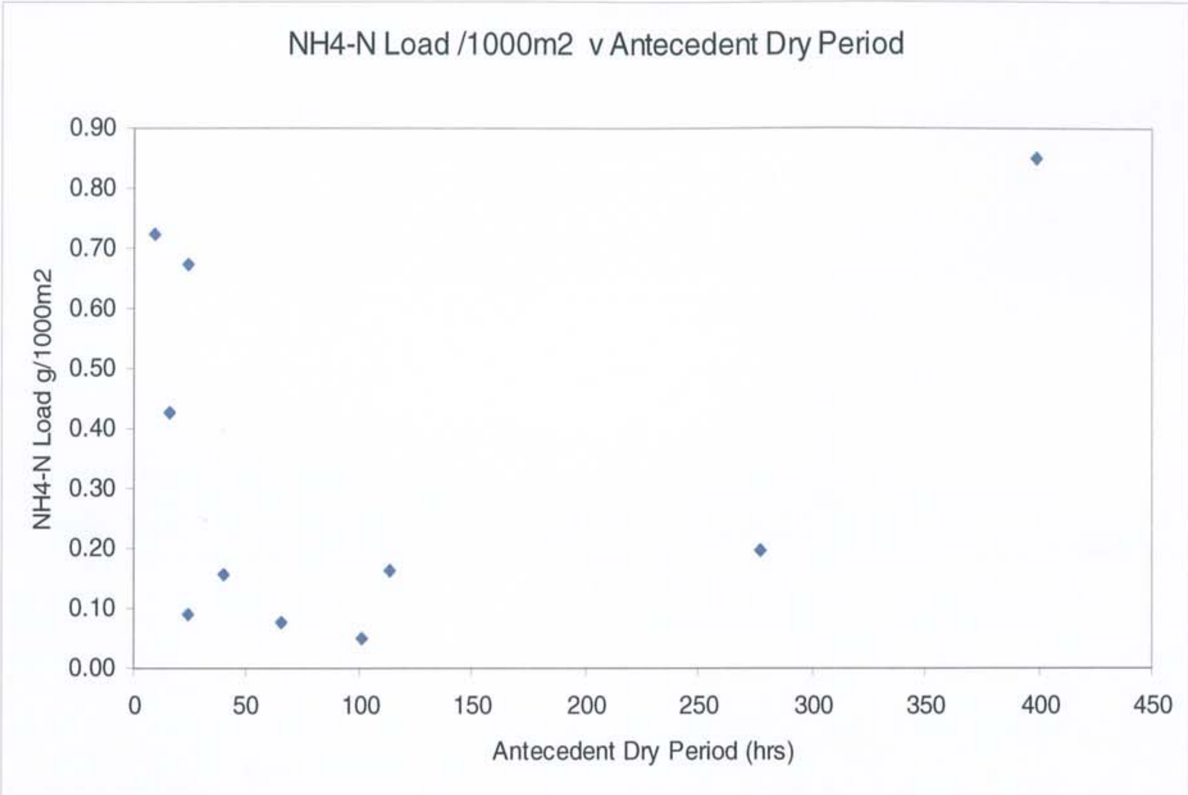
NH4-N Load /1000m2 v Average Rainfall Intensity
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
NH4-N Load g/1000m2
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Average Rainfall Intensity (mm/hr)

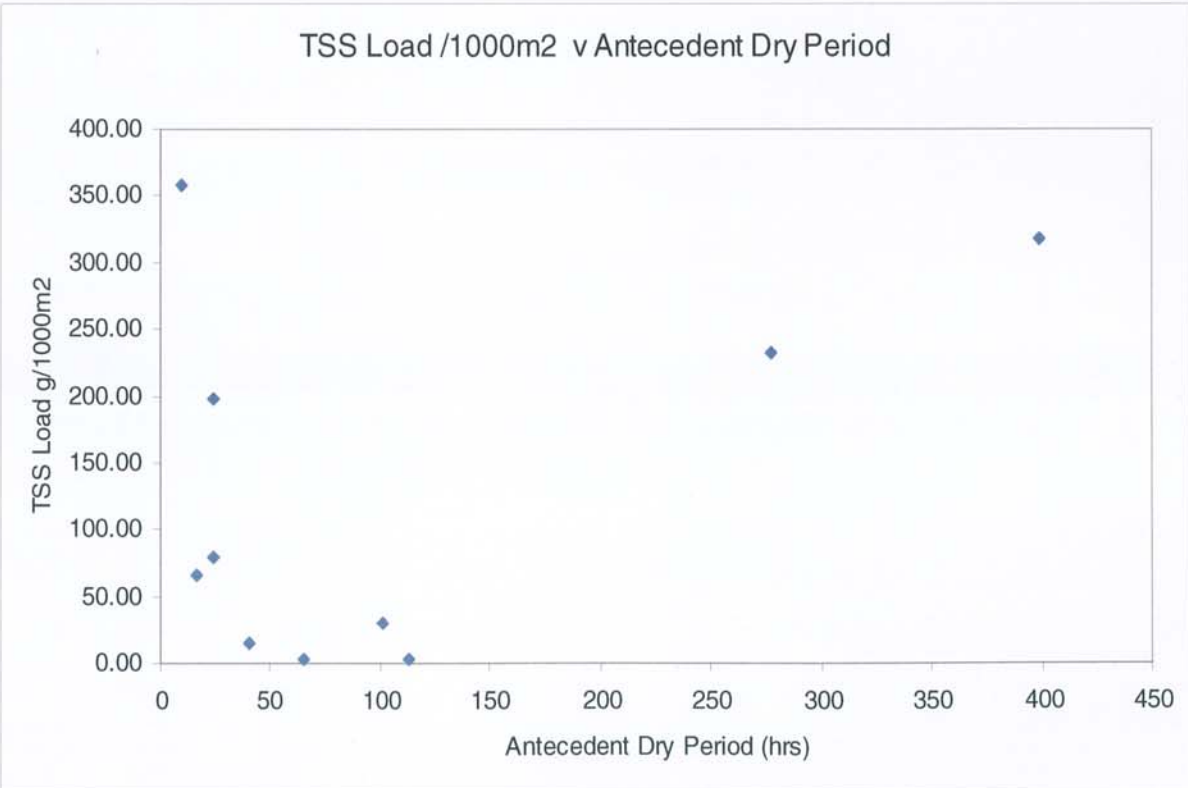


TSS Load /1000m2 v Average Rainfall Intensity
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
TSS Load g/1000m2
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Average Rainfall Intensity (mm/hr)

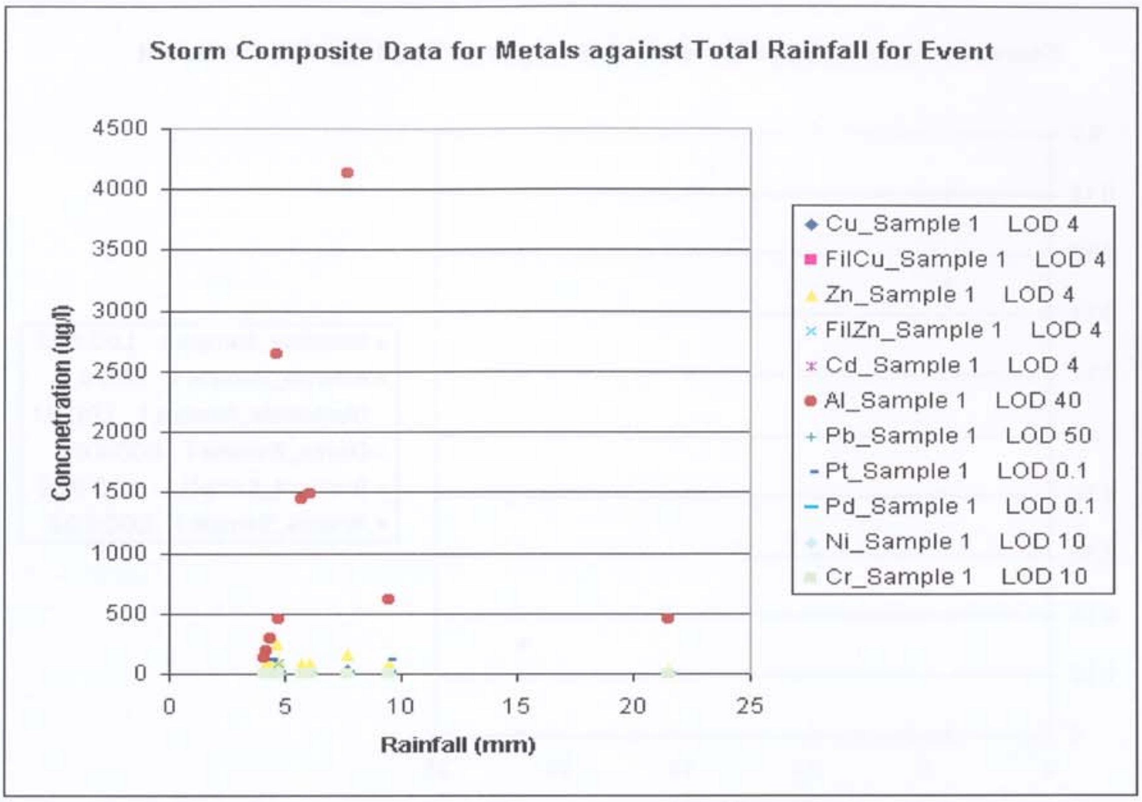

BOD Load /1000m2 v Antecedent Dry Period
BOD Load g/1000m2
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
50
100
150
200
250
300
350
400
450
Antecedent Dry Period (hrs)

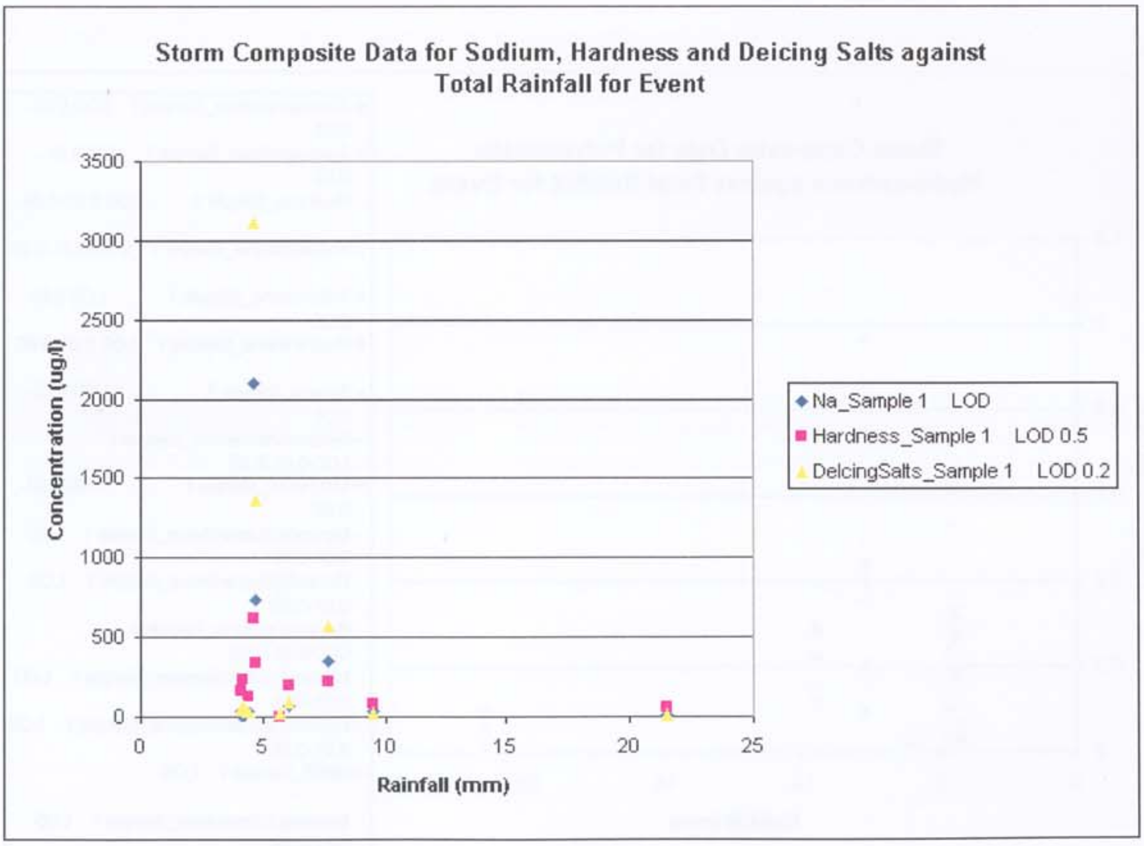

COD Load /1000m2 v Antecedent Dry Period
COD Load g/1000m2
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0
50
100
150
200
250
300
350
400
450
Antecedent Dry Period (hrs)

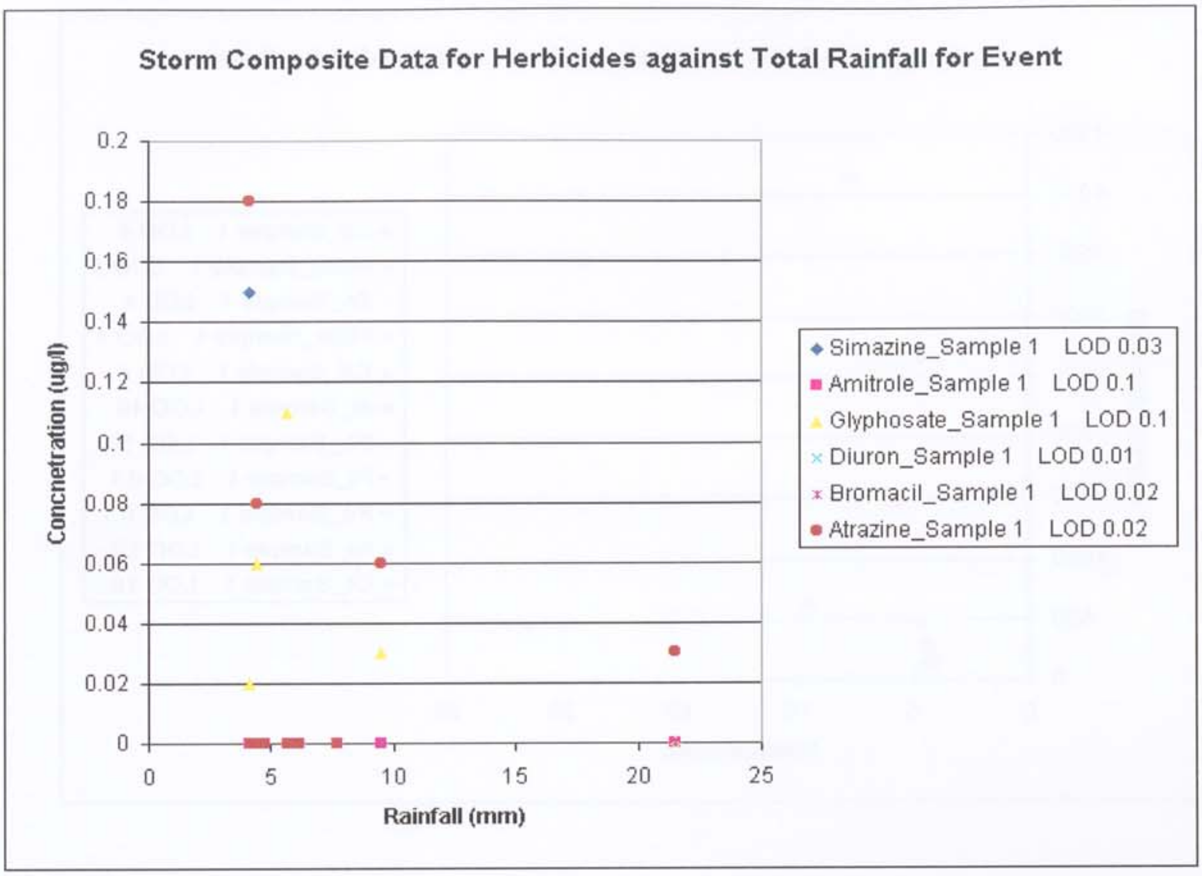

NH4-N Load /1000m2 v Antecedent Dry Period
NH4-N Load g/1000m2
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
0
50
100
150
200
250
300
350
400
450
Antecedent Dry Period (hrs)


TSS Load /1000m2 v Antecedent Dry Period
TSS Load g/1000m2
0.00
50.00
100.00
150.00
200.00
250.00
300.00
350.00
400.00
0
50
100
150
200
250
300
350
400
450
Antecedent Dry Period (hrs)

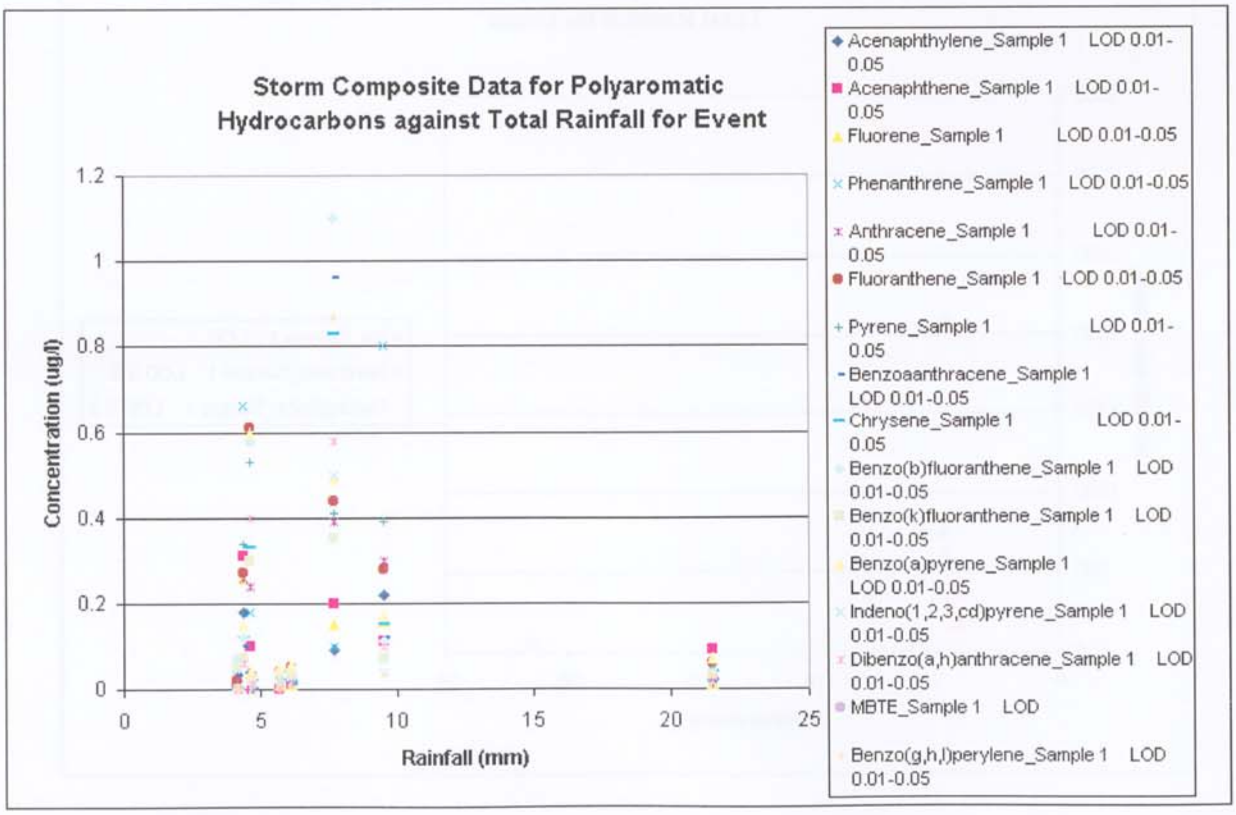
APPENDIX I GRAPHICAL PLOTS OF STORM EVENT COMPOSITE SAMPLE ANALYSIS RESULTS AGAINST EVENT PARAMETERS


Storm Composite Data for Metals against Total Rainfall for Event
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Concnetration (ug/l)
0
5
10
15
20
25
Rainfall (mm)
Cu_Sample 1 LOD 4
FilCu_Sample 1 LOD 4
Zn_Sample 1 LOD 4
FilZn_Sample 1 LOD 4
Cd_Sample 1 LOD 4
Al_Sample 1 LOD 40
Pb_Sample 1 LOD 50
Pt_Sample 1 LOD 0.1
Pd_Sample 1 LOD 0.1
Ni_Sample 1 LOD 10
Cr_Sample 1 LOD 10

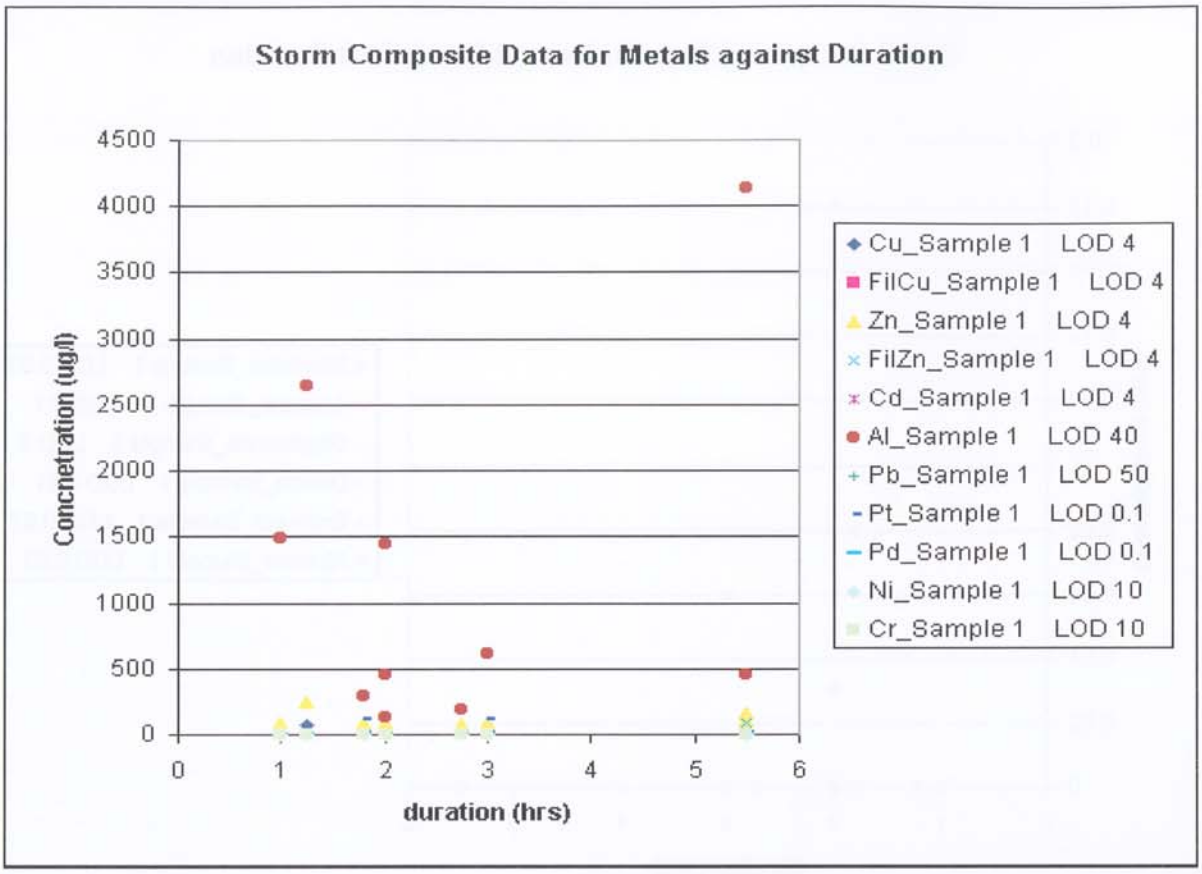

Storm Composite Data for Sodium, Hardness and Deicing Salts against Total Rainfall for Event
3500
3000
2500
2000
1500
1000
500
0
Concentration (ug/l)
0
5
10
15
20
25
Rainfall (mm)
Na_Sample 1 LOD
Hardness_Sample 1 LOD 0.5
DeicingSalts_Sample 1 LOD 0.2



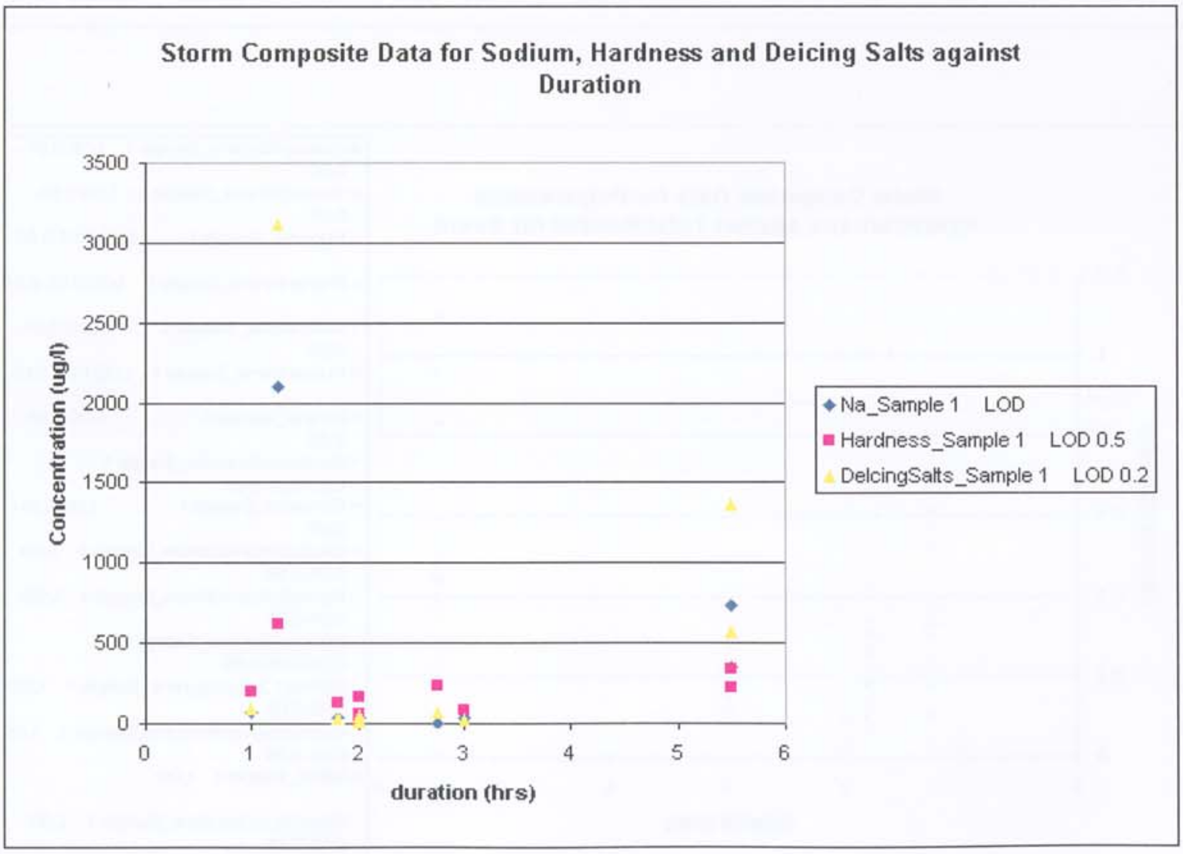
Storm Composite Data for Herbicides against Total Rainfall for Event
Concnetration (ug/l)
Rainfall (mm)
Simazine_Sample 1 LOD 0.03
Amitrole_Sample 1 LOD 0.1
Glyphosate_Sample 1 LOD 0.1
Diuron_Sample 1 LOD 0.01
Bromacil_Sample 1 LOD 0.02
Atrazine_Sample 1 LOD 0.02



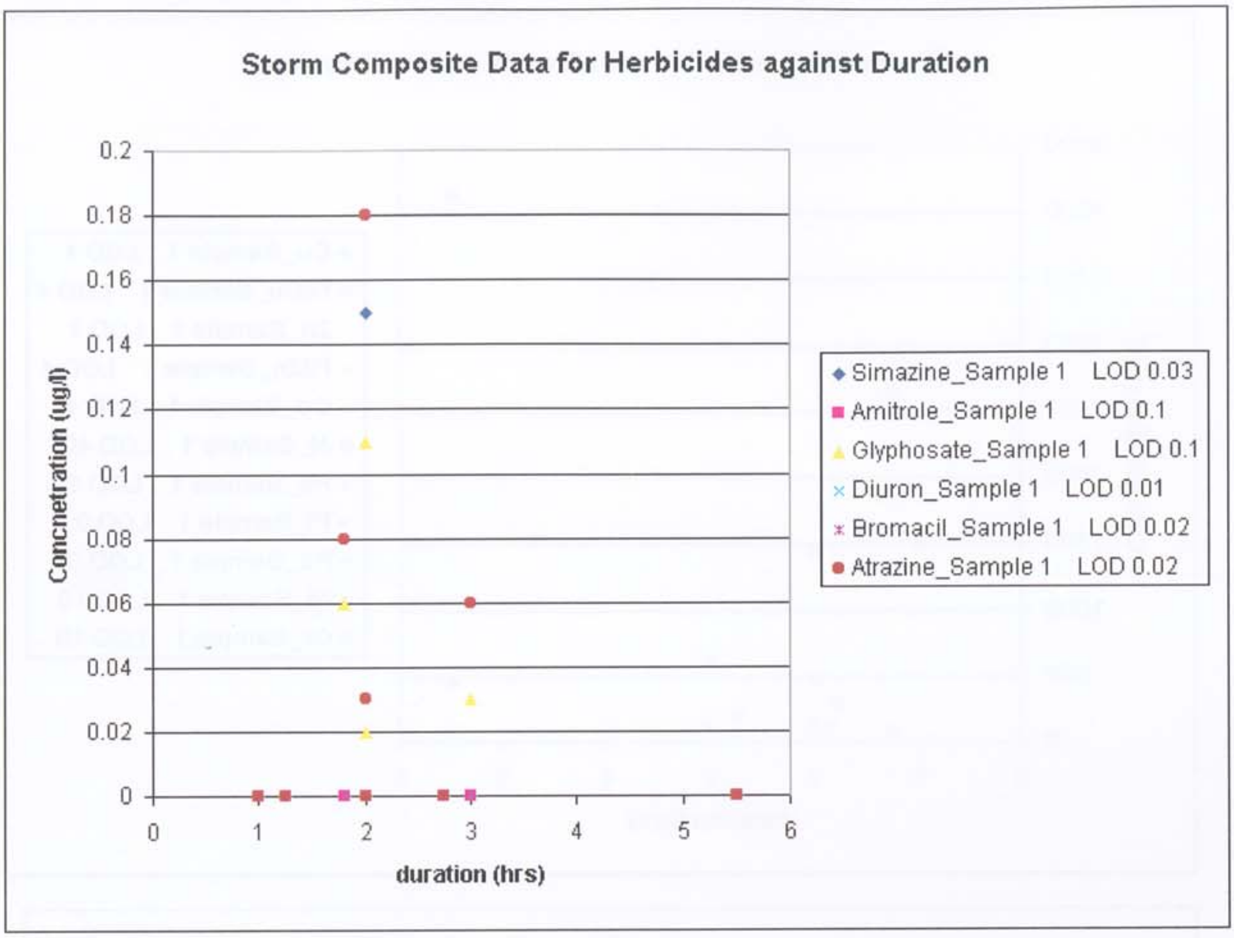
Storm Composite Data for Polyaromatic Hydrocarbons against Total Rainfall for Event
Concentration (ug/l)
Rainfall (mm)
Acenaphthylene_Sample 1 LOD 0.01-0.05
Acenaphthene_Sample 1 LOD 0.01-0.05
Fluorene_Sample 1 LOD 0.01-0.05
Phenanthrene_Sample 1 LOD 0.01-0.05
Anthracene_Sample 1 LOD 0.01-0.05
Fluoranthene_Sample 1 LOD 0.01-0.05
Pyrene_Sample 1 LOD 0.01-0.05
Benzoaanthracene_Sample 1 LOD 0.01-0.05
Chrysene_Sample 1 LOD 0.01-0.05
Benzo(b)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(k)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(a)pyrene_Sample 1 LOD 0.01-0.05
Indeno(1,2,3,cd)pyrene_Sample 1 LOD 0.01-0.05
Dibenzo(a,h)anthracene_Sample 1 LOD 0.01-0.05
MBTE_Sample 1 LOD
Benzo(g,h,l)perylene_Sample 1 LOD 0.01-0.05



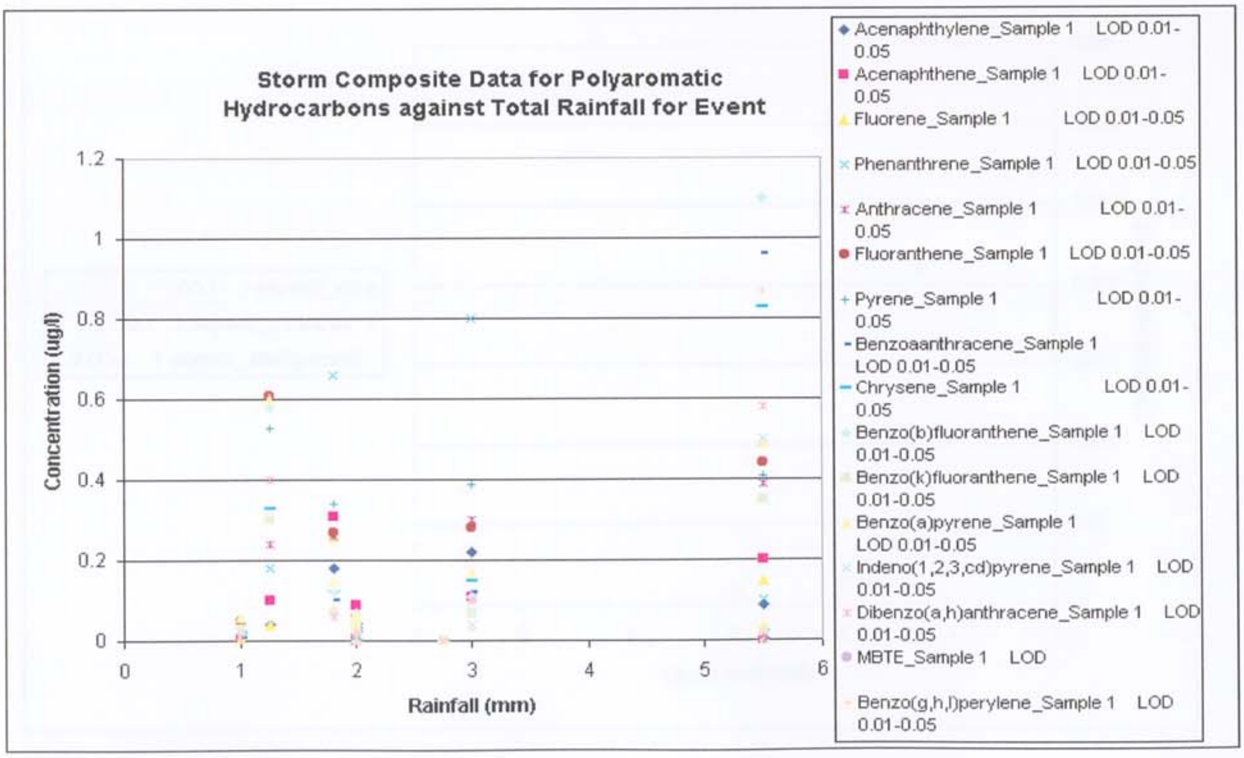
Storm Composite Data for Metals against Duration
Concnetration (ug/l)
duration (hrs)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
1
2
3
4
5
6
Cu_Sample 1 LOD 4
FilCu_Sample 1 LOD 4
Zn_Sample 1 LOD 4
FilZn_Sample 1 LOD 4
Cd_Sample 1 LOD 4
Al_Sample 1 LOD 40
Pb_Sample 1 LOD 50
Pt_Sample 1 LOD 0.1
Pd_Sample 1 LOD 0.1
Ni_Sample 1 LOD 10
Cr_Sample 1 LOD 10



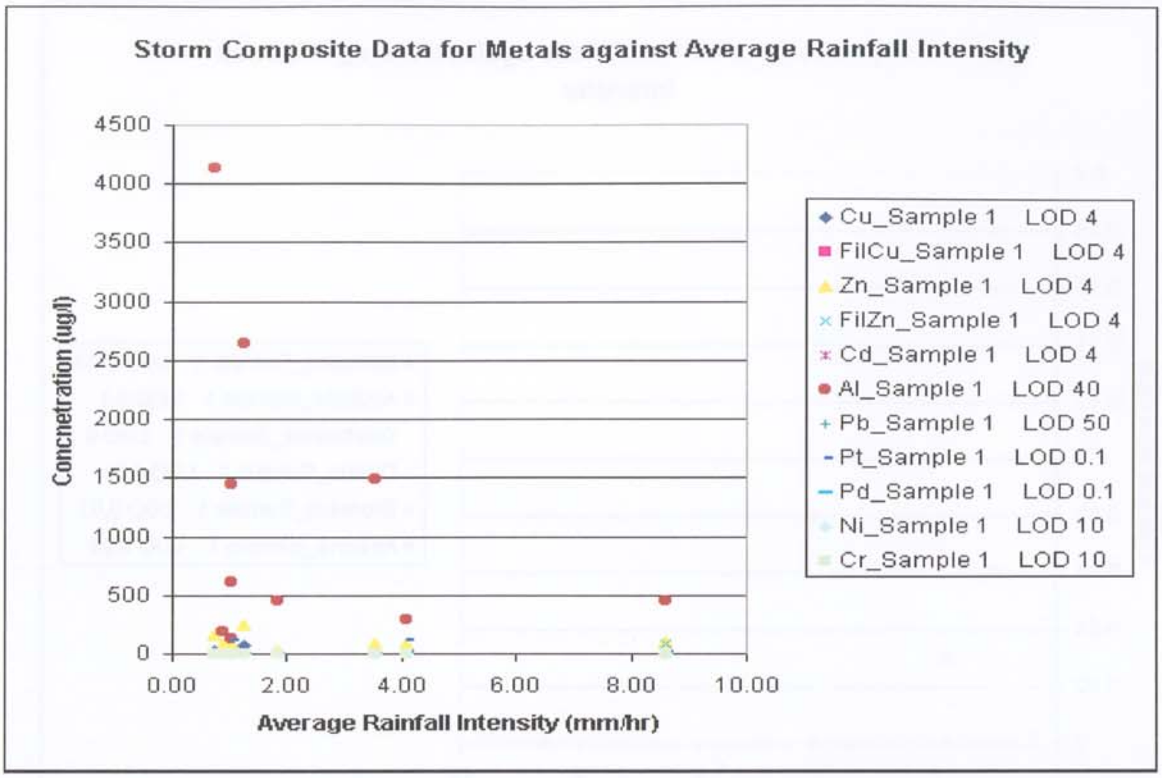
Storm Composite Data for Sodium, Hardness and Deicing Salts against Duration
Concentration (ug/l)
duration (hrs)
0
500
1000
1500
2000
2500
3000
3500
0
1
2
3
4
5
6
Na_Sample 1 LOD
Hardness_Sample 1 LOD 0.5
DeIcingSalts_Sample 1 LOD 0.2

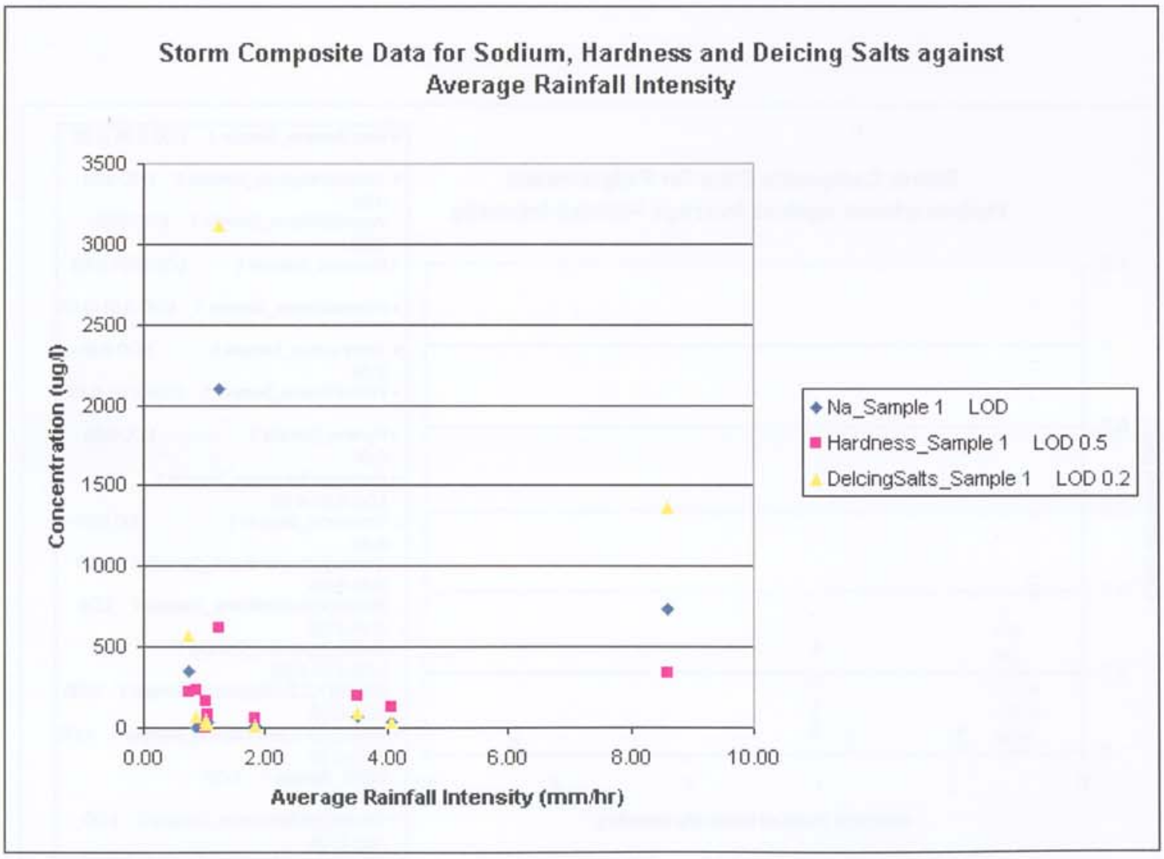


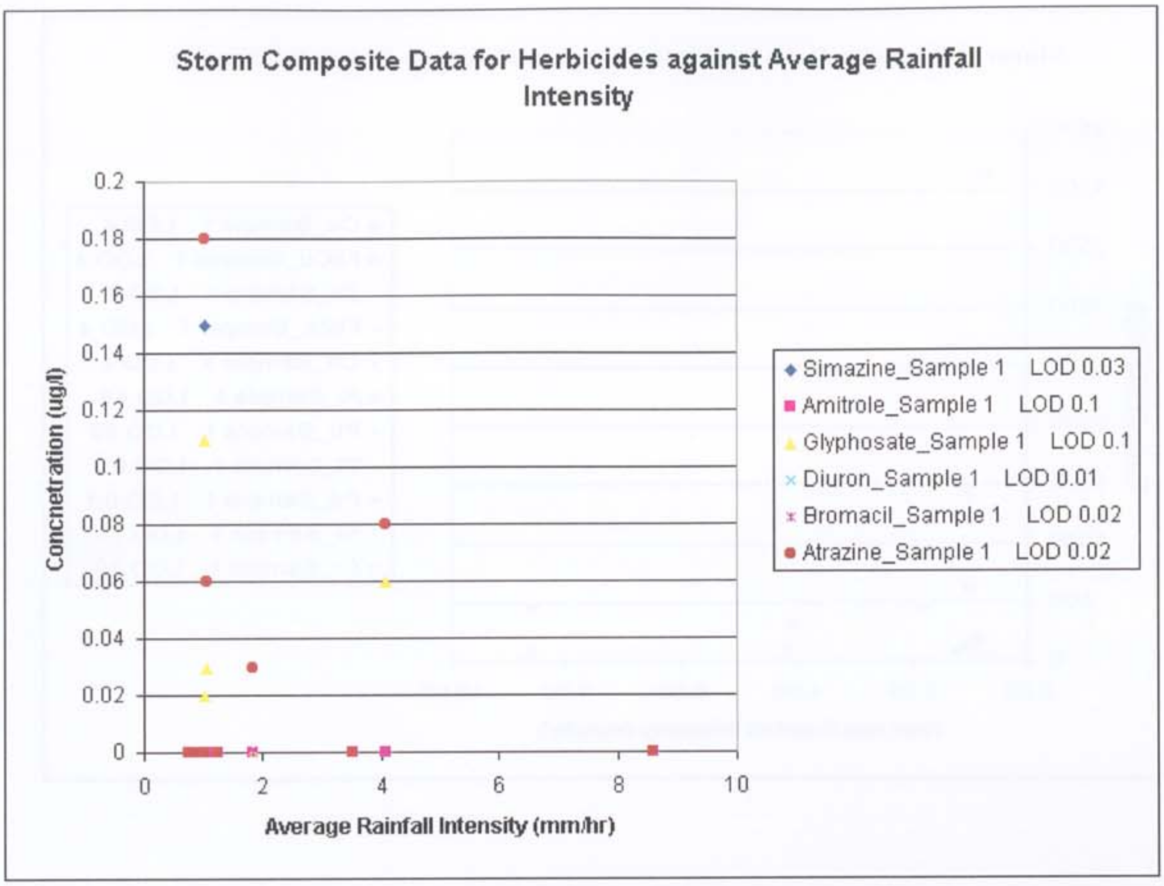
Storm Composite Data for Herbicides against Duration
Concnetration (ug/l)
duration (hrs)
Simazine_Sample 1 LOD 0.03
Amitrole_Sample 1 LOD 0.1
Glyphosate_Sample 1 LOD 0.1
Diuron_Sample 1 LOD 0.01
Bromacil_Sample 1 LOD 0.02
Atrazine_Sample 1 LOD 0.02

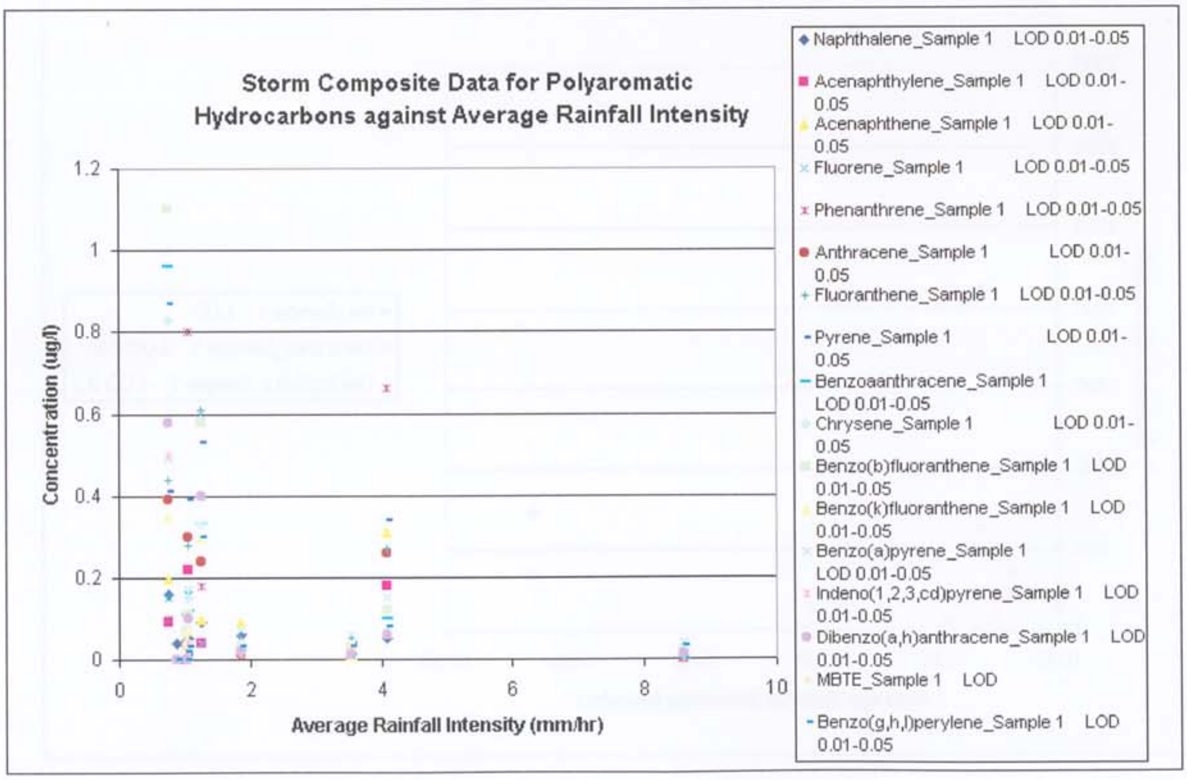


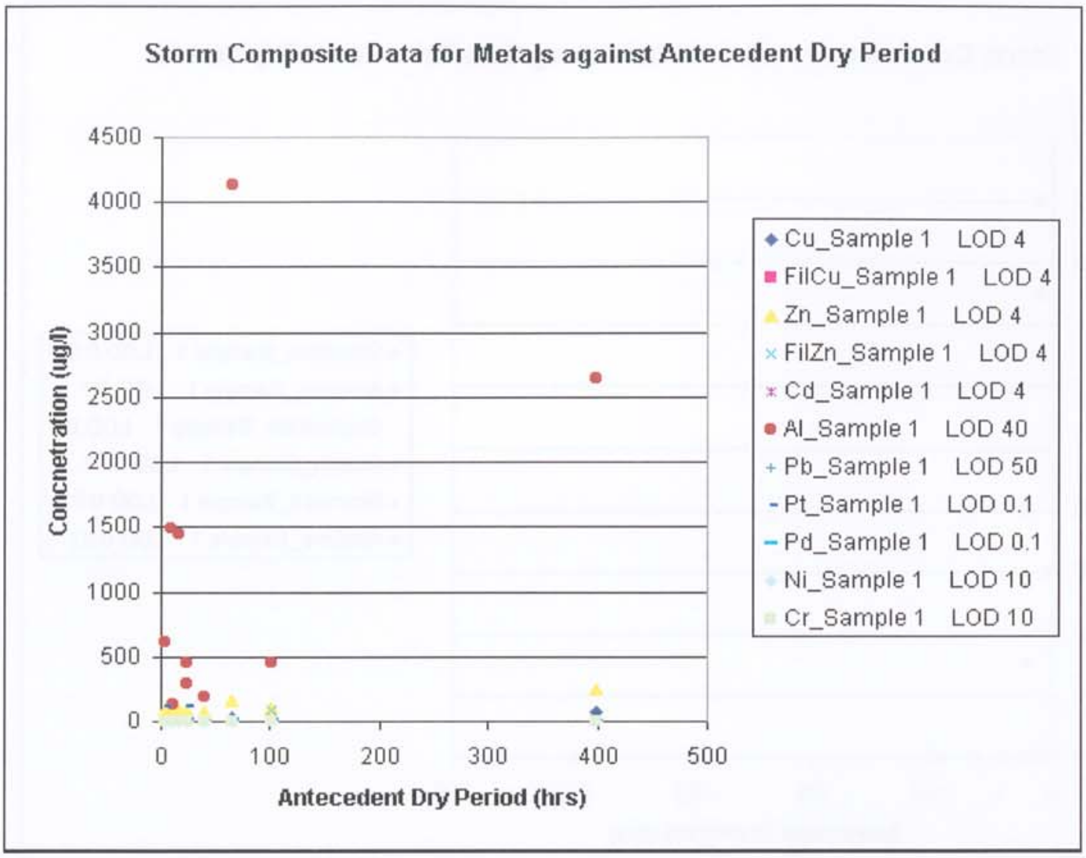
Storm Composite Data for Polyaromatic Hydrocarbons against Total Rainfall for Event
Concentration (ug/l)
Rainfall (mm)
Acenaphthylene_Sample 1 LOD 0.01-0.05
Acenaphthene_Sample 1 LOD 0.01-0.05
Fluorene_Sample 1 LOD 0.01-0.05
Phenanthrene_Sample 1 LOD 0.01-0.05
Anthracene_Sample 1 LOD 0.01-0.05
Fluoranthene_Sample 1 LOD 0.01-0.05
Pyrene_Sample 1 LOD 0.01-0.05
Benzoaanthracene_Sample 1 LOD 0.01-0.05
Chrysene_Sample 1 LOD 0.01-0.05
Benzo(b)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(k)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(a)pyrene_Sample 1 LOD 0.01-0.05
Indeno(1,2,3,cd)pyrene_Sample 1 LOD 0.01-0.05
Dibenzo(a,h)anthracene_Sample 1 LOD 0.01-0.05
MBTE_Sample 1 LOD
Benzo(g,h,I)perylene_Sample 1 LOD 0.01-0.05

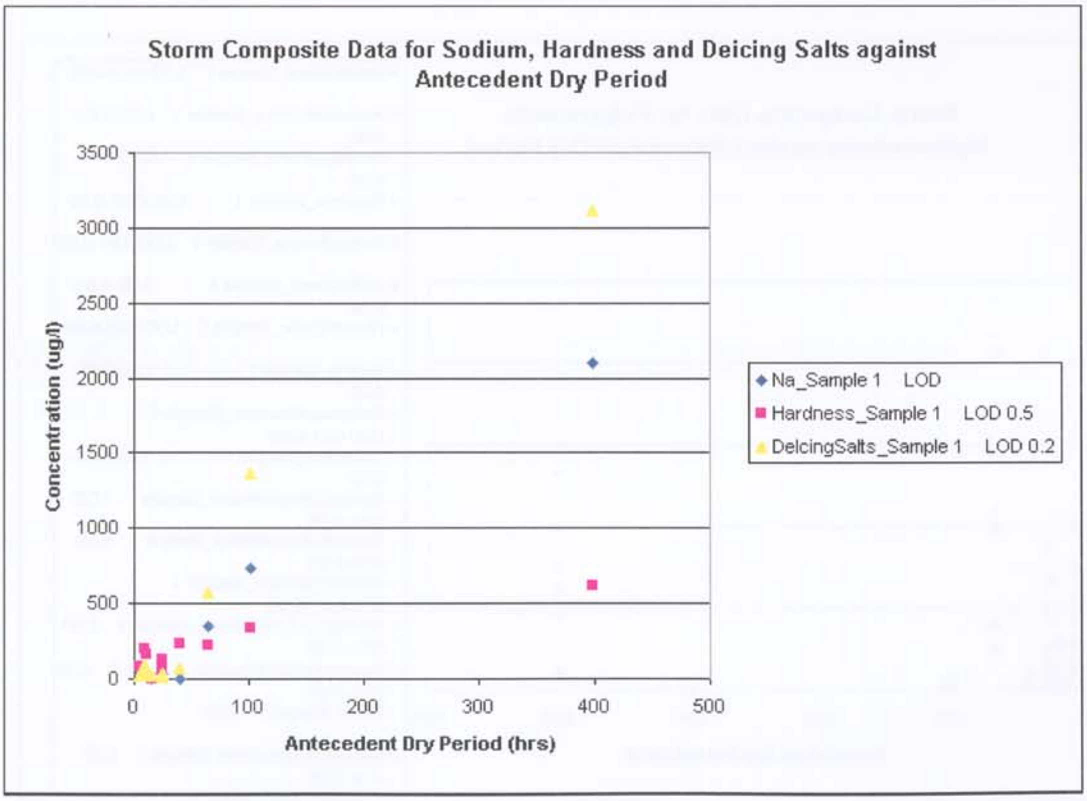

Storm Composite Data for Metals against Average Rainfall Intensity
Concnetration (ug/l)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.00
2.00
4.00
6.00
8.00
10.00
Average Rainfall Intensity (mm/hr)
Cu_Sample 1 LOD 4
FilCu_Sample 1 LOD 4
Zn_Sample 1 LOD 4
FilZn_Sample 1 LOD 4
Cd_Sample 1 LOD 4
Al_Sample 1 LOD 40
Pb_Sample 1 LOD 50
Pt_Sample 1 LOD 0.1
Pd_Sample 1 LOD 0.1
Ni_Sample 1 LOD 10
Cr_Sample 1 LOD 10

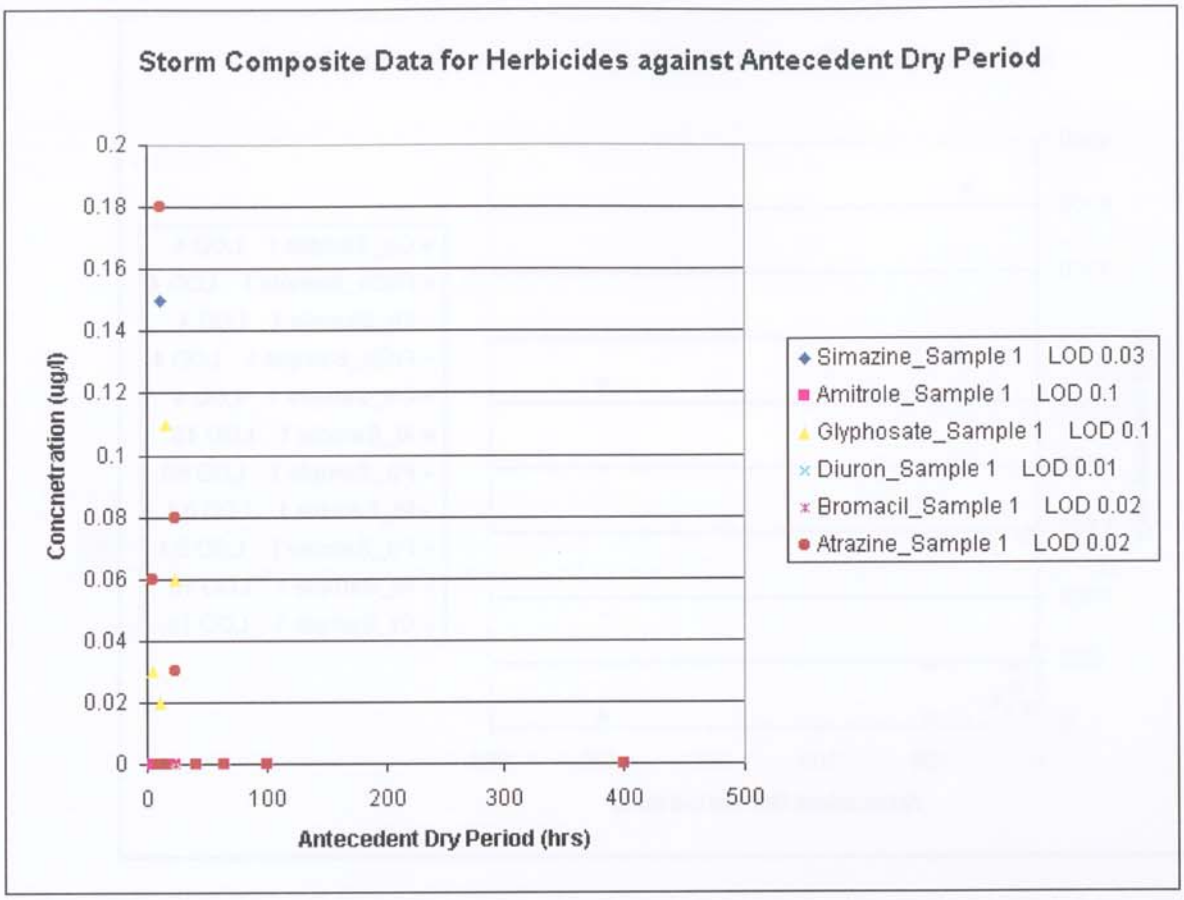

Storm Composite Data for Sodium, Hardness and Deicing Salts against Average Rainfall Intensity
Concentration (ug/l)
3500
3000
2500
2000
1500
1000
500
0
0.00
2.00
4.00
6.00
8.00
10.00
Average Rainfall Intensity (mm/hr)
Na_Sample 1 LOD
Hardness_Sample 1 LOD 0.5
DeIcingSalts_Sample 1 LOD 0.2


Storm Composite Data for Herbicides against Average Rainfall Intensity
Concnetration (ug/l)
Average Rainfall Intensity (mm/hr)
Simazine_Sample 1 LOD 0.03
Amitrole_Sample 1 LOD 0.1
Glyphosate_Sample 1 LOD 0.1
Diuron_Sample 1 LOD 0.01
Bromacil_Sample 1 LOD 0.02
Atrazine_Sample 1 LOD 0.02

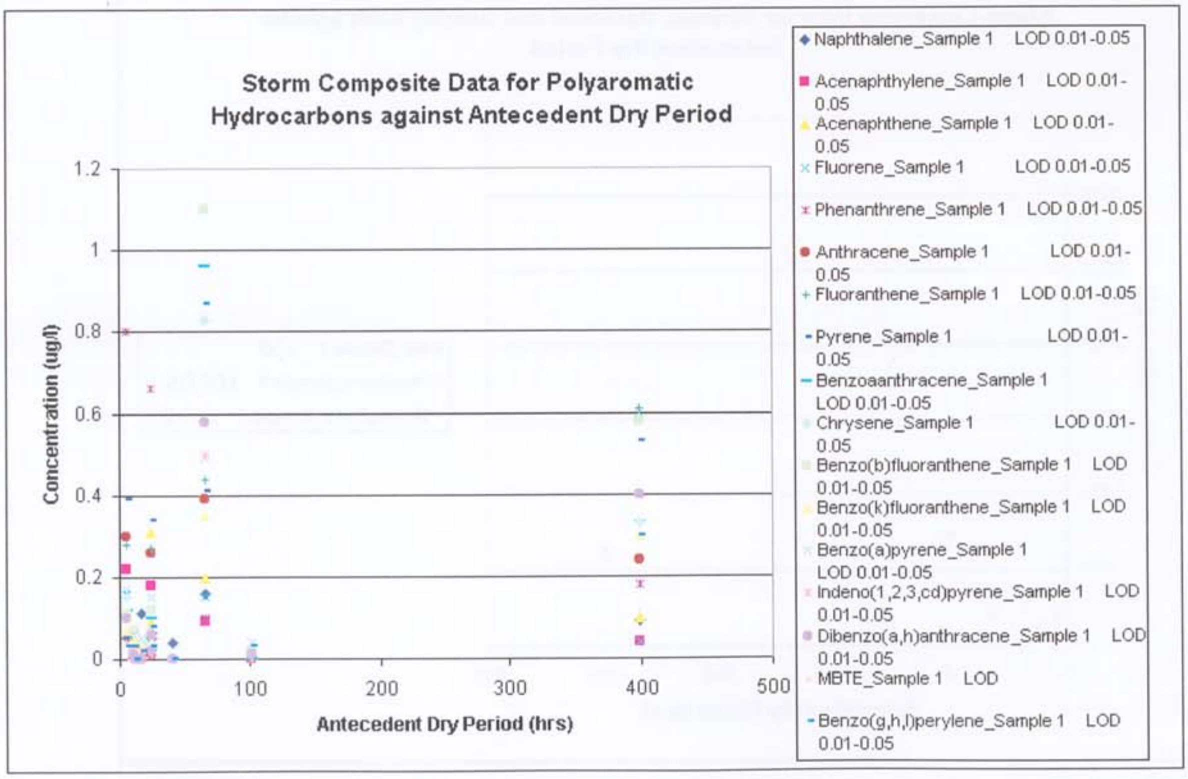

Storm Composite Data for Polyaromatic Hydrocarbons against Average Rainfall Intensity
Concentration (ug/l)
Average Rainfall Intensity (mm/hr)
Naphthalene_Sample 1 LOD 0.01-0.05
Acenaphthylene_Sample 1 LOD 0.01-0.05
Acenaphthene_Sample 1 LOD 0.01-0.05
Fluorene_Sample 1 LOD 0.01-0.05
Phenanthrene_Sample 1 LOD 0.01-0.05
Anthracene_Sample 1 LOD 0.01-0.05
Fluoranthene_Sample 1 LOD 0.01-0.05
Pyrene_Sample 1 LOD 0.01-0.05
Benzoaanthracene_Sample 1 LOD 0.01-0.05
Chrysene_Sample 1 LOD 0.01-0.05
Benzo(b)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(k)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(a)pyrene_Sample 1 LOD 0.01-0.05
Indeno(1,2,3,cd)pyrene_Sample 1 LOD 0.01-0.05
Dibenzo(a,h)anthracene_Sample 1 LOD 0.01-0.05
MBTE_Sample 1 LOD
Benzo(g,h,I)perylene_Sample 1 LOD 0.01-0.05


Storm Composite Data for Metals against Antecedent Dry Period
Concnetration (ug/l)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Antecedent Dry Period (hrs)
Cu_Sample 1 LOD 4
FilCu_Sample 1 LOD 4
Zn_Sample 1 LOD 4
FilZn_Sample 1 LOD 4
Cd_Sample 1 LOD 4
Al_Sample 1 LOD 40
Pb_Sample 1 LOD 50
Pt_Sample 1 LOD 0.1
Pd_Sample 1 LOD 0.1
Ni_Sample 1 LOD 10
Cr_Sample 1 LOD 10

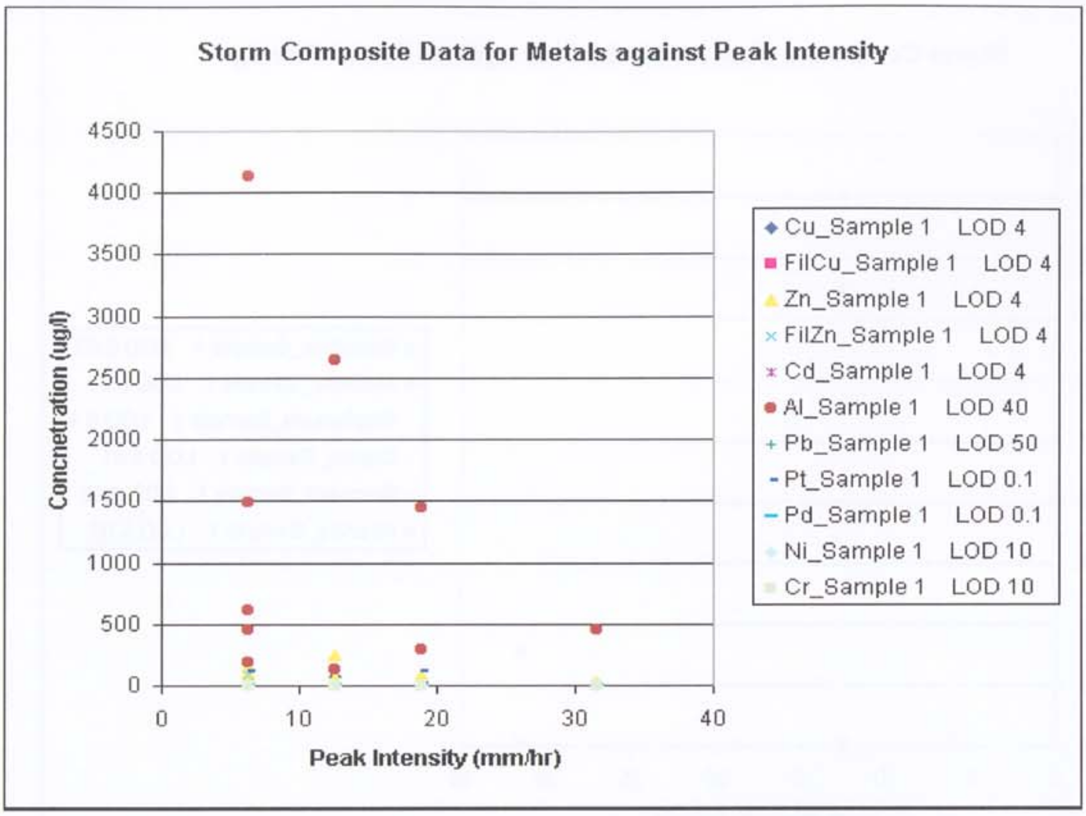

Storm Composite Data for Sodium, Hardness and Deicing Salts against Antecedent Dry Period
Concentration (ug/l)
3500
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Antecedent Dry Period (hrs)
Na_Sample 1 LOD
Hardness_Sample 1 LOD 0.5
DeicingSalts_Sample 1 LOD 0.2

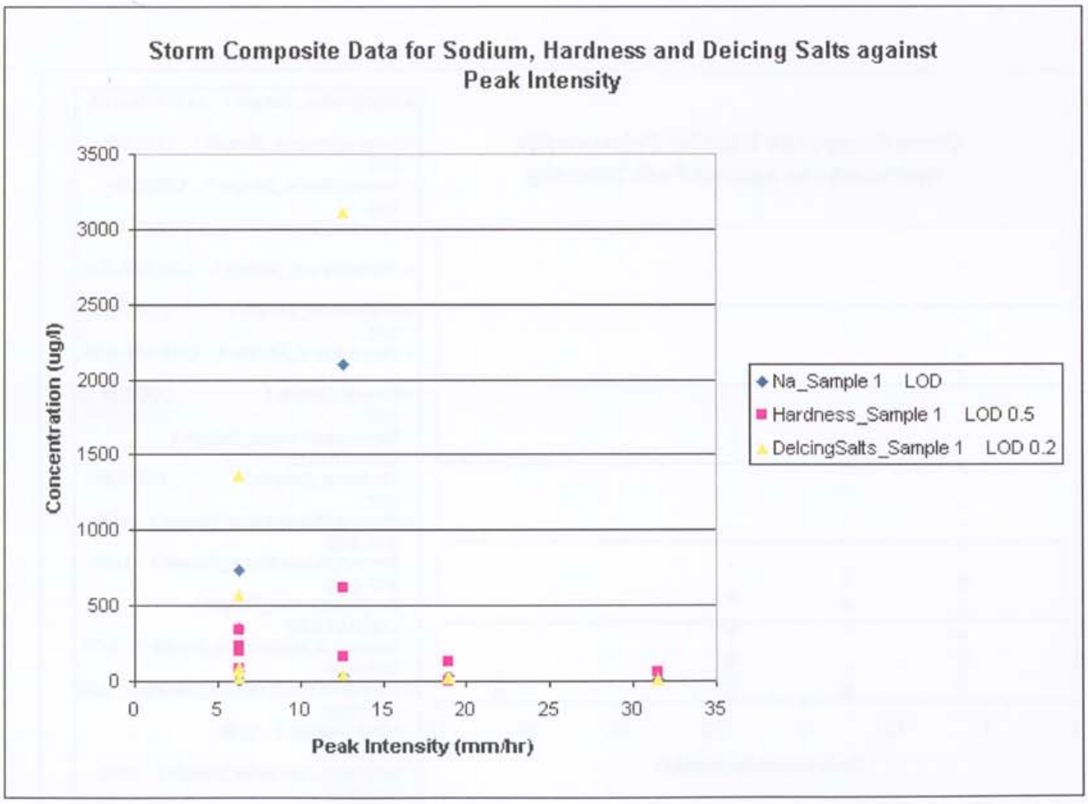


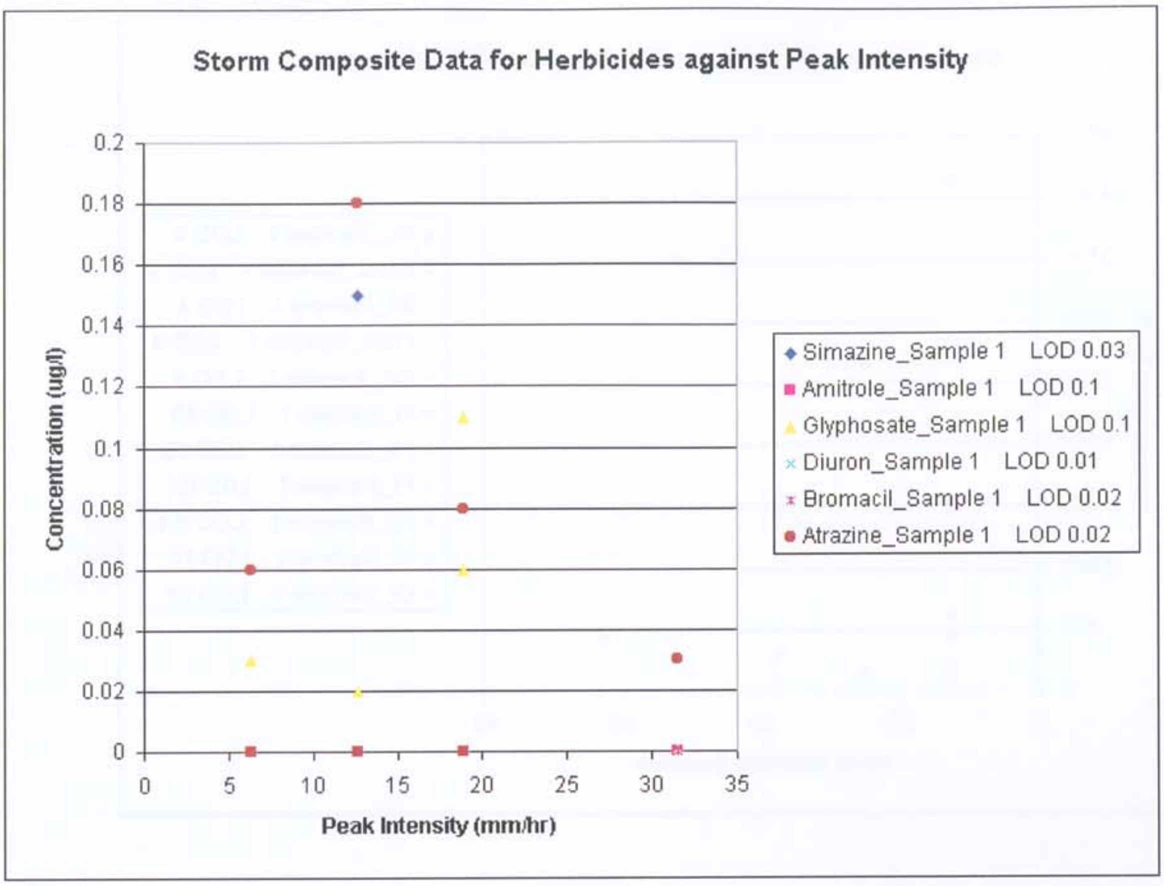
Storm Composite Data for Herbicides against Antecedent Dry Period
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Concnetration (ug/l)
0
100
200
300
400
500
Antecedent Dry Period (hrs)
Simazine_Sample 1 LOD 0.03
Amitrole_Sample 1 LOD 0.1
Glyphosate_Sample 1 LOD 0.1
Diuron_Sample 1 LOD 0.01
Bromacil_Sample 1 LOD 0.02
Atrazine_Sample 1 LOD 0.02

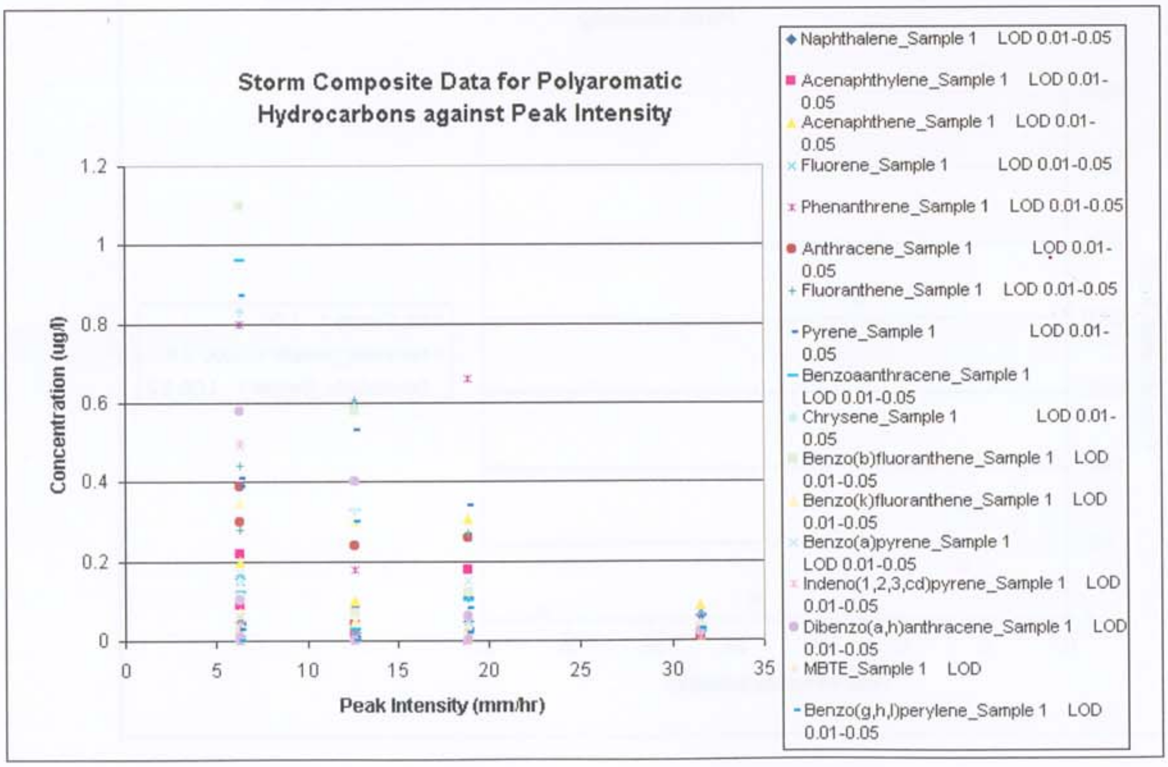


Storm Composite Data for Polyaromatic Hydrocarbons against Antecedent Dry Period
1.2
1
0.8
0.6
0.4
0.2
0
Concentration (ug/l)
0
100
200
300
400
500
Antecedent Dry Period (hrs)
Naphthalene_Sample 1 LOD 0.01-0.05
Acenaphthylene_Sample 1 LOD 0.01-0.05
Acenaphthene_Sample 1 LOD 0.01-0.05
Fluorene_Sample 1 LOD 0.01-0.05
Phenanthrene_Sample 1 LOD 0.01-0.05
Anthracene_Sample 1 LOD 0.01-0.05
Fluoranthene_Sample 1 LOD 0.01-0.05
Pyrene_Sample 1 LOD 0.01-0.05
Benzoaanthracene_Sample 1 LOD 0.01-0.05
Chrysene_Sample 1 LOD 0.01-0.05
Benzo(b)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(k)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(a)pyrene_Sample 1 LOD 0.01-0.05
Indeno(1,2,3,cd)pyrene_Sample 1 LOD 0.01-0.05
Dibenzo(a,h)anthracene_Sample 1 LOD 0.01-0.05
MBTE_Sample 1 LOD
Benzo(g,h,l)perylene_Sample 1 LOD 0.01-0.05

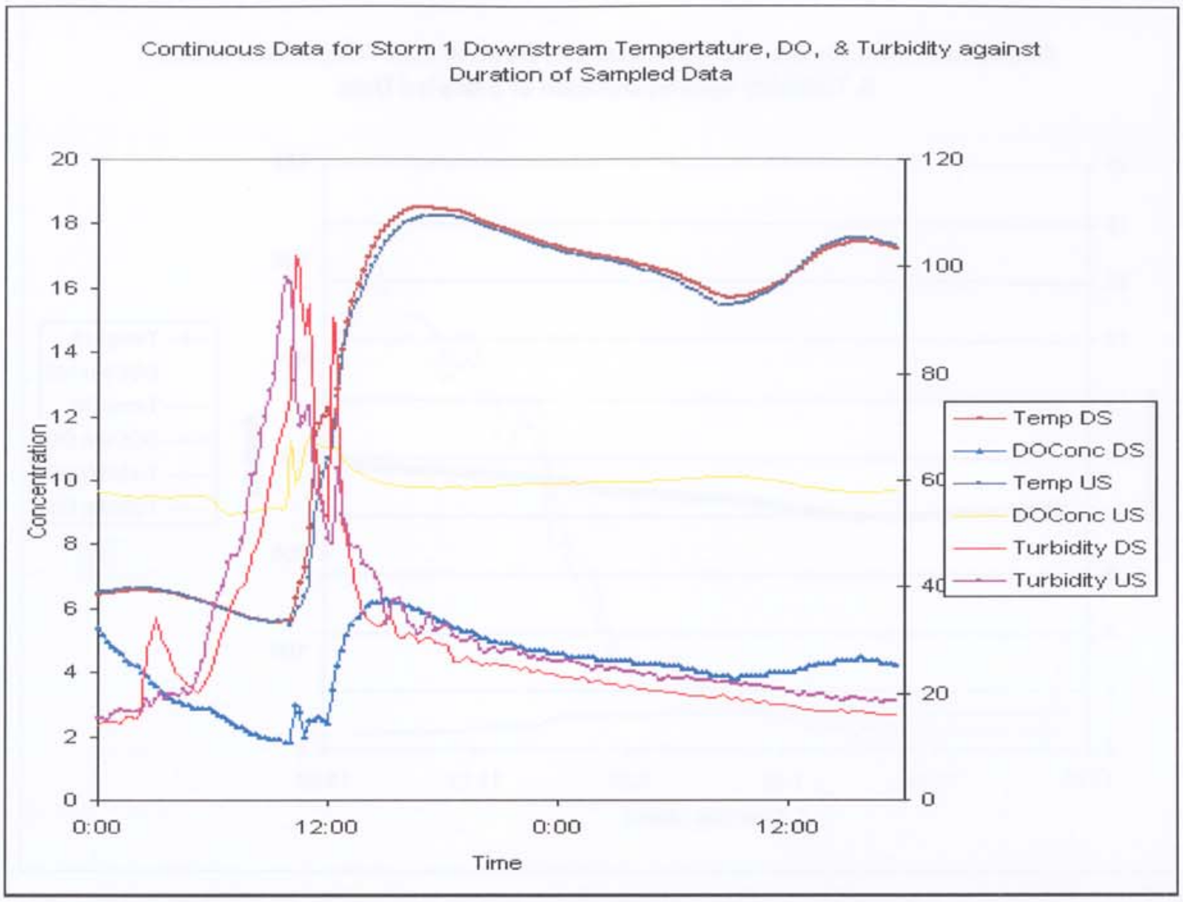

Storm Composite Data for Metals against Peak Intensity
Concnetration (ug/l)
Peak Intensity (mm/hr)
Cu_Sample 1 LOD 4
FilCu_Sample 1 LOD 4
Zn_Sample 1 LOD 4
FilZn_Sample 1 LOD 4
Cd_Sample 1 LOD 4
Al_Sample 1 LOD 40
Pb_Sample 1 LOD 50
Pt_Sample 1 LOD 0.1
Pd_Sample 1 LOD 0.1
Ni_Sample 1 LOD 10
Cr_Sample 1 LOD 10

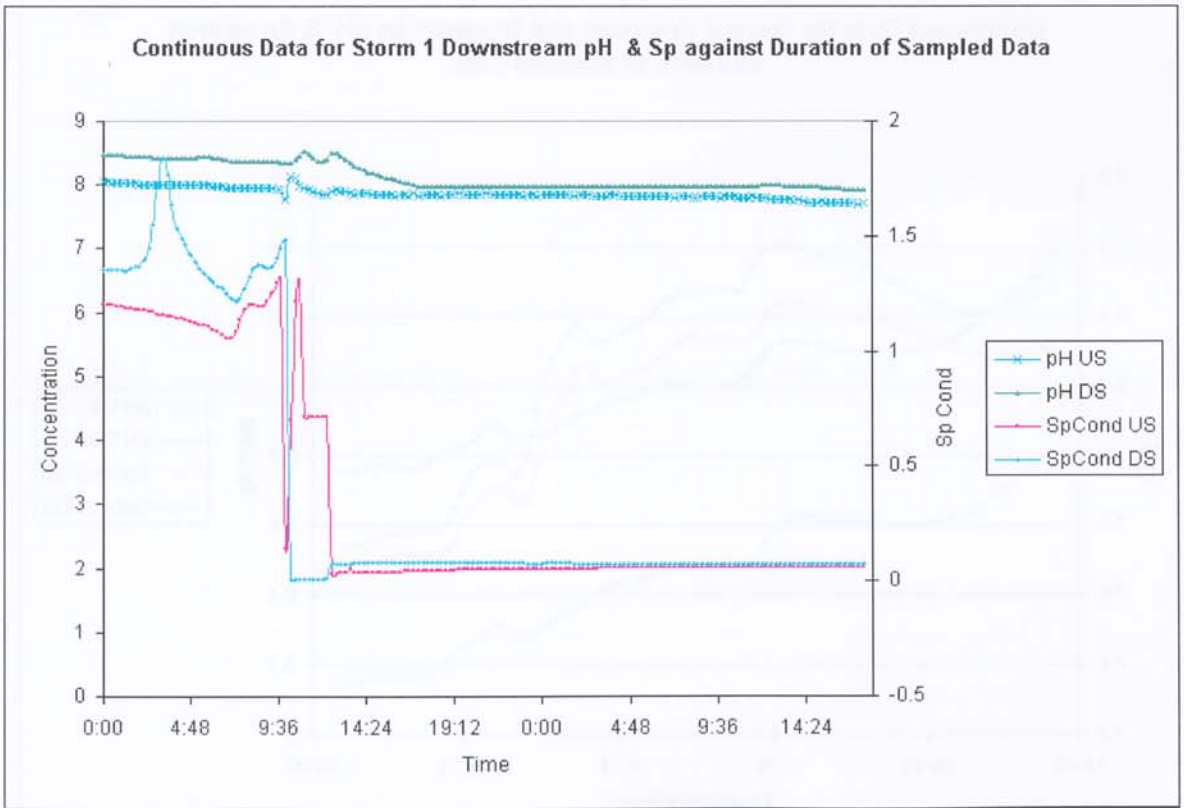

Storm Composite Data for Sodium, Hardness and Deicing Salts against Peak Intensity
Concentration (ug/l)
Peak Intensity (mm/hr)
Na_Sample 1 LOD
Hardness_Sample 1 LOD 0.5
DeIcingSalts_Sample 1 LOD 0.2

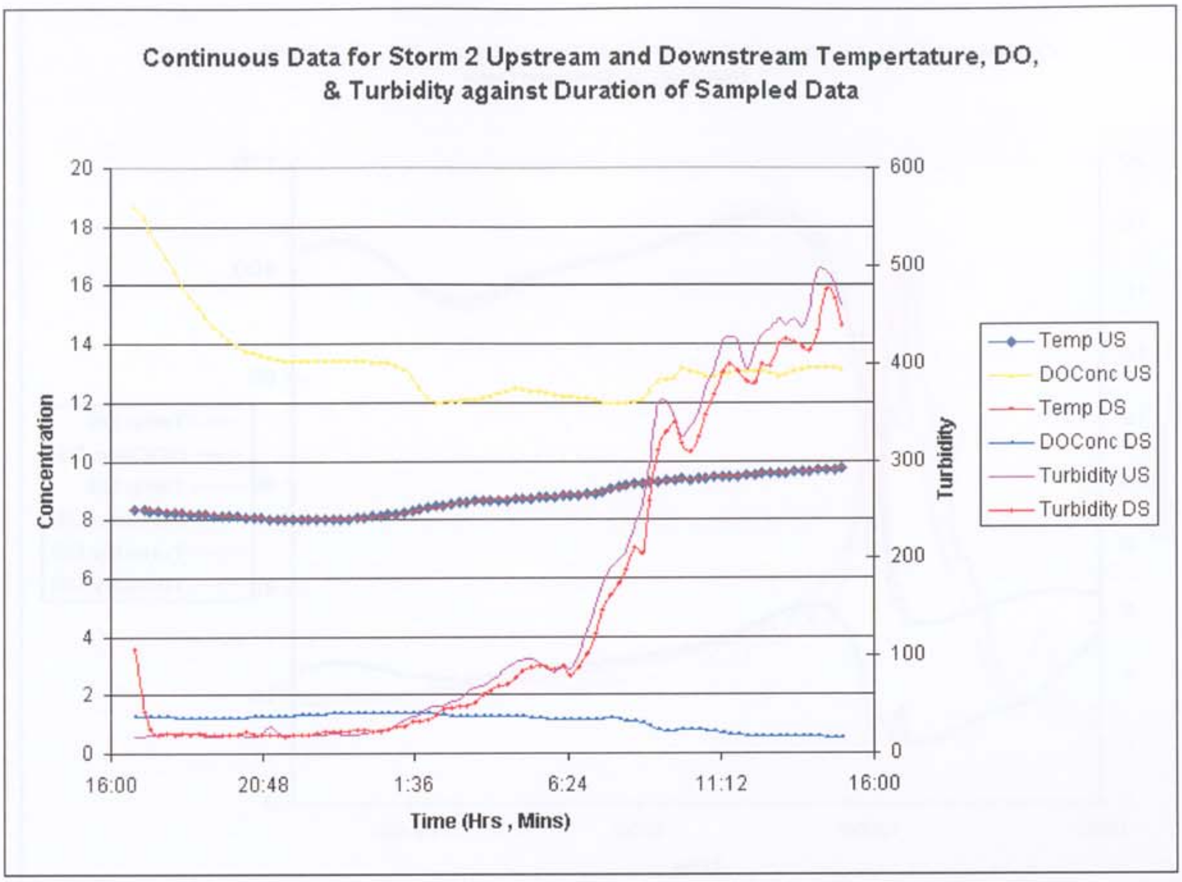

Storm Composite Data for Herbicides against Peak Intensity
Concentration (ug/l)
Peak Intensity (mm/hr)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0
5
10
15
20
25
30
35
Simazine_Sample 1 LOD 0.03
Amitrole_Sample 1 LOD 0.1
Glyphosate_Sample 1 LOD 0.1
Diuron_Sample 1 LOD 0.01
Bromacil_Sample 1 LOD 0.02
Atrazine_Sample 1 LOD 0.02

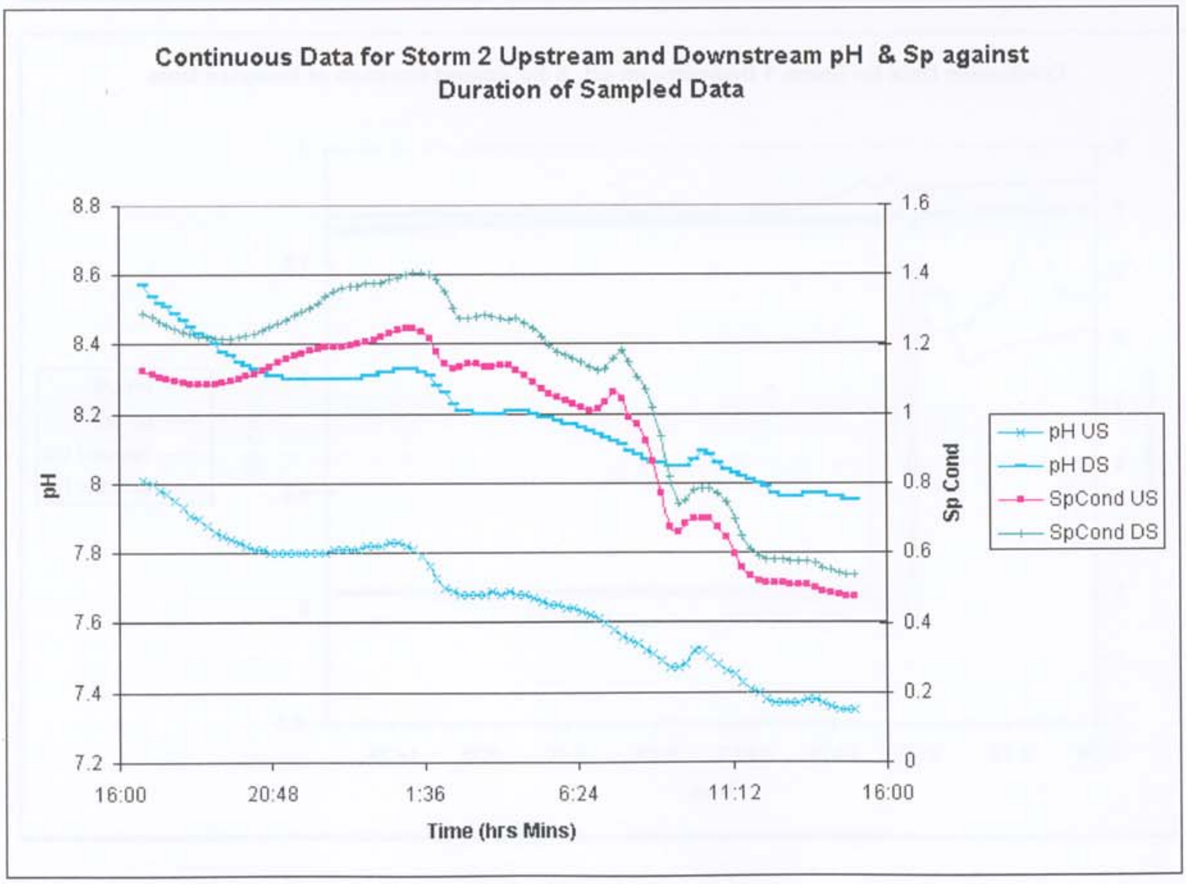

Storm Composite Data for Polyaromatic Hydrocarbons against Peak Intensity
Concentration (ug/l)
Peak Intensity (mm/hr)
1.2
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
35
Naphthalene_Sample 1 LOD 0.01-0.05
Acenaphthylene_Sample 1 LOD 0.01-0.05
Acenaphthene_Sample 1 LOD 0.01-0.05
Fluorene_Sample 1 LOD 0.01-0.05
Phenanthrene_Sample 1 LOD 0.01-0.05
Anthracene_Sample 1 LOD 0.01-0.05
Fluoranthene_Sample 1 LOD 0.01-0.05
Pyrene_Sample 1 LOD 0.01-0.05
Benzoaanthracene_Sample 1 LOD 0.01-0.05
Chrysene_Sample 1 LOD 0.01-0.05
Benzo(b)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(k)fluoranthene_Sample 1 LOD 0.01-0.05
Benzo(a)pyrene_Sample 1 LOD 0.01-0.05
Indeno(1,2,3,cd)pyrene_Sample 1 LOD 0.01-0.05
Dibenzo(a,h)anthracene_Sample 1 LOD 0.01-0.05
MBTE_Sample 1 LOD
Benzo(g,h,l)perylene_Sample 1 LOD 0.01-0.05

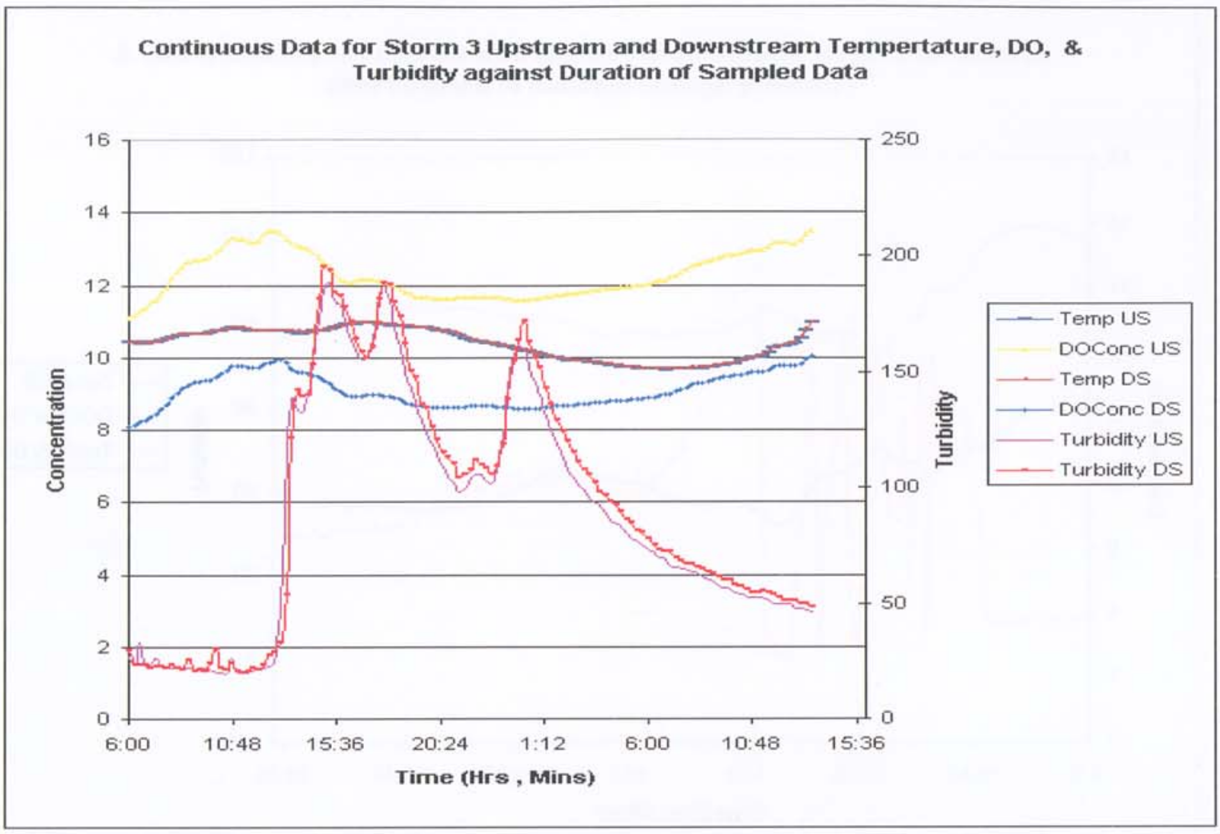
APPENDIX J UPSTREAM AND DOWNSTREAM WATERCOURSE CONTINUOUS WATER QUALITY DATA FOR INDIVIDUAL EVENTS

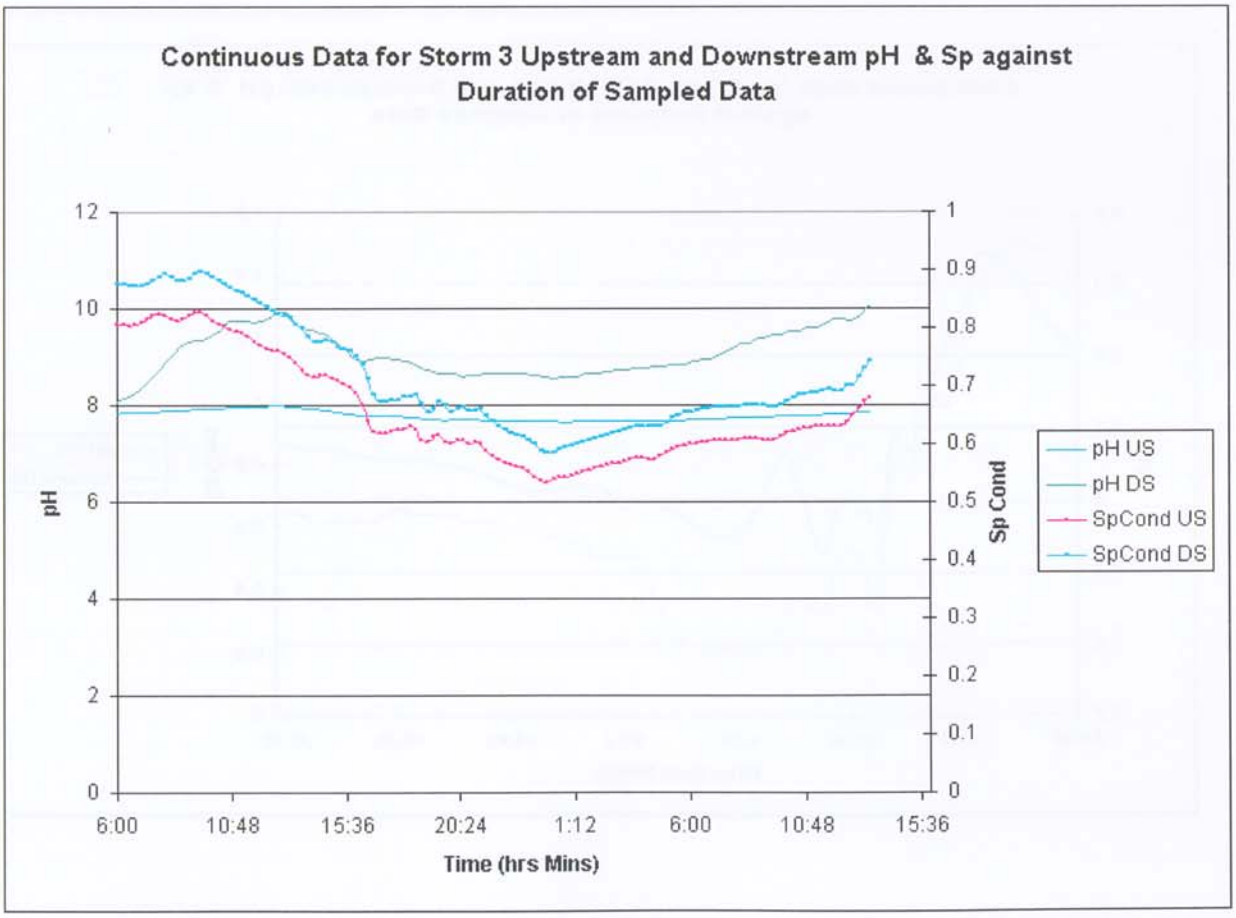

Continuous Data for Storm 1 Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
Concentration
Time
0:00
12:00
0:00
12:00
Temp DS
DOConc DS
Temp US
DOConc US
Turbidity DS
Turbidity US

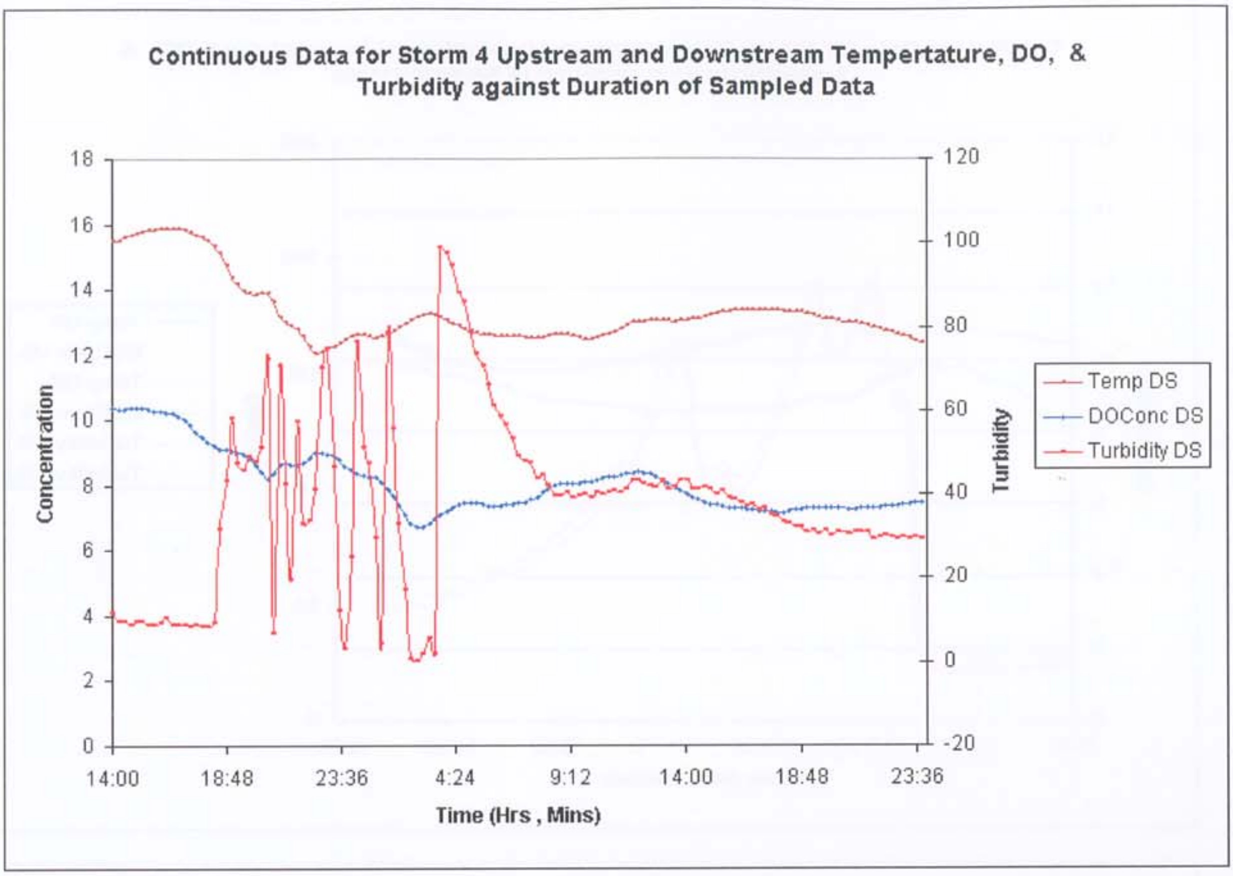

Continuous Data for Storm 1 Downstream pH & Sp against Duration of Sampled Data
Concentration
Sp Cond
Time
0:00
4:48
9:36
14:24
19:12
0:00
4:48
9:36
14:24
pH US
pH DS
SpCond US
SpCond DS

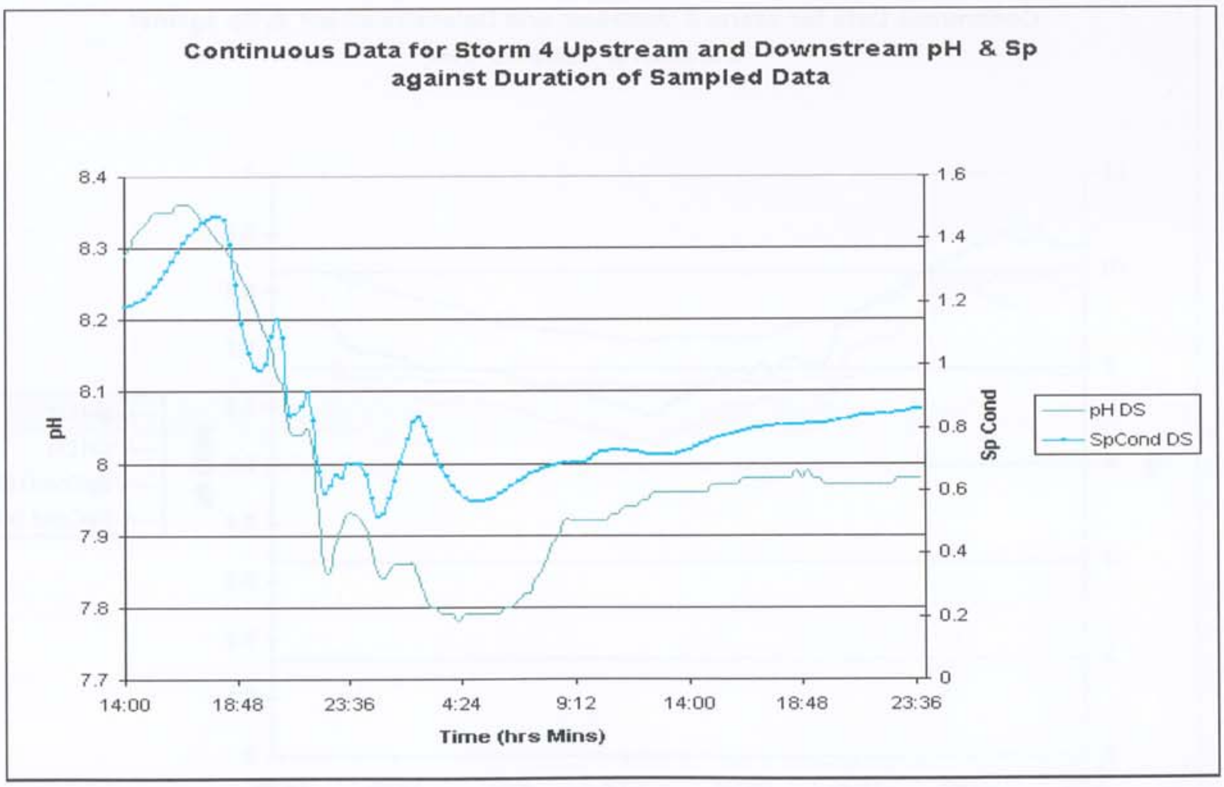

Continuous Data for Storm 2 Upstream and Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
Concentration
Turbidity
Time (Hrs , Mins)
16:00
20:48
1:36
6:24
11:12
16:00
Temp US
DOConc US
Temp DS
DOConc DS
Turbidity US
Turbidity DS

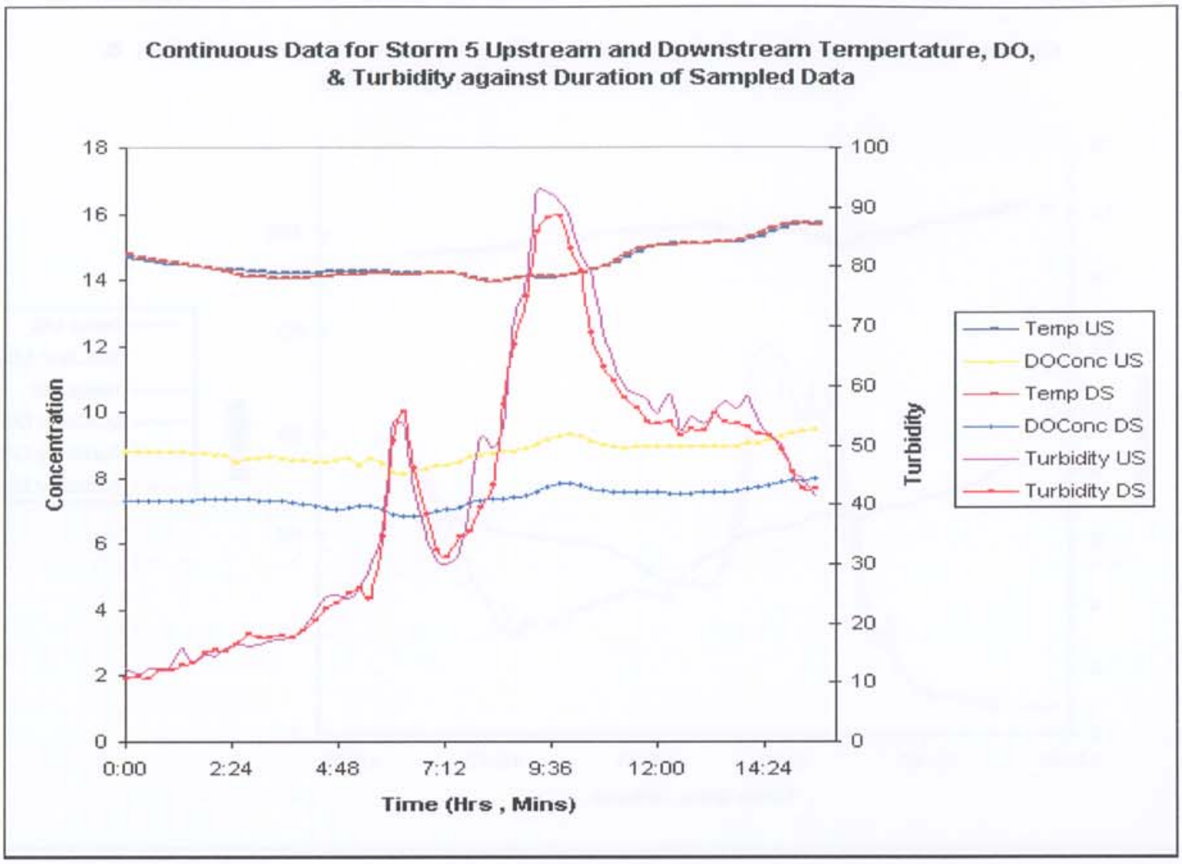

Continuous Data for Storm 2 Upstream and Downstream pH & Sp against Duration of Sampled Data
pH
Sp Cond
Time (hrs Mins)
16:00
20:48
1:36
6:24
11:12
16:00
pH US
pH DS
SpCond US
SpCond DS

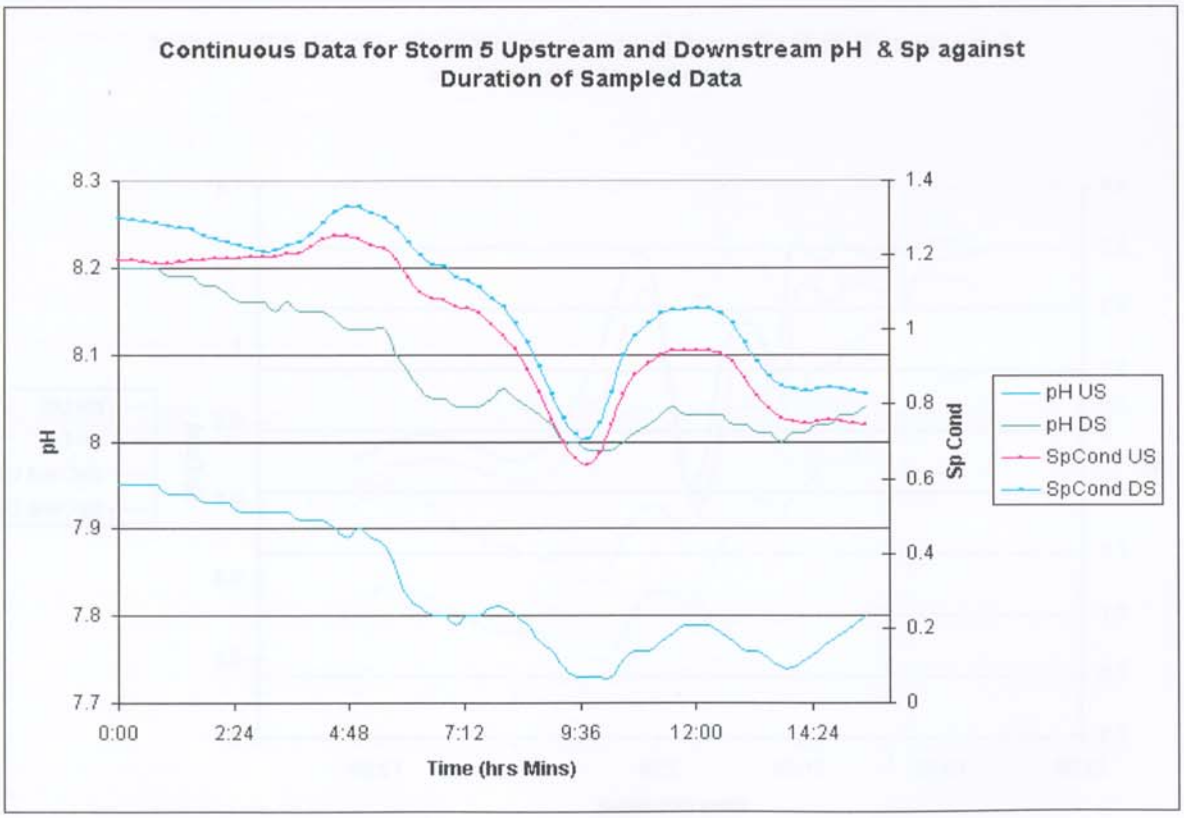

Continuous Data for Storm 3 Upstream and Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
Concentration
Turbidity
Time (Hrs , Mins)
6:00
10:48
15:36
20:24
1:12
6:00
10:48
15:36
Temp US
DOConc US
Temp DS
DOConc DS
Turbidity US
Turbidity DS

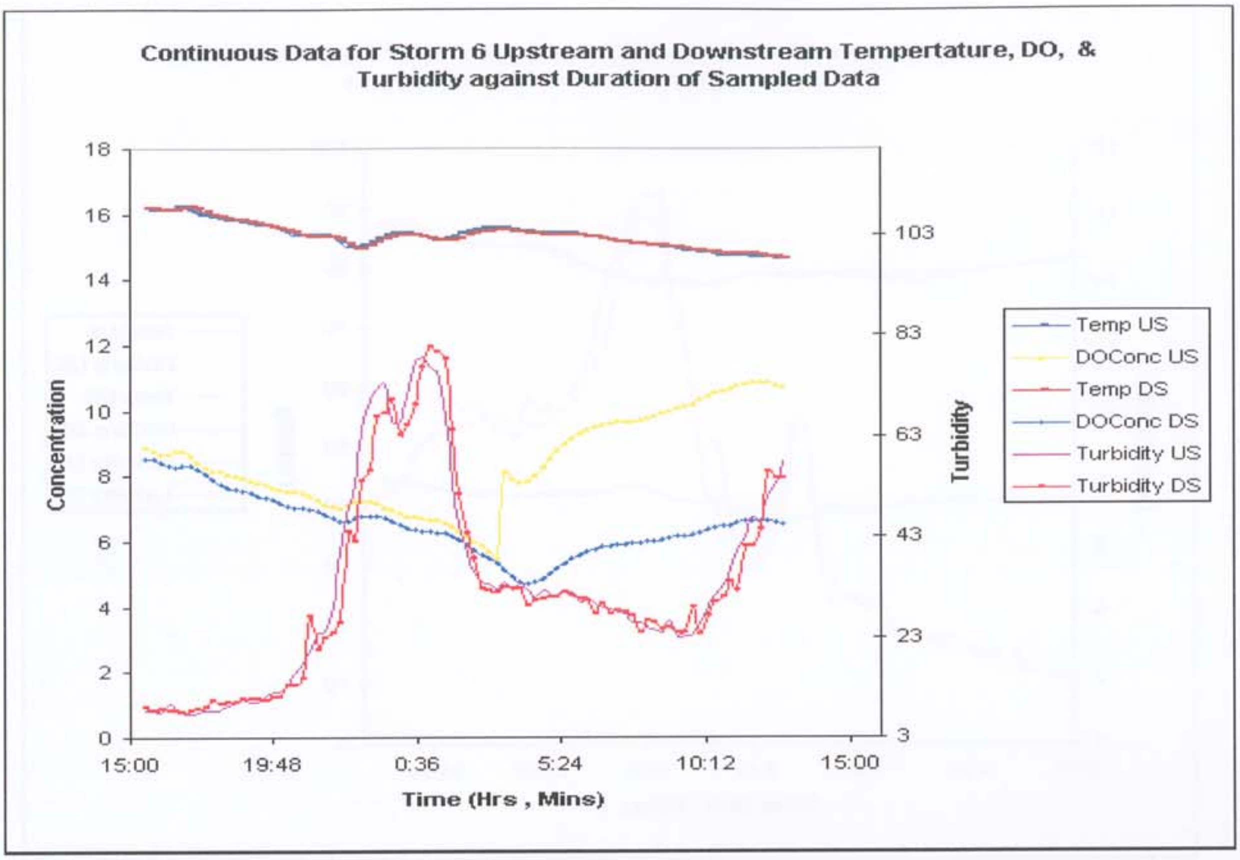

Continuous Data for Storm 3 Upstream and Downstream pH & Sp against Duration of Sampled Data
pH
Sp Cond
Time (hrs Mins)
6:00
10:48
15:36
20:24
1:12
6:00
10:48
15:36
pH US
pH DS
SpCond US
SpCond DS

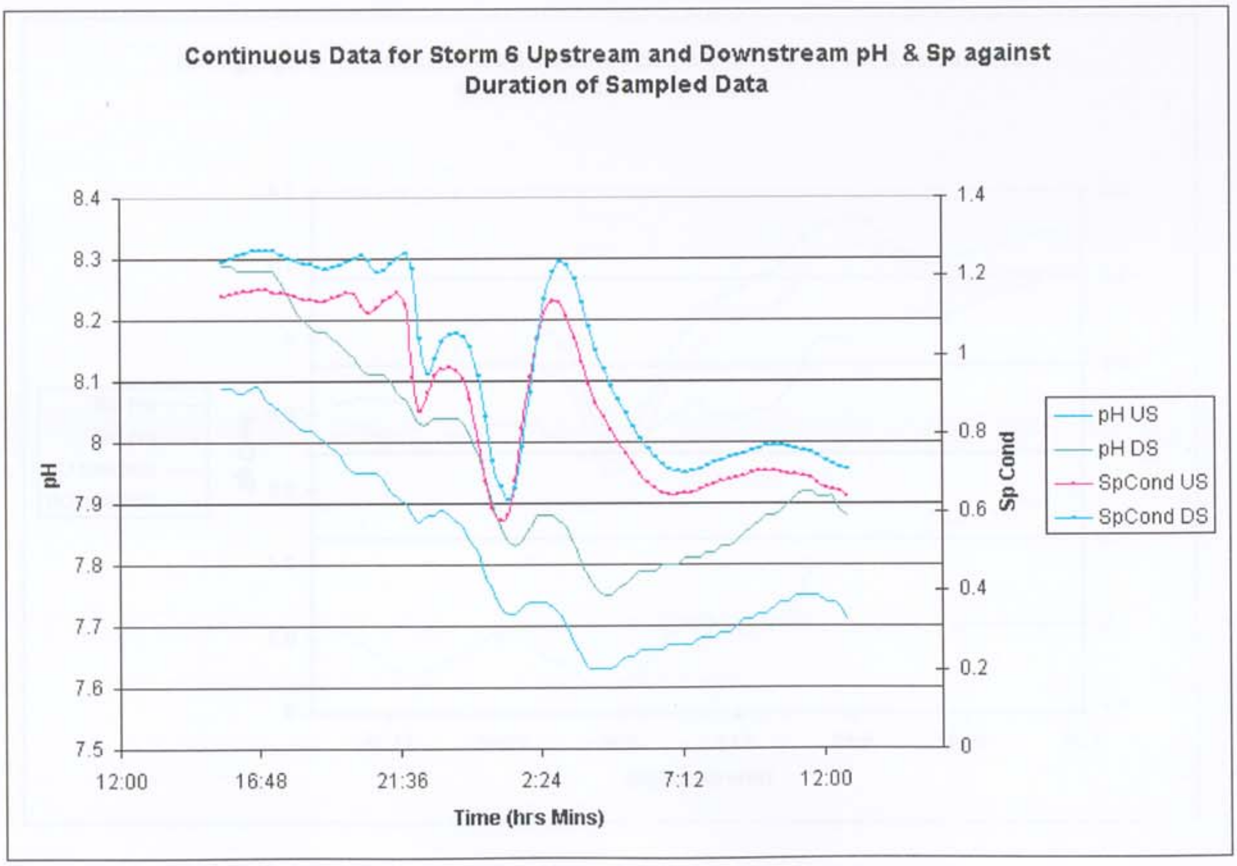

Continuous Data for Storm 4 Upstream and Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
Concentration
Turbidity
Time (Hrs , Mins)
Temp DS
DOConc DS
Turbidity DS
14:00
18:48
23:36
4:24
9:12
14:00
18:48
23:36

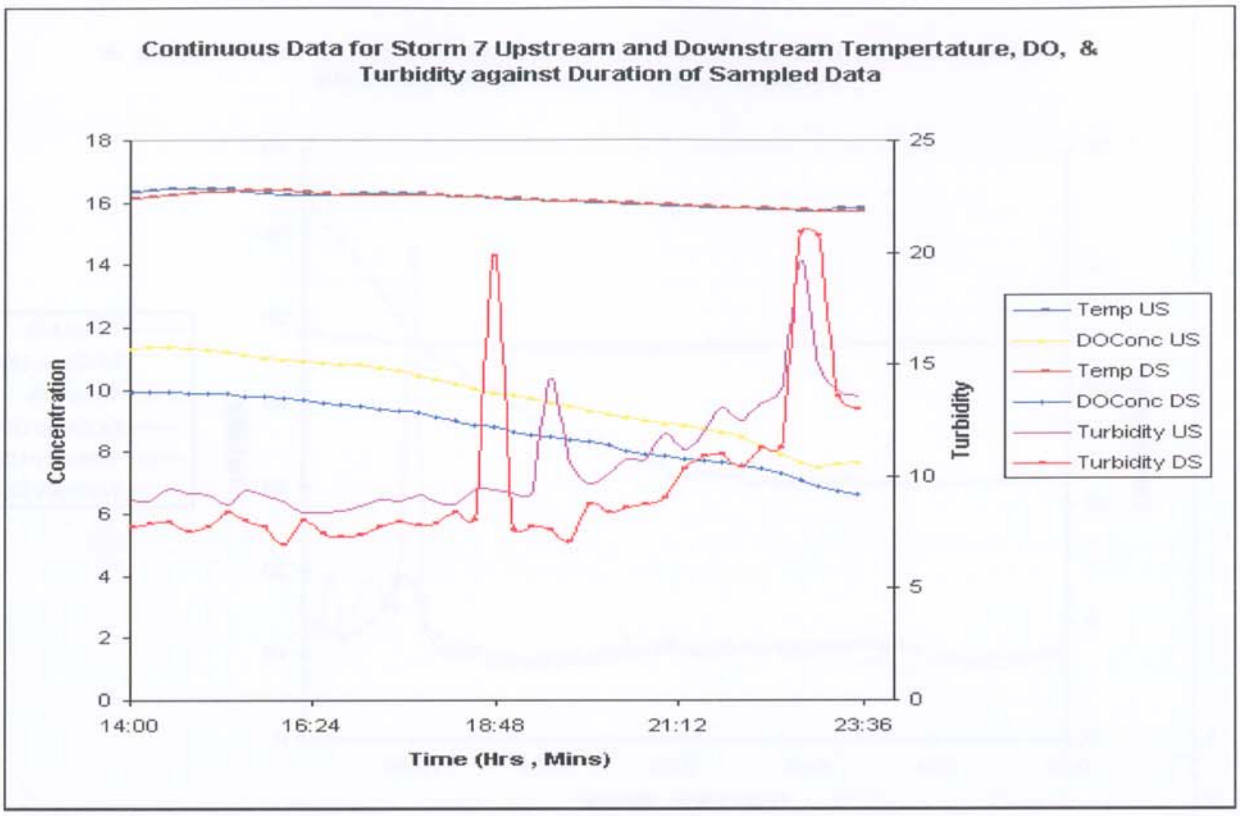

Continuous Data for Storm 4 Upstream and Downstream pH & Sp against Duration of Sampled Data
pH
Sp Cond
Time (hrs Mins)
pH DS
SpCond DS
14:00
18:48
23:36
4:24
9:12
14:00
18:48
23:36

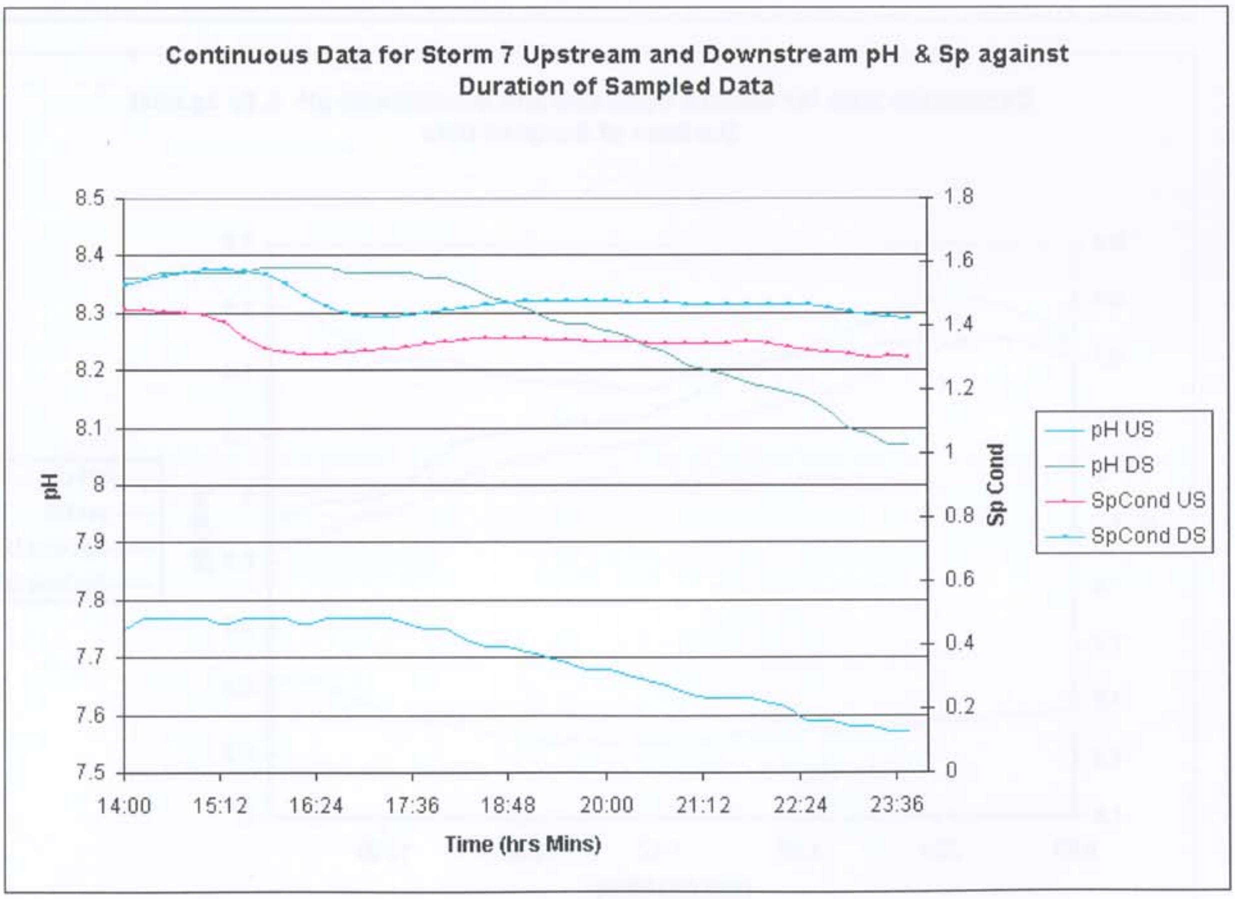

Continuous Data for Storm 5 Upstream and Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
Concentration
Turbidity
Time (Hrs , Mins)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
Temp US
DOConc US
Temp DS
DOConc DS
Turbidity US
Turbidity DS

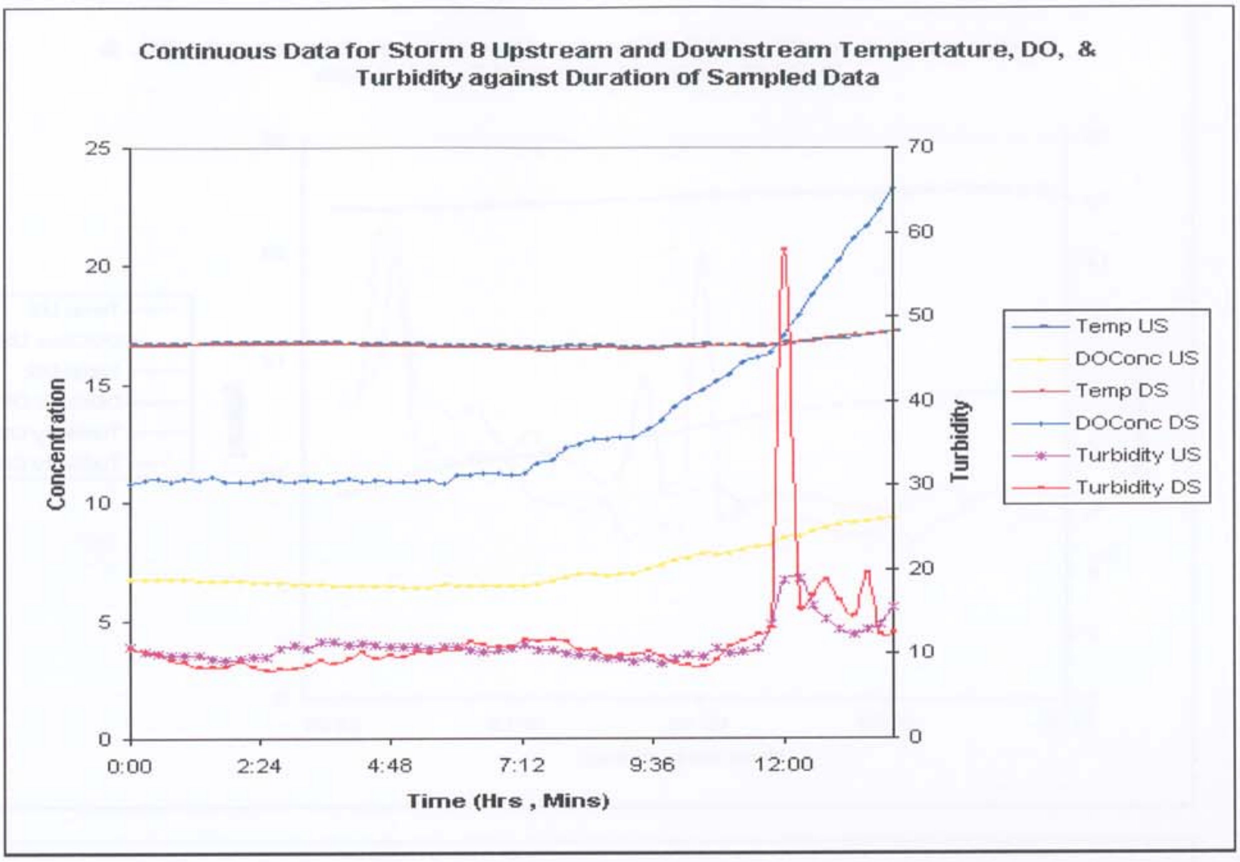

Continuous Data for Storm 5 Upstream and Downstream pH & Sp against Duration of Sampled Data
pH
Sp Cond
Time (hrs Mins)
0:00
2:24
4:48
7:12
9:36
12:00
14:24
pH US
pH DS
SpCond US
SpCond DS


Continuous Data for Storm 6 Upstream and Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
Concentration
Turbidity
Time (Hrs , Mins)
Temp US
DOConc US
Temp DS
DOConc DS
Turbidity US
Turbidity DS
0
2
4
6
8
10
12
14
16
18
3
23
43
63
83
103
15:00
19:48
0:36
5:24
10:12
15:00

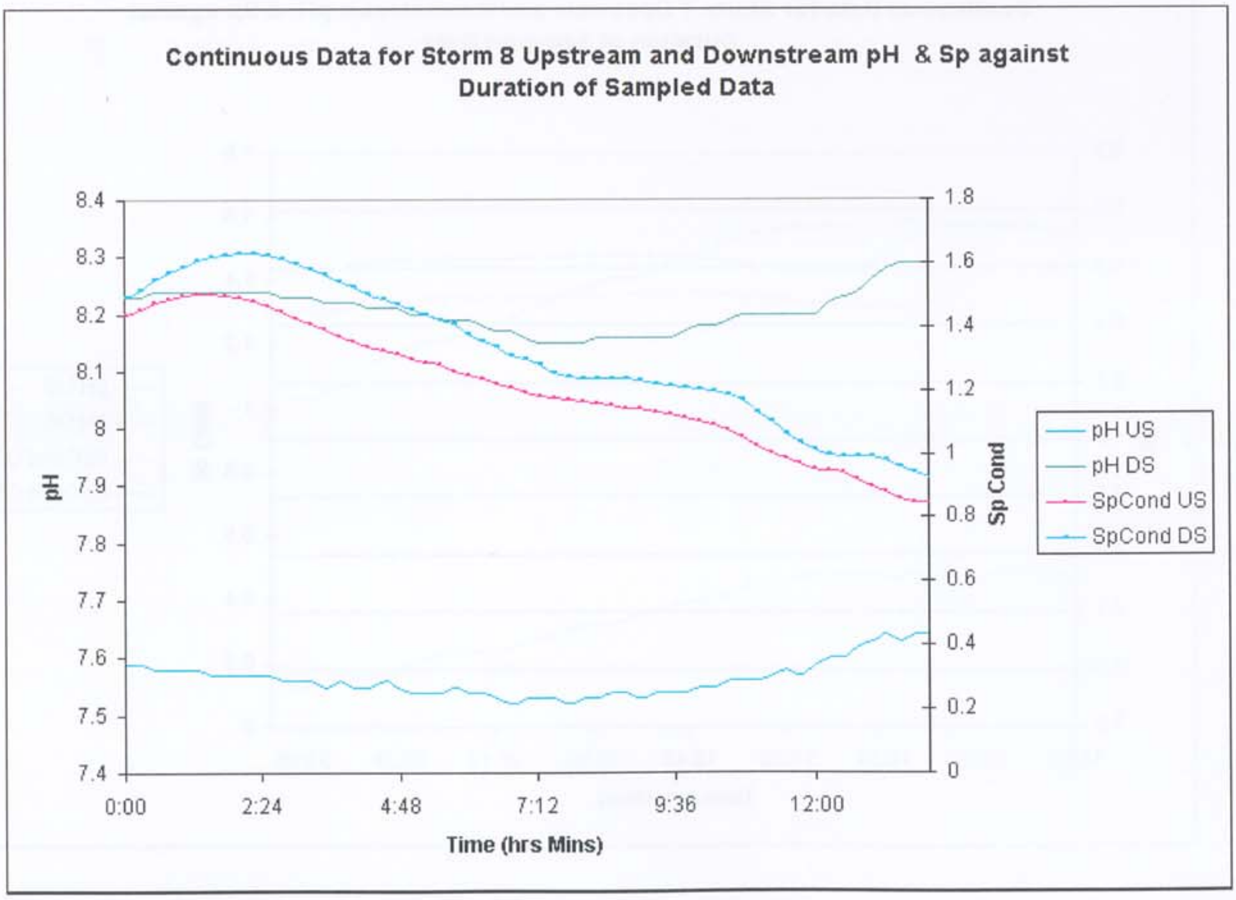

Continuous Data for Storm 6 Upstream and Downstream pH & Sp against Duration of Sampled Data
pH
Sp Cond
Time (hrs Mins)
pH US
pH DS
SpCond US
SpCond DS
7.5
7.6
7.7
7.8
7.9
8
8.1
8.2
8.3
8.4
0
0.2
0.4
0.6
0.8
1
1.2
1.4
12:00
16:48
21:36
2:24
7:12
12:00


Continuous Data for Storm 7 Upstream and Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
18
16
14
12
10
8
6
4
2
0
Concentration
25
20
15
10
5
0
Turbidity
14:00
16:24
18:48
21:12
23:36
Time (Hrs , Mins)
Temp US
DOConc US
Temp DS
DOConc DS
Turbidity US
Turbidity DS

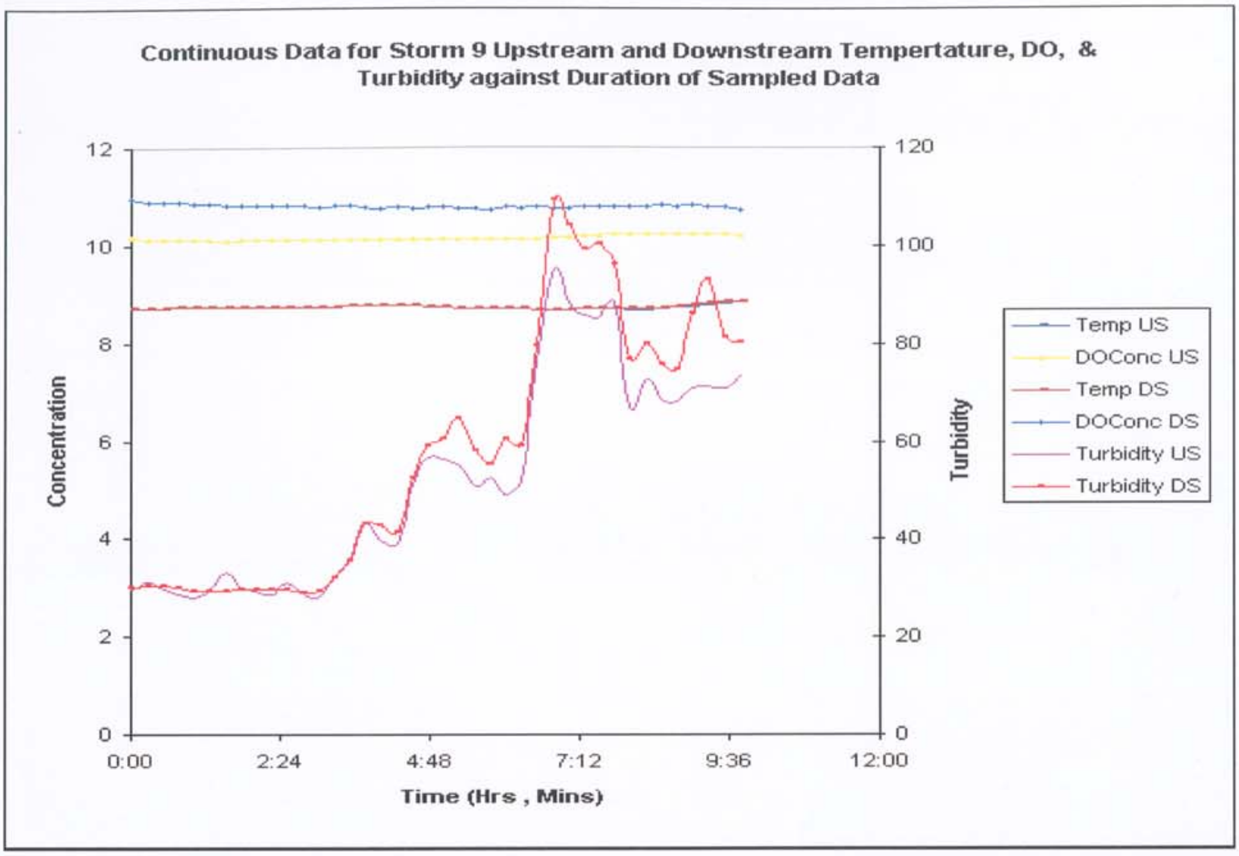

Continuous Data for Storm 7 Upstream and Downstream pH & Sp against Duration of Sampled Data
8.5
8.4
8.3
8.2
8.1
8
7.9
7.8
7.7
7.6
7.5
pH
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Sp Cond
14:00
15:12
16:24
17:36
18:48
20:00
21:12
22:24
23:36
Time (hrs Mins)
pH US
pH DS
SpCond US
SpCond DS



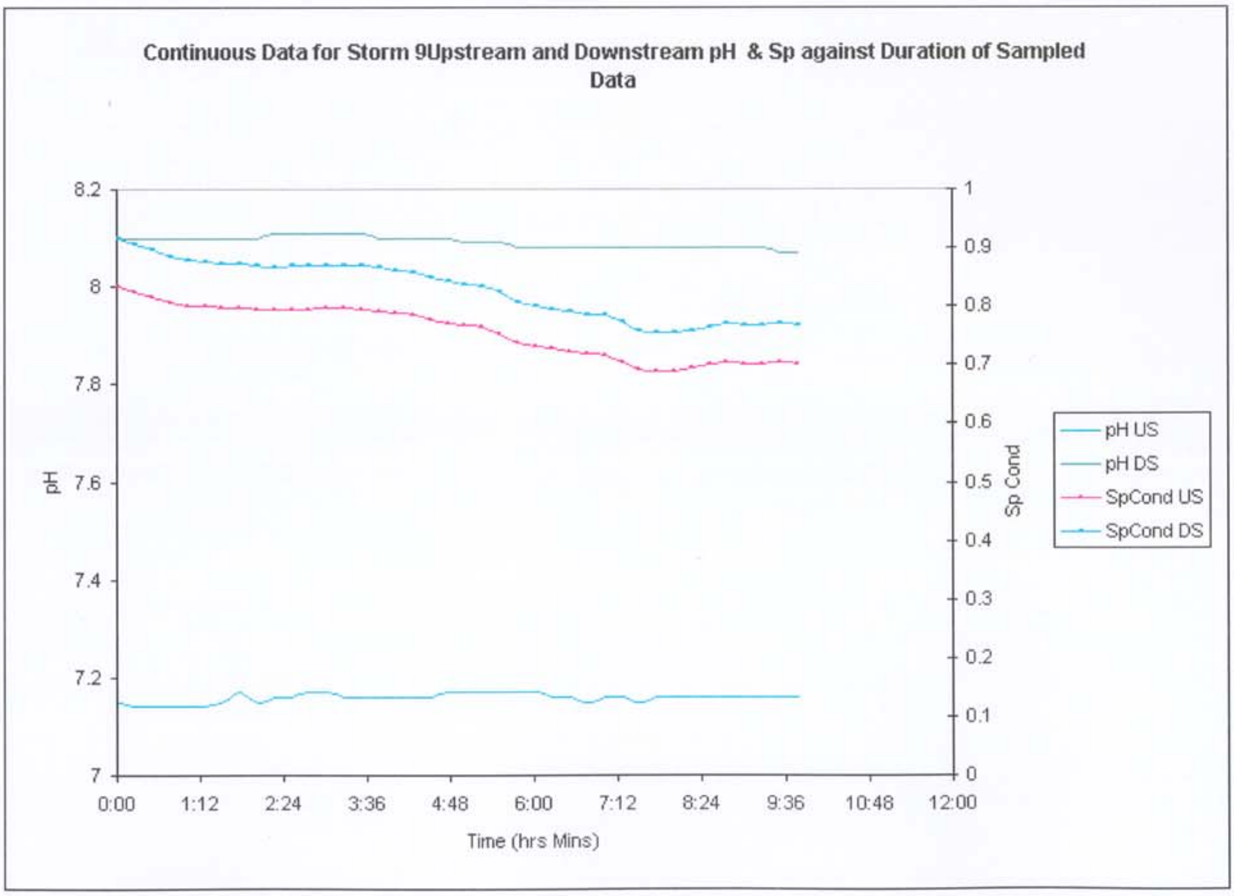
Continuous Data for Storm 8 Upstream and Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
Concentration
Turbidity
Time (Hrs , Mins)
0:00
2:24
4:48
7:12
9:36
12:00
Temp US
DOConc US
Temp DS
DOConc DS
Turbidity US
Turbidity DS



Continuous Data for Storm 8 Upstream and Downstream pH & Sp against Duration of Sampled Data
pH
Sp Cond
Time (hrs Mins)
0:00
2:24
4:48
7:12
9:36
12:00
pH US
pH DS
SpCond US
SpCond DS



Continuous Data for Storm 9 Upstream and Downstream Tempertature, DO, & Turbidity against Duration of Sampled Data
Concentration
Turbidity
Time (Hrs , Mins)
Temp US
DOConc US
Temp DS
DOConc DS
Turbidity US
Turbidity DS
0
2
4
6
8
10
12
20
40
60
80
100
120
0:00
2:24
4:48
7:12
9:36
12:00



Continuous Data for Storm 9Upstream and Downstream pH & Sp against Duration of Sampled Data
pH
Sp Cond
Time (hrs Mins)
pH US
pH DS
SpCond US
SpCond DS
7
7.2
7.4
7.6
7.8
8
8.2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0:00
1:12
2:24
3:36
4:48
6:00
7:12
8:24
9:36
10:48
12:00