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The Long Term Monitoring of Pollution from Highway Runoff: Final Report

R&D Technical Report P2-038 / TR1

HIGHWAYS AGENCY

ENVIRONMENT AGENCY

THE LONG TERM MONITORING OF POLLUTION FROM HIGHWAY RUNOFF: FINAL REPORT

R&D Technical Report P2-038/TR1

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This report summarises the results of a long term study on road runoff 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.

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SUMMARY

Highway surface runoff discharges may contain pollutants that have accumulated on the carriageway, particularly following periods of dry weather. In response to rainfall, these pollutants may be transported via the highway surface water drainage system and discharge to receiving watercourses or groundwaters. Previous studies have demonstrated that highway runoff affects the quality of waters and sediments. Increased concentrations of metals, hydrocarbons and anions are associated with changes in the structure and functioning of biological communities. The Highways Agency has a duty to ensure that discharges from the trunk roads and motorways do not pollute receiving waters. Various treatment facilities have been designed and incorporated into recent trunk road and motorway construction but these designs are based on predicted pollutant concentrations. The Highways Agency, in association with the Environment Agency, commissioned this study to collect data to improve the understanding of contaminants in routine non urban highway runoff and to examine the treatment efficiency of drainage systems and drainage devices in the non urban environment. Many of these systems have been installed to provide environmental protection through hydraulic control. However, the potential for additional treatment has been recognised but not quantified. The data from this study will be used to assess the impact of highway runoff on receiving waters and to assist in the future design of highway drainage systems.

The objectives of the study were to:

- undertake a programme of data collection for non urban highways under a range of site conditions;
- create a database of flows, pollutant load, rainfall and site details obtained during the study;
- identify key determinands and concentrations in non urban highway runoff;
- establish any relationship between pollutant concentrations and traffic flows, pollutant concentrations and rainfall totals, intensity, duration and antecedent dry periods;
- identify the treatment efficiency of a number of specified highway drainage types or combinations of treatment facilities; and,
- evaluate the chemical and biological impact of highway runoff on receiving water quality.

The study was carried out by WRc plc over a 5 year period from December 1997. This involved the instrumentation and monitoring of non urban highway surface water drainage and the receiving water at 6 sites. The sites selected were in central Southern England. All sites had a minimum Annual Average Daily Traffic (AADT) of 15,000 vehicles/day. The sites had the following drainage types or combinations of treatment facilities: untreated runoff; bypass oil interceptor and dry balancing pond; oil trap manhole and sedimentation tank; full retention oil trap and wet balancing pond; untreated runoff and filter drain; and, bypass oil interceptor and wet pond/surface flow wetland. Each site was monitored for a minimum of 1 year. Continuous flow monitoring of the watercourse upstream and downstream of the highway runoff discharge location and continuous monitoring of rainfall were undertaken. Water quality samples and in situ measurements were taken at quasi-monthly intervals. Sediment samples were taken at the beginning and end of the monitoring period from the drainage system and

from the watercourse. Highway runoff was recorded and sampled for 10 wet weather events during the monitoring period. Flow measurement was undertaken at the point of discharge from the carriageway and liquid samples were taken upstream and downstream of each runoff treatment device. In addition to flow measurement in the watercourse, water quality probes were deployed at the upstream and downstream locations. Biological surveys were undertaken on three occasions at each site at selected locations upstream and downstream of the highway discharge. Highway runoff, the discharge to the watercourse and associated sediment samples were analysed for up to 40 determinands, including metals, herbicides, hydrocarbons, suspended solids, BOD, COD and Ammoniacal Nitrogen.

The data have been collated in to a database and used to identify ranges of pollutant concentrations in highway runoff; relationships between runoff concentrations/loads and highway/environmental factors; treatment efficiencies; and impacts on receiving waters. This database can be used to support further analysis, investigation and interpretation. While the overall quantity of runoff data is large, with 60 events captured, the number of event data sets collected at individual sites is relatively small taking into consideration the observed variability of the events, background environmental conditions and highway characteristics. This has limited the identification of relationships between event and site characteristics and the resulting runoff quality at individual sites. In addition, the number of highway variables between sites has limited the conclusions that may be drawn from inter site comparisons of runoff, treatment device efficiency and environmental impact in the receiving watercourse.

A number of determinands were not detected. However, the sites monitored do not represent the full range of characteristics across the highway network and, therefore, these determinands may be identified elsewhere. A number of determinands were detected during all monitored rainfall events and at concentrations well above limits of detection. Some were also shown to have concentrations greater than prescribed maximum and annual average concentrations identified for Drinking Water and Freshwater Environmental Quality Standards. The range of observed event mean flow weighted pollutant concentrations is higher than those quoted in the Design Manual for Roads and Bridges, Volume 11, Section 3:10, Water Quality and Drainage.

A number of possible relationships associated with highway runoff quality can be proposed. Determinand concentrations, and in particular metals, appear in higher concentrations following winter salting and a relationship may exist between runoff concentration and rainfall intensity.

Assessment of treatment efficiency indicates that there is a wide range of pollution removal efficiencies for the individual and combinations of treatment devices at the monitored sites. The greatest observed pollution removal efficiency was produced by a combination of a bypass oil separator and wet pond-surface flow wetland.

Event monitoring and background monitoring in the receiving waters at five sites where data could be collected showed no apparent impact of highway runoff over background conditions. Watercourse sediment analysis showed little significant accumulation of contaminated sediments downstream of highway runoff discharges. Highway drainage from these sites appears not to have adversely affected macro-invertebrate communities in the receiving waters.

Overall, the results from the study seem to differ from previous studies of runoff quality and receiving water impact, largely associated with urban highways, higher traffic densities and different regional climates and receiving water characteristics.

ABBREVIATIONS AND ACRONYMS

AA	Annual Average
AADT	Annual Average Daily Traffic
ADP	Antecedent Dry Period
ASPT	Average Score Per Taxon
BMWP	Biological Monitoring Working Party
C	Circa
DMRB	Design Manual for Roads and Bridges, Volume 11, Section 3, Part 10, Water Quality and Drainage
DWS	Drinking Water Standard
EMC	Event Mean Concentration
EQS	Environmental Quality Standards
HGV	Heavy Goods Vehicles
LOD	Limits Of Detection
MAC	Maximum Acceptable Concentration
PAH	Polynuclear Aromatic Hydrocarbons
TSS	Total Suspended Solids
VM	Volatile Material
Q 5%ile Exceedence	Flows exceed value for 95% of time
Q 95%ile Exceedence	Flows exceed value for 5% of time

1. INTRODUCTION

1.1 Background

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 receiving watercourses.

The potential for the impact of highway runoff on receiving waters is likely to increase and previous studies have demonstrated that highway runoff affects the quality of waters and sediments. Increased concentrations of metals, hydrocarbons and anions are associated with changes in the structure and functioning of biological communities.

The Highways Agency has a duty to ensure that discharges from the trunk roads and motorways do not pollute receiving waters. Various treatment facilities have been designed and incorporated into recent trunk road and motorway construction but these designs are based on predicted pollutant concentrations. The Highways Agency in association with the Environment Agency commissioned this study to collect data to improve the understanding of contaminants in routine non urban highway runoff and to examine the treatment efficiency of drainage systems and drainage devices in the non urban environment. Many of these systems have been installed to provide environmental protection through hydraulic control but the potential for additional treatment was recognised.

These data will be used to assess the impact of highway runoff on receiving waters to assist in the future design of highway drainage systems.

1.2 Objectives

The objectives of the study were:

1. To undertake a programme of data collection for non urban highways under a range of site conditions.

2. To create a database of flows, pollutant loads, rainfall and site details obtained during the study.

3. To identify key determinands and their concentrations in highway runoff.

4. To establish any relationships between pollutant concentrations and traffic flows, rainfall totals, rainfall intensity, rainfall duration and antecedent dry periods.

5. To identify the treatment efficiency of a number of specified highway drainage types or combinations of treatment devices or facilities.

6. To evaluate the chemical and biological impact of highway runoff on receiving water quality.

1.3 Implementation, work programme, schedule

WRc plc was contracted to obtain information regarding the quantity and quality of non urban highway surface water drainage and of the receiving waters at 6 sites incorporating untreated runoff and 8 different drainage treatment facilities.

Data collection took place over a four and a half year period commencing in December 1997 with monitoring being undertaken at two sites concurrently. Monitoring periods are given in Table 1-1

Table 1-1 Monitoring Sites/Periods

Site (Highway/Receiving watercourse)	AADT	Surface Material	Monitoring Period
M4/Brinkworth Brook	71929	Asphalt	December 1997 to December 1998
A417/River Frome	23647	Asphalt	June 1998 to July 1999
M4/River Ray	36107	Asphalt	December 1998 to March 2000
M40/Souldern Brook	83579	Asphalt	August 1999 to October 2000
A34/Gallos Brook	64953	Concrete	September 2000 to March 2002
A34/Newbury (River Enborne)	37192	Porous Asphalt	May 2001 to June 2002

Each site was monitored for a minimum of 1 year. Continuous flow monitoring of the watercourse upstream and downstream of the highway runoff discharge location and continuous monitoring of rainfall was undertaken. Water quality samples and in situ measurements were taken at quasi-monthly intervals. Sediment samples were taken at the beginning and end of the monitoring period from the drainage system and from the watercourse.

During the monitoring period, highway runoff was recorded and sampled for 10 wet weather events. Flow measurement was undertaken at the point of discharge from the carriageway drainage and liquid samples were taken upstream and downstream of each runoff treatment device. In addition to flow measurement in the watercourse water quality probes were deployed at the upstream and downstream locations.

These data are archived in a database and have been used to evaluate the efficiency of the treatment facilities in removing the pollutants, and to evaluate the effect of wet weather discharge quality on the receiving water.

Individual site reports have been produced relating to the Flow Measurement and Water Quality data collection programme implemented at each site listed in Table 1-1 above. The data collected are presented in the Appendices to each report, along with graphical output of the preliminary analysis of the data.

A literature review was conducted at the beginning of the study. This outlined the results of studies that examined the effects of highway runoff on the quality of receiving waters and sediments and the effect on biological communities. The review showed that previous studies identified elevated concentrations of metals and hydrocarbons in waters and sediments and that these elevations are associated with changes in the structure and functioning of biological communities. This literature review is presented as an associated report.

2. METHODOLOGY

2.1 Principles

The key aims of the study were to establish highway runoff quality; to evaluate the efficiency of a range of currently employed treatment devices; and, to assess the effect of highway runoff on receiving waters. A programme of data collection was proposed to provide adequate reliable data for these objectives to be met.

The programme was designed to collect data that would allow analysis of runoff quality at an individual site over a range of event characteristics and to allow comparison of results between a number of sites with different highway characteristics.

2.2 Approach

Five programmes of data collection were conducted during the monitoring period to establish background levels and the effect of intermittent storm runoff on the watercourse at each site.

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

2. background river water liquid 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. sediment sampling at the commencement and conclusion of the monitoring period from the upstream and downstream watercourse and highway runoff monitoring locations,

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

5. biological surveys of the receiving watercourse on three occasions in different seasons during the monitoring period, upstream and downstream of the point of discharge.

2.2.1 Continuous Data Collection

Continuous monitoring of rainfall and river flows was undertaken upstream and downstream of the highway runoff discharge point.

Table 2-1 Continuous data collection - Hydrology

Data Type	Logging interval
Rainfall	Tips (0.2mm) per 1 minute intervals
River Flows	scanned at 5 minute intervals with logged average every 15 minutes

2.2.2 Background Monitoring

Monitoring of the watercourses was carried out for a minimum of 1 year.

During this period river water samples were taken and analysed and in situ measurements taken at approximately monthly intervals, where possible during periods of established dry weather flow, upstream and downstream of the highway discharge. These data would provide a data set that would allow sampling and seasonal variations to be taken into account during assessment. The parameters monitored are listed in Table 2-2.

Table 2-2 Background 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	^oC	0.01 ^oC
	pH	units	0.01 units
	Dissolved Oxygen	mg/l O_2	0.01 mg/l

2.2.3 Sediment Sampling

Sediment samples were taken at the beginning and end of the monitoring period for comparison of upstream and downstream determinands, and to record any progressive changes in sediment quality.

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.

River sediments were collected using a trowel or shovel. The sediments were representative of fine grained material deposited due to low flow velocities and not taken from adjacent to the river banks where sediments are likely to be sorted and unrepresentative.

Pond discharge sediments were taken adjacent to the outlet structures or from the floor of the device where the sediments retain some moisture throughout the year.

Highway sediments were collected from the drainage channel at the side of the carriageway and from the catchpits upstream of any treatment devices.

Table 2-3 Sediment sampling

Sample Type	Determinands	Units	LOD
Sediment	Metals*	mg/l	**µg/l
	Polyaromatic Hydrocarbons*	µg/l	0.05µg/l
	Weathered Hydrocarbons*	µg/l	**µg/l
	Particle size distribution	mm	2µm
	Organic content	VM %	0.1%

* The full suite of determinands is given in Appendix A
** Variable

2.2.4 Biological Surveys

Biological surveys were undertaken on three occasions at each site, (with the exception of the A34/Newbury site), during three different seasons, at selected locations upstream and downstream of the runoff discharge.

Invertebrates were sampled with a hand net using a three-minute kick sample (Furse *et al.*, 1981). The samples were preserved in alcohol in the field and returned to the laboratory where the organisms were sorted from the debris, identified to family level and enumerated. The Biological Monitoring Working Party (BMWP) score and ASPT (Average Score Per Taxon) were calculated for each sample.

2.2.5 Event Monitoring

To identify the effect of different event characteristics on runoff quality it was proposed to carry out intensive data collection for 10 events during the monitoring period. Sampling of the highway runoff and in-situ water quality monitoring of the watercourse during storm events was carried out. Determinands are summarised in Table 2.4.

These 10 events were selected to give a range of different antecedent dry periods (ADP), rainfall intensities and durations subject to events previously monitored and weather forecasts. A Meteorological Office forecasting service was contracted to assist in the selection of suitable events.

Liquid samples were collected from highway runoff and treated runoff locations. 12 discrete samples were selected at suitable time intervals to cover the period of the event response and flow proportional composites were prepared for subsequent analysis.

Table 2-4 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*	µg/l	**µg/l
	Polyaromatic Hydrocarbons*	µg/l	**µg/l
	Herbicides*	µg/l	**µg/l
	De-icing salts	mg/l Cl	0.2 mg/l
In-situ measurement	Temperature	^oC	0.01 ^oC
	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 is given in Appendix A
** Variable

2.3 Laboratory sample analysis

WRc/NSF NAMAS Accredited laboratories carried out sample analysis. All analytical procedures are fully documented and based on existing nationally recognised methods, (e.g. SCA, BSI, AWWA). Method summaries are given in Appendix B.

Where analytical procedures were not available in house, or were not NAMAS accredited, the analysis was subcontracted to approved sub-contract laboratories. Initially, analysis of the Herbicide suite, Platinum and Palladium, particle size analysis and sediment PAHs were sub-contracted.

The limits of detection for metals analysIs specified in the individual site reports, Appendices A and B, are based on the Flame Atomic Absorption technique. However, from February 1999 the Inductively Coupled Plasma-Mass Spectrometry (ICPMS) technique was used for metals analysis. This technique significantly improved the limits of detection, i.e. for Pb the FAA technique LOD of 50 µg/l is 0.5 µg/l for the ICPMS technique. ICPMS LODs are included in Appendix A.

The Method Limit of Detection is statistically defined as:

$$LOD = 4.65 * \text{std devn}$$

Where ‘std devn’ is the within batch standard deviation of the analysis of blank samples, which is determined when the method performance characteristics are evaluated before the method is put into routine use.

The limit of detection for solid samples is derived from the method LOD and depends upon the amount of sample taken and the final volume that the digest is made up to.

e.g. if the method limit of detection is 1 µg/l, and 2.00 gms of solid material are digested and made up to a final volume of 50 ml, then the LOD for the solid becomes 0.025 µg/gm.

The method LOD may not be attained if a sample needs to be diluted (e.g. due to matrix effects) then the LOD should be multiplied by this factor before reporting.

2.4 Site selection

Site searches were conducted by WRc during the study. Sites that satisfied the criteria were formally proposed to the clients, following discussions regarding site characteristics and the proposed monitoring regime.

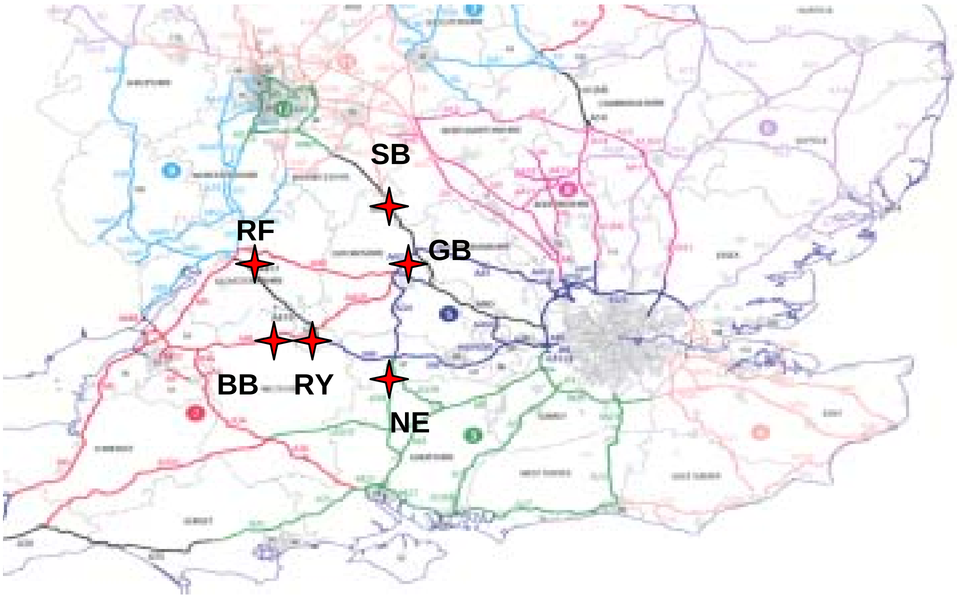
A minimum Annual Average Daily Traffic (AADT) of 15,000 vehicles/day was specified. Sites where untreated highway runoff and runoff treated by a combination of any two of the following facilities were to be considered.

- Untreated,
- Filter drain,
- Settling tank,
- Oil trap manhole,
- In stream oil trap(full retention),
- Bypass oil interceptor,
- Balancing pond (dry),
- Balancing pond (wet),
- Balancing pond (wet)/Surface flow wetland.

The major considerations for receiving waters were that they should have similar characteristics to allow inter site comparisons to be made, they should be unaffected by other sources of pollutants; and, that the downstream watercourse impact may be determined without other influences. However in practice the characteristics of the watercourse became a secondary consideration to finding suitable monitoring conditions for the drainage and treatment facilities.

Equipment security, safe access from off the highway and safe methods of working were also taken into consideration.

The sequential approach of staged data collection and the non-specified combinations of treatment devices permitted selection of sites through the study period subject to the satisfaction of site characteristics and successful data acquisition at previous sites. Sites selected and site details are given in Table 2-5. Site locations are shown in Figure 2-1below.



For site codes see Table 2-5

Figure 2-1 Monitoring Site Locations

Table 2-5 Runoff and Treatment Monitoring sites

Site (Highway / Receiving Watercourse)	Site Code	Treatment Devices Monitored	Monitoring Location Code	AADT	Surface Material
M4/Brinkworth Brook NGR SU 03758320	BB	Runoff Untreated	Location 1	71929	Asphalt
A417/River Frome NGR SO 94951315	RF	Runoff Bypass oil interceptor Dry Balancing Pond	Location 1 Location 2 Location 3	23647	Asphalt
M4/River Ray NGR SU 15428190	RY	Runoff Oil trap manhole Sedimentation tank	Location 1 Location 2 Location 3	36107	Asphalt
M40/Souldern Brook NGR SU 50903065	SB	Runoff Full retention oil trap Wet Balancing Pond	Location 1 Location 2 Location 3	83579	Asphalt
A34/Gallos Brook NGR SP 53131710	GB	Runoff Untreated Filter Drain	Location 1 Location 2	64953	Concrete
A34/Newbury Pond D (small tributary to the River Enborne) NGR SP 44406365	NE	Runoff Bypass oil interceptor Wet Pond/Surface flow Wetland	Location 1 Location 2 Location 3	37192	Porous Asphalt

2.5 Site Reports

Individual site reports have been issued. Each is a stand-alone report but is an integral component of the final reporting.

The site reports contains full details of:

- The highway and watercourse;
- Monitoring locations;
- Equipment specifications;
- Sample collection and analysis;
- Results
    - continuous data, - rainfall, river flows;
    - background monitoring, watercourse quality;
    - sediment sampling, - analysis results;
    - event monitoring, - event characteristics;
    - additional data, - traffic flows, application of road salt etc.;
- Preliminary data analysis; and
- Biological surveys.

Appendices of the site reports, C to I, contain graphical plots of:

- Rainfall;
- Depth and flow;
- Monthly sample analysis;
- Storm event discrete sample analysis;
- Storm event composite sample analysis;
- Storm event discrete sample analysis results against event parameters;
- Storm event composite analysis results against event parameters;
- Watercourse continuous water quality data for individual events.

2.6 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

3. DATA COLLECTION SITES

Monitoring sites were selected on the basis of satisfying a number of predetermined criteria listed in the project specification. These criteria related to the type of highway, treatment devices and suitability of the receiving waters.

The following site descriptions give a summary of site characteristics. Full details are given in the individual site reports.

3.1 Site 1 M4/Brinkworth Brook - NGR SU 03758320

The first monitoring site was selected as a control site monitoring untreated runoff. This was on the M4 in Wiltshire 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.

The M4, London to South Wales motorway, was constructed in 1969 with 3 lanes per carriageway. Wearing course is hot rolled asphalt (non porous). Traffic density is in the range of 62,230 to 79,433 vehicles per day (two way). Heavy Goods Vehicles (HGV) component is 18%.

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. The drainage system installed at the monitoring site 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.

The course of the study reach of Brinkworth Brook was deepened and re-profiled 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 top width closing to a dry weather flow 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.

A Q 95%ile exceedence flow of 0.154 m^3/s (154l/s) and a Q 5%ile exceedence flow of 2.390 m^3/s (2390l/s) were recorded during the monitoring period.

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.

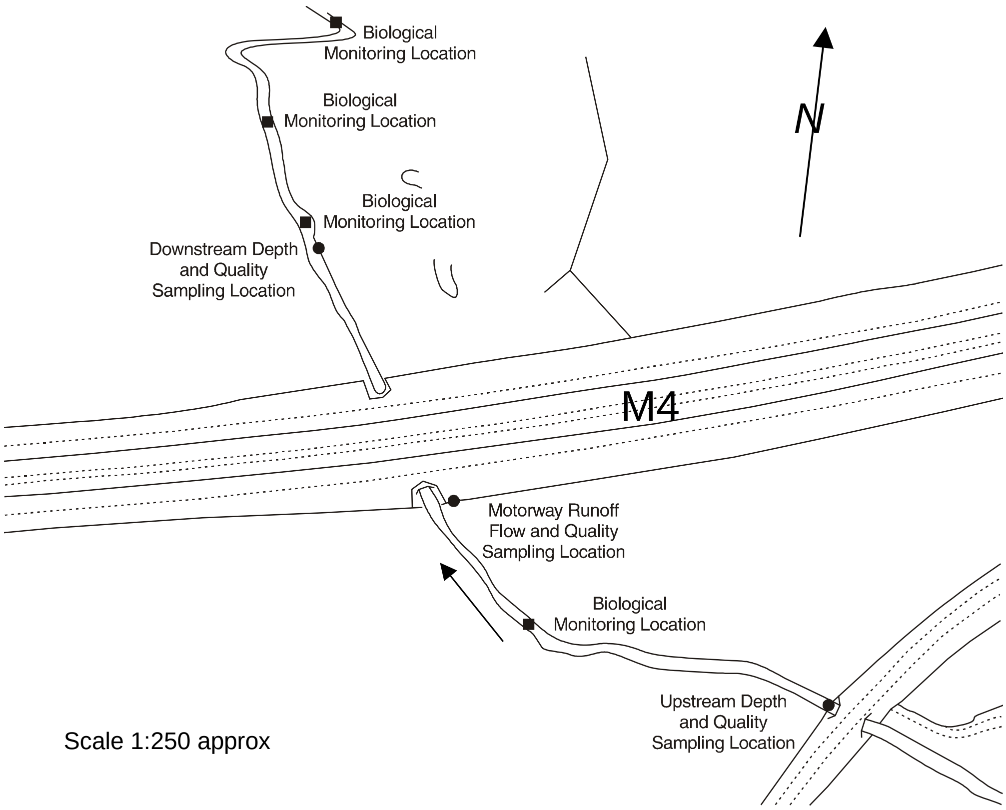


Figure 3-1 Schematic of study reach and monitoring locations – M4/Brinkworth Brook

Biological surveys were carried out at one upstream and 3 downstream locations in December 1997, June 1998 and September 1998.
The measured rainfall during the survey period was 949.7mm, c.33% above the annual average. 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 16.0mm and 13.4mm, followed 96mm of rainfall in 7 days. This resulted in a 10 day period (8th to 18th May 1998) 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.

The sampling equipment was deployed on 19 occasions, of which on 9 occasions the sampling was abandoned due to insufficient highway runoff. 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. Maximum sampled flows were 50mm deep with a discharge of 17.9l/s. During the summer months it was noted that highway runoff was lost to ground via cracks in the clay invert of the carrier ditch.

3.2 Site 2 A417/River Frome - NGR SO 94951315

The second monitoring site was on the A417 immediately south of the Cowley roundabout. Highway runoff discharge is to the River Frome.

The A417, Cirencester Bypass, is a dual carriageway constructed in 1998 with 2 lanes per carriageway. The wearing course is of hot rolled asphalt (non-porous) as laid on construction. Traffic density is in the range of 20,890 to 26,323 vehicles per day (two way). HGV component is 14%. The surface run-off collects in an in-situ formed concrete channel that is located either on the margin of the carriageway or in the central reserve depending on the camber of the road surface. The runoff migrates along the concrete channel and discharges to a piped drainage system via on line trapped gullies, installed at 50m intervals. The carrier drain discharges via a bypass separator and dry balancing pond from where the discharge is throttled and piped for a distance of c600m outfalling to a small spring fed ditch, which in turn discharges to the River Frome at Brimpsfield Park.

The study reach of the River Frome runs through a steep sided, wooded valley. The channel is incised and flow varies in depth during dry weather with riffles c.20 mm deep to pools c.500 mm deep. Width of the channel varies from 0.80 to 1.85 m. The substrate varies with sections of clay, calcified bed and sections of gravel overlying a soft substrate.

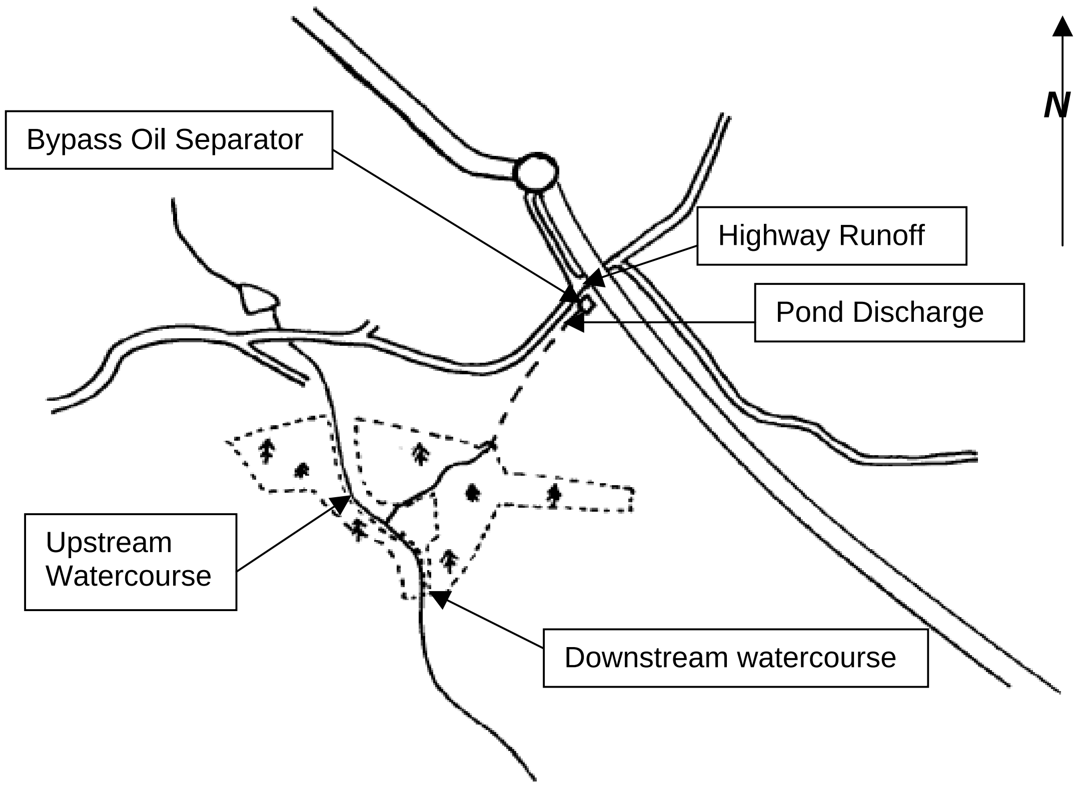


Figure 3-2 Schematic of study reach and monitoring locations – A417/River Frome

Installation of the continuous monitoring equipment was completed on 19 June 1998. Two depth and velocity monitors were installed in the River Frome, upstream and downstream of the highway drainage input. A single depth and velocity monitor was installed downstream of the confluence of the highway runoff system immediately upstream of the oil separator and a raingauge was installed adjacent to the catchment. Automatic water samplers and water quality sondes were deployed immediately prior to storm event sampling and monthly sampling where applicable.

Biological sampling was undertaken at four locations: one location upstream of the discharge, two downstream and one in the treated runoff ditch. Sampling was undertaken on three occasions: June 1998, September 1998 and January 1999.

A total of 986.4 mm of rainfall was recorded during the 13 month monitoring period. For the 12 month period from the commencement of the monitoring a total of 909.7mm were recorded, this compares with an annual average rainfall of 920mm.

An event on 24 October 1998, 16.8mm in 3 hours 44 minutes with a return period of 1:6 years, was observed but not monitored. This event resulted in the flushing of sediment through the oil separator into the balancing pond. Measured depth of water in the balancing pond reached 1.0m.

Another event in May 1999, an event with a return period of 1:1 year, 23.7mm in 1 hour 56minutes, resulted in the scouring of the stream bed at the upstream watercourse site, reducing the bed level by c.150mm.

A Q 95%ile exceedence flow is not appropriate as flows were below reliably measurable levels for long periods between July and October 1998. A Q 5%ile exceedence flow of 0.021 m^3/s (21l/s) was recorded during the monitoring period.

During the majority of rainfall events, strong flow responses were recorded subject to antecedent dry period. Depths of flow were typically 80-90 mm with a peak flow depth of 193 mm giving a discharge of 82 l/s.

The equipment was deployed on 22 occasions, of which on 12 occasions the sampling was abandoned due to insufficient rainfall and equipment failures.

No storm event sampling was attempted due to large background groundwater flows between the end of October 1998 and the end of January 1999.

3.3 Site 3 M4/River Ray - NGR SU 15428190

The third monitoring site was on the M4 to the west of junction 15 in Wiltshire where discharge of the surface drainage is to the River Ray, a tributary of the River Thames.

The section of motorway selected is between junctions 15 and 16, immediately east of the A4361 overbridge. As site 1, this section of the M4 was constructed in 1969 with 3 lanes per carriageway, hot rolled asphalt. Traffic density is in the range of 59744 to 82402 vehicles per day (two way). The drainage system discharges via a manhole, (modified for the purposes of this project to an oil trap manhole) to an existing sedimentation tank installed at the time of motorway construction. The tank then discharges over a weir to the River Ray.

The drainage system is as installed but with gully chambers, offline to the concrete drainage channel, retrofitted at 40 to 60 m intervals. The gully chambers are 1m diameter, online to the 300 mm carrier drain with a 300mm deep sump. A short length of 375 mm carrier drain passes down the embankment discharging the highway runoff to the oil trap and sedimentation tank.

The River Ray rises from a manmade lake, Coate Water. The outfall from Coate Water flows west approximately parallel to the motorway, crossing the motorway once. The Swinbourne tributary also crosses the motorway and at each crossing highway drainage discharges to the watercourse. A number of additional tributaries contribute flows along its length from Coate Water to the monitored section. Immediately downstream of the monitoring site, which is located on the southern side of the motorway, the River Ray crosses the highway and flows in a northerly direction, to the west of Swindon and joins the River Thames at Cricklade.

A Q 95%ile exceedence flow of 7734 m^3/day (89.5 l/s) was recorded at the site during the monitoring period and a Q 5%ile exceedence flow is not presented as flows were less than 0.5l/s for c.30% of the monitoring period. Depth of flow during dry weather is between 5 mm/no flow in summer and 80 mm to 140 mm in winter.

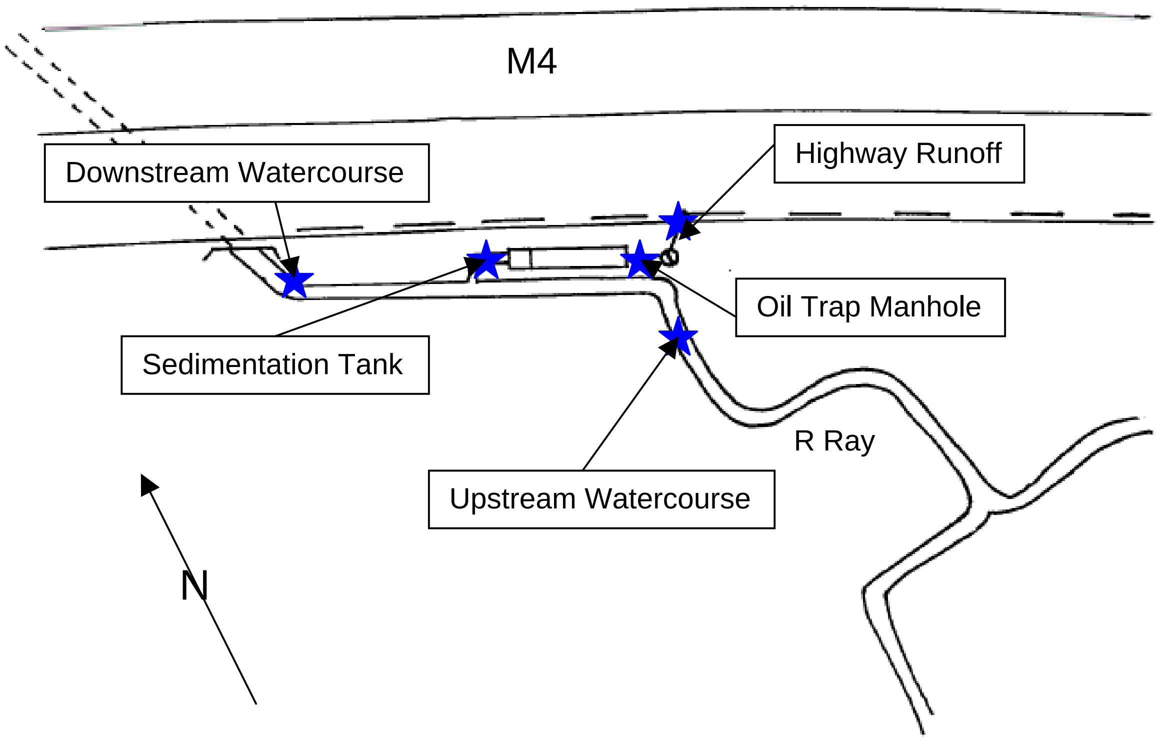


Figure 3-3 Schematic of study reach and monitoring locations – M4/River Ray

Installation of the continuous monitoring equipment was completed on 29 January 1999. Two depth and velocity monitors were installed in the River Ray, upstream and downstream of the highway drainage input, a single depth and velocity monitor was installed immediately upstream of the oil trap manhole and a rain gauge was installed adjacent to the catchment.

Automatic water samplers and water quality sondes were deployed immediately prior to storm event sampling and monthly sampling where applicable.

Biological surveys were carried out at two locations: one location upstream of the discharge and one downstream. The sampling sites were chosen to be as similar as possible with the stream bed at each location consisting of variable amounts of coarse gravel overlying a soft substrate. Sampling was undertaken on three occasions: January 1999, August 1999 and January 2000.

A total of 764.6 mm of rainfall was recorded during the 13.5 month monitoring period. For the 12 month period from the commencement of the monitoring a total of 679.8mm were recorded, this compares with an annual average rainfall of 725 mm.

The equipment was deployed on 31 occasions, of which on 15 occasions the sampling was abandoned due to insufficient highway runoff and on 6 occasions due to equipment failure.

During the majority of rainfall events, small but well defined flow responses were recorded with a minimum of 1.3 mm rainfall required to generate sufficient runoff to sample during wet periods and up to 5.8 mm rainfall required to generate sufficient runoff to sample during summer conditions. Depths of flow were typically 20-50 mm with discharges of c.0.4 to 5.0 l/s.

3.4 Site 4 M40/Souldern Brook - NGR SU 50903065

The fourth monitoring site on the M40, between junctions 10 and 11, discharged to Souldern Brook in the Cherwell Valley. Surface runoff from the carriageway passes through a full retention oil trap to a large balancing pond. The pond discharges via a throttled outlet to Souldern Brook.

The M40, Oxford to Birmingham section of motorway, was constructed in 1991 with 3 lanes per carriageway. Wearing course is hot rolled asphalt, laid in 1990. Traffic density is in the range of 71870 to 87348 vehicles per day (two way) with 18 % HGV.

On the monitored section of motorway, the drainage arrangements installed are for surface run-off to pass from the paved surface to open ditches along the downslope side of the carriageway. In the central reserve and cut section of highway at the southern end of the catchment runoff is to filter drains which in turn discharge either to carrier drains or the open ditches which in turn discharge to Souldern Brook via a full retention oil separator and wet balancing pond.

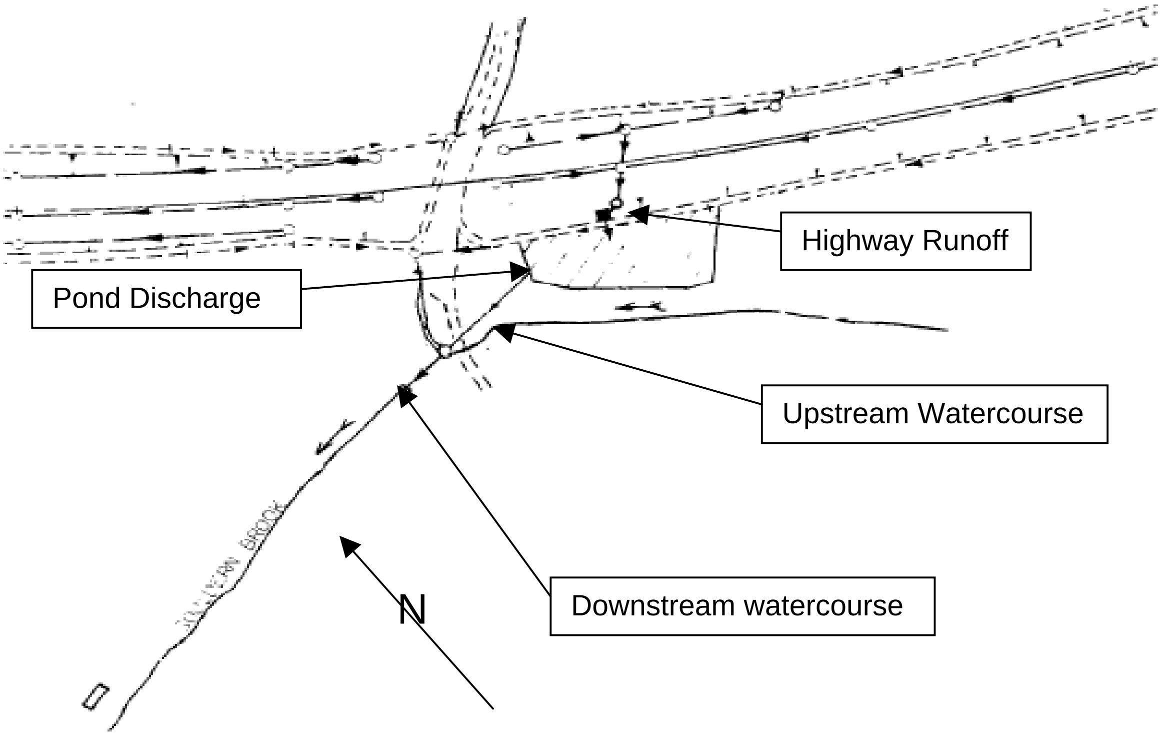


Figure 3-4 Schematic of study reach and monitoring locations – M40/Souldern Brook

Souldern Brook originally discharged to the River Cherwell but the flows were diverted to charge the Oxford canal. It rises c.1km to the north of the upstream monitoring site at a series of springs. The watercourse is unfenced for the first 400m and is trodden by agricultural stock. The 600m section of watercourse immediately upstream of the upstream monitoring location is fenced and shaded by dense hedgerow bushes and willows. Mature hedgerow bushes also shade the section of brook downstream of the downstream monitoring location but the channel is incised and better defined. A 20m section of the brook is culverted at the Holtage Lane crossing.

A Q 95%ile exceedence flow of 0.0005 m^3/s (0.5l/s) and a Q 5%ile exceedence flow of 0.0059 m^3/s (5.9l/s) was recorded during the monitoring period.

Installation of the continuous monitoring equipment was completed on 4 August 1999. Two depth and velocity monitors were installed in a culverted section of Souldern Brook, upstream and downstream of the highway drainage input. A single depth and velocity monitor was installed downstream of the confluence of the highway runoff system immediately upstream of the oil separator and a rain gauge was installed within the balancing pond compound. Automatic water samplers and water quality sondes were deployed permanently throughout the monitoring period and a system was developed to remotely monitor the highway drainage operation and initiate sampling when suitable events were forecast.

Biological surveys were carried out at one upstream and 3 downstream locations where the stream bed at each site consisted of variable amounts of coarse gravel overlying a soft substrate. Sampling was undertaken at the four sites on three occasions: September 1999, December 1999 and July 2000.

A total of 1074.3 mm of rainfall was recorded during the 15 month monitoring period. For the 12 month period from the commencement of the monitoring a total of 831.7mm were recorded, this compares with an annual average rainfall of 920mm.

The equipment was deployed on 18 occasions. Flow responses were recorded with as little as 0.4mm rainfall but an average of 1.8mm rainfall generated runoff subject to antecedent dry period and rainfall intensity. Depths of flow were in the range 65 to 240 mm with discharges in the range 2.8 l/s to 80.0 l/s.

3.5 Site 5 A34/Gallos Brook - NGR SP 53131710

The fifth monitoring site was on the A34 approximately 1 mile south of the junction with the M40, junction 9, at the Family Farm Services area near Weston on the Green. This section of highway was constructed in 1990 as part of the Pear Tree Hill to Wendlebury improvement scheme and is two lanes per carriageway with a concrete surface. Traffic density is in the range of 58460 – 69461 vehicles per day (two way) and HGV is 13%.

Drainage is largely by filter drains on either side of the carriageway with some sections, notably adjacent to service areas, junctions etc., drained via gully pots and piped carrier drains.

This site was selected as a suitable site to monitor filter drainage as it was possible to modify the gully drainage on an adjacent section of highway to provide non-attenuated flow measurement and untreated runoff quality. This permitted a direct comparison to be made with the filter drain discharge, therefore, enabling treatment efficiency to be assessed.

Gallos Brook rises c.10km north of the upstream monitoring location at Upper Heyford. It crosses a rural catchment with a glacial gravel and clay geology. Small tributaries from similar catchments join along its length.

At the time of construction of the A34, the brook was diverted so as to flow along the north side of the highway in a southerly direction. Approximately 290m downstream of the diversion there is a confluence with Gallos Brook West. The combined brooks are culverted under the A34 and flow south to the River Ray c. 1.5km upstream of its confluence of the with the River Cherwell and subsequently to the River Thames.

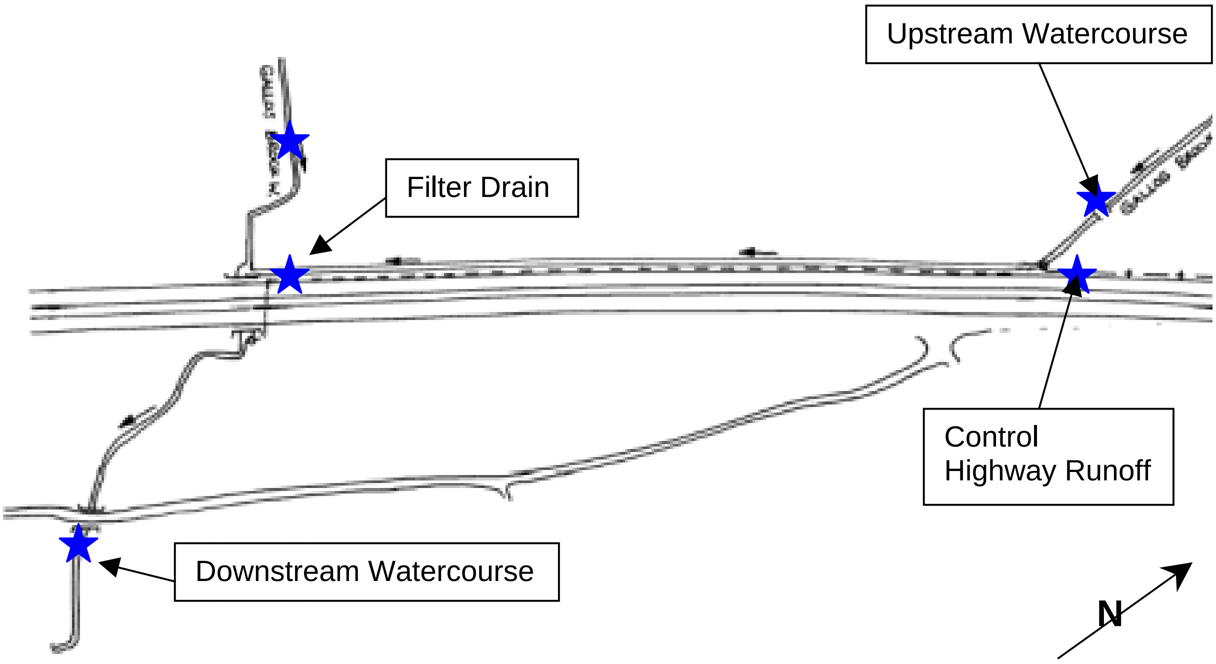


Figure 3-5 Schematic of study reach and monitoring locations – A34/Gallos Brook

A Q 95%ile exceedence flow of 0.0097 m^3/s (9.7l/s) and a Q 5%ile exceedence flow of 0.365 m^3/s (365l/s) were recorded during the monitoring period.

Installation of the continuous monitoring equipment was completed on 8 May 2000. However, due to a series of equipment failures and incomplete data sets, the official start date of monitoring was taken from 7 September 2000. Two depth and velocity monitors were installed in Gallos Brook upstream and downstream of the highway drainage inputs. A depth and velocity monitor was installed immediately upstream of the outfall of the piped system discharging untreated runoff and a second depth and velocity monitor was installed immediately upstream of the outfall of a section of filter drainage system.

A rain gauge was installed within the catchment adjacent to the highway. Automatic water samplers and water quality sondes were deployed permanently throughout the monitoring period and a system to remotely monitor the highway drainage operation and initiate sampling when suitable events were forecast was employed.

Biological sampling was undertaken at four locations: one upstream of the discharge on Gallos Brook, one on West Brook, a tributary of Gallos Brook, and two 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 on three occasions: May 2000, October 2000 and February 2001. Two sets of downstream sites were sampled. In May 2000, the two downstream sites were located 15m and 100m downstream of the highway. After this sampling exercise, it was discovered that under wet conditions highway runoff by-passed these sites via an otherwise dry ditch. Consequently, the downstream sites were relocated to just below the confluence of the ditch and Gallos Brook and 200m further downstream for subsequent sampling occasions.

A total of 1266.4 mm of rainfall was recorded during the 19 month monitoring period. A total of 892.0mm were recorded for the 12 month period from the commencement of the monitoring. This compares with an annual average rainfall of 650mm.

The equipment was deployed on 35 occasions, of which sampling was abandoned on 17 occasions due to equipment failure and on 8 occasions due to insufficient rainfall response in the filter drain.

Depths of flow at the direct runoff monitoring location were in the range 40 to 120mm with discharges in the range 0.8 l/s to 27.0 l/s.

Flows monitored at the filter drain location were typically attenuated and during all events little flow occurred during the initial response period as compared to the direct runoff location. Recorded flows were in the range 12 to 65mm deep with discharges in the range 0.1 l/s to 7.0 l/s. During the summer months many short duration events where runoff was observed at the direct runoff location did not generate any measurable flow in the filter drain. This is believed to be due to surface wetting of the filter medium and attenuation of the flows. One short duration high intensity summer event of this nature was monitored in July 2001. A second event showing this pattern was monitored during January 2002 following 4 weeks without significant rainfall.

No storm event sampling was attempted between the 4 December 2000 and 25 January 2001, 27 October to 1 November and 5 to 8 December 2001 due to backup of the watercourse into the direct runoff (untreated) monitoring location.

3.6 <u>Site 6 A34/Newbury Bypass (Pond D) - NGR SP 44406365</u>

The sixth monitoring site was on the A34 Newbury bypass. Runoff from the section of highway north of the River Enborne overbridge, at the southern end of the Newbury bypass, discharges via a culverted section of a small watercourse to the River Enborne, a tributary of the Kennet.

The A34 Newbury Bypass was constructed in 1997 with 2 lanes per carriageway and with a porous asphalt surface. Traffic density is in the range of 31374 to 41727 vehicles per day (two way).

Highway runoff passes through porous tarmac, discharging to channels running along the downslope side of the carriageway. These discharge via channel outlets to a carrier drain that in turn discharges to the treatment facilities. Treatment is provided by a bypass interceptor and a wet balancing pond planted with reeds (Pond D). The pond discharges via a throttled outlet to a small culverted watercourse, to the River Enborne.

Biological surveys to determine the effect of the highway runoff on the invertebrate populations of the receiving watercourse have been carried out at the previous five monitoring sites of this study. However at this site the immediate receiving watercourse has been culverted and the discharge of the culvert is to a watercourse where other factors would have an impact on the biology. Therefore, it was considered that a biological survey was inappropriate.

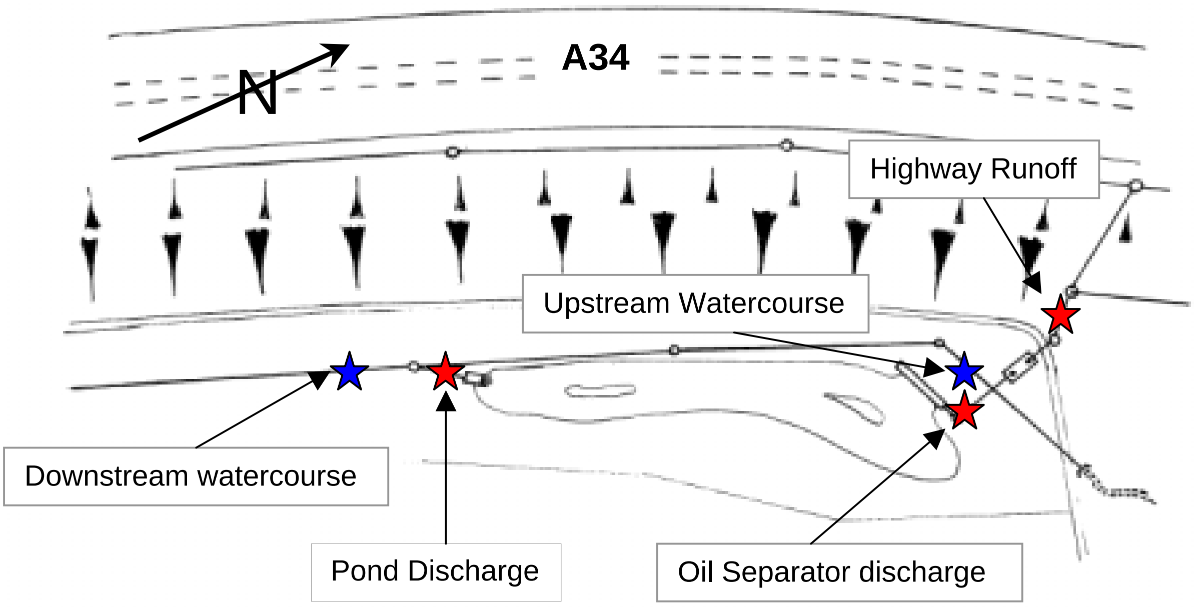


Figure 3-6 Schematic of monitoring locations – A34/Newbury Bypass Pond D

Installation of the continuous monitoring equipment was completed on 17 May 2001. Two depth and velocity monitors were installed in a culverted section of the unnamed culverted watercourse, upstream and downstream of the highway drainage input. A single depth and velocity monitor was installed to monitor the highway runoff immediately upstream of the oil separator and a raingauge was installed in a compound immediately to the west of the highway. Automatic water samplers and water quality sondes were deployed permanently throughout the monitoring period and a system was employed to remotely monitor the highway drainage operation and initiate sampling when suitable events were forecast.

A total of 826.5 mm of rainfall was recorded during the 13 month monitoring period. For the 12 month period from the commencement of the monitoring a total of 722.2mm were recorded, this compares with an annual average rainfall of 770mm.

Within the culverted section flows were below measurable levels for 18 May to 7 October with the exception of brief rainfall responses on 8 occasions.

The equipment was deployed on 15 occasions, of which sampling was abandoned on 2 occasions due to equipment failure and on 3 occasions due to insufficient rain.

Flow responses were recorded with as little as 0.6mm rainfall in February 2002 but an average of 2.2mm rainfall generated runoff subject to antecedent dry period and rainfall intensity. Depths of flow were in the range 75 mm to 309 mm with discharges in the range 6.5 l/s to 68.0 l/s.

No storm event sampling was attempted between the 25 October and 15 November, 5 and 10 December 2001 and 3 and 18 February 2002 due to large groundwater background flows.

Runoff flows were monitored immediately upstream of the oil separator. During the monitoring period backwater effects were observed at relatively low depth of flow in the 675mm pipe. It was noted that the threshold level of backwater varied between 120 and 250mm and was thought possibly due to floating debris within the oil separator. The effect on through flow varied, during Event 10 flows were maintained at 30l/s during the backwater period but during Event 5 flows rose to 60 l/s before being reduced to 10l/s 1 hour after the initial response.

4. SITE RESULTS

Runoff Quality - Site Results

An analysis of discrete and composite sample analysis results has been undertaken on the completion of the monitoring.

The following Tables have been produced for analysis of individual site results as listed below and can be located in the relevant referenced documents that make up this final report:

Table 4-1 Site analysis data sources

Table	Contents	
Flow proportional composite sample concentrations	Analysis results for each event at each location for each site	Section 5, Site reports
Composite sample event load	Analysis results for each event at each location for each site	Section 5, Site reports
Composite sample event load/1000m^2	Analysis results for each event at each location for each site	Section 5, Site reports
Event Mean concentrations	Minimum, Maximum and Average concentrations at each location for each site	Appendix C
Sediment sample analysis results	Analysis results for initial and final samples at each location at each site	Section 4, Site reports
Particle size distribution	Results for initial and final samples at each location at each site	Section 4, Site reports
Comparison of Runoff Quality with Standards	Comparison of Maximum and average concentrations against EQS and DWS.	Appendix D
Treatment Device Reduction Efficiency-Liquids	Comparison of treatment efficiency between devices	Appendix E
Treatment Device Reduction Efficiency-Sediments	Comparison of treatment efficiency between devices	Appendix H

4.1 Highway Runoff Quality - Concentrations

All determinands (with the exception of Amitrole) were detected at least at 1 site, or location within a site, during a monitored event. However a number of determinands were only detected at a singe location on a limited number of occasions. The following observations are made with reference to the Flow Proportional Composite Sample Concentrations and Event Mean Concentration Tables.

A strong correlation exists between concentrations of metals and PAHs at all sites.

4.1.1 Metals

Platinum (LOD 0.15 µg/l) was detected only at the M4/Brinkworth Brook site, on two occasions and at a concentration of 120µg/l. Both events were in the same month.

Palladium (LOD 0.5 µg/l) was detected at five sites during 4 events or less, at an average concentration of 0.43µg/l and not detected at the A34/Newbury site.

Cadmium (LOD 0.001 µg/l l) was detected during the majority of events at all sites but at an average concentration of 0.47µg/l l.

Aluminium (LOD 0.4 µg/l) was detected at all sites with elevated levels following application of roadsalt to the highway. The analytical method used will have released naturally occurring Aluminium from the particulate component of the sample to give a measure of total rather than soluble reactive Aluminium. Application of roadsalt containing impurities and the increased level of sediments on the highway during the winter months increased the amount of total Aluminium detected in the runoff. The draft EQS for Aluminium relates to soluble reactive Aluminium not total Aluminium.

4.1.2 Herbicides

Amitrole (LOD 0.1 µg/l) was not detected.

Diuron (LOD 0.01 µg/l) was detected only at the A417/River Frome site during two events at an average concentration of 0.33µg/l l.

Bromacil (LOD 0.02 µg/l) was not detected at 4 sites and detected at the M4/River Ray site on only 2 occasions. Both occasions were events in February, 5 days apart.

Glyphosate was detected on up to 5 occasions at all sites, apart from the A34/Newbury site where Glyphosate was not detected.

The detection of Herbicides was directly related to application along the highway in the majority of instances and in most cases was detected only in the event monitored immediately following the application. However at the M40/Souldern Brook site a series of 4 events were monitored in the 4 weeks following application of a weak solution of Glyphosate to the hard shoulder and central reserve. The analysis identified the persistence of the herbicide in the runoff over the following month. Event dates and concentrations are given below.

Table 4-2 M40/Souldern Brook Glyphosate concentrations - October 2000 events

Event date	Event mean runoff Concentration
25-30 September 2000	Glyphosate application
1 October 2000	17.5 µg/l
5 October 2000	11.0 µg/l
10 October 2000	5.8 µg/l
20 October 2000	3.0 ug/l

High values (max 0.18 µg/l) for Atrazine, Glyphosate and Simazine were detected during 3 events at the M4/Brinkworth Brook site are unrelated to application on the highway. The events were coincidental with summer sampling. A possible explanation is wash-off of herbicides from surrounding agricultural land during flooding in May.

4.1.3 PAHs

All PAHs (LOD 0.01-0.05 µg/l) were detected at all sites with the exception of Napthalene and Acenapthalene at the A34/Newbury site. Average concentrations for all sites are at or below 0.15 µg/l. The highest average concentration of any PAH for a single site is 0.24 µg/l.

The analysis of detected PAHs identified a approximate grouping of light PAHs, Naphalene through to Pyrene, and the heavier group, Benzo(a)anthracene through to Benzo(g,h,I)perylene. The heavier PAH group correspond approximately to the Key PAH determinands, as described in Section 4.4.

4.1.4 MTBE

MTBE analysis was added to the suite of determinands to identify the presence and concentrations in highway runoff. The analytical method used was MTBE Analysis by purge and trap GCMS, method reference OA112. This analysis was carried out at the M40/Souldern Brook site only.

MTBE was not detected, to an LOD of 0.2µg/l, during all events monitored with the exception of a concentration of 2.1µg/l detected during the first event on 5 November 1999. Enquiries did not identify any incident that may have been the source.

4.1.5 BOD, COD, NH4-N, TSS

Average BOD concentrations at all sites are in the range 5.3 to 9.1mg/l. The highest individual event average value was 31.3mg/l. This was over twice any other event average and corresponded to the longest ADP of all monitored events. However other peak values did not consistently correspond with long ADP.

4.2 Comparison with the Design Manual for Roads and Bridges

Comparison with the ranges of pollutant levels for rural roads as listed in Table 5 of the Design Manual for Roads and Bridges, Volume 11, Section 3, Part 10, Water Quality and Drainage (DMRB), is limited to 5 determinands. In all cases the range of mean concentrations monitored during this study is greater than presented in the DMRB with the exception of Lead concentrations. This may reflect the current use of lead free fuels.

Table 4-3 compares the ranges listed in the DMRB (Colwill et al, 1984; Strecker et al, 1990) and the site mean range. Also presented are the minimum/maximum event mean concentrations range monitored during this study. The DMRB values are derived from a variety of sources and are presented for illustrative purposes. (For Rural highways the DMRB values are from analysis by Strecker et al of 31 U.S. sites with between 2 and 139 events at each site).

Table 4-3 Comparison of ranges of pollutant levels with DMRB.

Pollutant	DMRB (Rural Roads) Median EMC*	WRc Site mean range	WRc Min/Max Range EMC
Total Copper (μg/l)	10 - 50	24 – 64	<4.0 - 242
Total Zinc (μg/l)	35 - 85	53 – 222	21 - 688
Lead (μg/l)	24 – 272	4 – 45	0.2 - 178
COD (mg/l)	28 – 85	70 – 138	28 – 458
Total Suspended Solids	12 – 135	53 - 318	<1.0 - 256

* value exceeded by 10% and 90% of sites respectively

4.3 Comparison with EQS and DWS Standards

Highway runoff concentrations have been compared with Environmental Water Quality Standards (EQS) and Drinking Water Standards (DWS). Comparison has been made with Annual Average concentration (AA) or Maximum Allowable Concentration (MAC) where EQS standards are prescribed. The results of the analysis for individual sites are given in tabular format in Appendix D. A summary of all 6 sites, 60 events, is given in Table 4-4. The following observations are made with reference to these Tables.

All sites show a similar pattern of values either within or exceeding the Standards with the exception of the A34/Newbury site which shows that the majority of determinands fall within both DWS and EQS, MAC and AA standards.

Where DWS standards are specified, maximum Aluminium, Lead and Sodium concentrations and maximum concentrations of the PAHs are exceeded. Glyphosate, Simazine and Cadmium are each exceeded at a single site.

Table 4-4 Summary of Runoff Comparison with Environmental Quality Standards and Drinking Water Standards

		Overall Average	Overall Maximum	Overall Minimum			Drinking Water Standard	EQS							
					MAX	LOD	Prescribed Conc.or Values (Maximum)	Annual Average (AA) "T" value	Maximum Allowable Concentration (MAC) "T" value	Max - DWS Standard	Max - EQS (AA) Standard	Max - EQS (MAC) Standard	Average - DWS Standard	Average - EQS (AA) Standard	Average - EQS (MAC) Standard
	Units														
Copper	ug/l	41.08	242.00	0.00	242.00	4	2000		50	-1758.00		192	-1959.00		-8.92
Filtered Copper	ug/l	17.22	98.00	0.00	98.00	4		28	112		62	-22		-10.78	-94.78
Zinc	ug/l	145.30	608.00	20.50	608.00	4		125	500		563	108		15.30	-355.70
Filtered Zinc	ug/l	50.50	536.00	0.00	536.00	4									
Cadmium	ug/l	0.47	5.40	0.00	5.40	4	5	5		0.4	0.4		-4.53	-4.53	
Aluminium	ug/l	1232.02	20700.00	17.50	20700.00	40	200			20500			1032.02		
Lead	ug/l	25.66	178.00	0.00	178.00	50	25	50	75	153	128	103	0.66	-24.34	-49.34
Platinum	ug/l	24.08	120.00	0.00	120.00	0.1									
Palladium	ug/l	0.45	7.00	0.00	7.00	0.1									
Nickel	ug/l	5.92	40.00	0.00	40.00	10	20	50		20	-10		-14.08	-44.08	
Chromium	ug/l	6.66	49.90	0.00	49.90	10	50	50	75	-0.1	-0.1	-25.1	-43.34	-43.34	-68.34
Simazine	ug/l	0.12	0.90	0.00	0.90	0.02	0.1	2		0.8	-1.1		0.02	-1.88	
Amitrole	ug/l	0.18	1.00	0.00	1.00	0.1	0.1			0.9			0.08		
Glyphosate	ug/l	0.07	17.50	0.00	17.50	0.1	0.1			17.4			0.17		
Diuron	ug/l	0.33	2.02	0.00	2.02	0.01	0.1			1.92			0.23		
Bromacil	ug/l	0.03	0.20	0.00	0.20	0.02	0.1			0.1			-0.08		
Atrazine	ug/l	0.03	0.20	0.00	0.20	0.02	0.1	2		0.1	-1.8		-0.07	-1.97	
Total Herbicides	ug/l				0.00		0.5			-0.5			-0.50		
Naphthalene	ug/l	0.17	4.75	0.00	4.75	0.01-0.05		10			-5.25			-9.83	
Acenaphthylene	ug/l	0.03	0.22	0.00	0.22	0.01-0.05									
Acenaphthene	ug/l	0.03	0.31	0.00	0.31	0.01-0.05									
Fluorene	ug/l	0.03	0.26	0.00	0.26	0.01-0.05									
Phenanthrene	ug/l	0.08	0.80	0.00	0.80	0.01-0.05									
Anthracene	ug/l	0.07	0.39	0.00	0.39	0.01-0.05									
Fluoranthene	ug/l	0.16	1.40	0.00	1.40	0.01-0.05									
Pyrene	ug/l	0.13	1.30	0.00	1.30	0.01-0.05									
Benzo(a)anthracene	ug/l	0.11	1.30	0.00	1.30	0.01-0.05									
Chrysene	ug/l	0.12	1.00	0.00	1.00	0.01-0.05									
Benzo(b)fluoranthene	ug/l	0.14	1.10	0.00	1.10	0.01-0.05	0.1			1			0.04		
Benzo(k)fluoranthene	ug/l	0.08	0.70	0.00	0.70	0.01-0.05	0.1			0.6			-0.02		
Benzo(a)pyrene	ug/l	0.15	0.70	0.00	0.70	0.01-0.05	0.010			0.69			0.14		
Indeno(1,2,3	ug/l	0.09	0.90	0.00	0.90	0.01-0.05	0.1			0.8			-0.01		
Dibenzo(a,h)anth	ug/l	0.07	0.50	0.00	0.50	0.01-0.05									
Benzo(g,h,i)peryl	ug/l	0.11	0.90	0.00	0.90	0.01-0.05	0.1			0.8			0.01		
Na	mg/l	171.62	2100.00	0.00	2100.00	0.5									
Hardness	mg/l	145.03	619.00	0.00	619.00	0.5									
De-Icing Salts	mg/l	258.43	3120.00	4.40	3120.00	0.2	200			2920			58.43		
BOD	mg/l	8.29	31.27	2.10	31.27	1			3			28.27			5.29
COD	mg/l	90.16	450.00	20.23	450.00	20									
TSS	mg/l	117.13	1350.00	15.15	1350.00	1.00				25		1325.00			-8.05
NH4-N	mg/l	0.05	0.73	0.25	0.73	0.05			0.78			-0.05			-0.73
	Green – concentrations within standards														

Against EQS MAC standards, Copper, Lead, BOD and TSS exceed standards at 5 sites with Zinc exceeded at only 1 site.

All EQS Annual Average standards are met with the exception of zinc that exceeded standards at 2 sites.

4.4 Key Determinands

Of the determinands monitored a number were present at low concentrations or below the limit of detection (not detected) during a number of events and/or at a number of sites.

Other determinands were consistently detected, some at concentrations at or slightly above LODs and some at relatively consistently higher concentration levels. It is the determinands that were detected consistently at relatively high concentrations that may be considered significant as a measure of highway runoff quality.

Two criteria, frequency of occurrence and level of concentration above LOD, may be used as an initial measure of potentially significant determinands.

From the flow proportional composite sample concentration tables presented in the site reports, determinands detected in over 50% of the events with concentrations 50% above LOD are identified as potentially significant.

Table 4-5 below shows those determinands that are potentially significant and those not significant subject to these criteria.

Table 4-5 Significance of Individual Determinands

Determinand	% events detected	LOD µg/l	Average Concentration µg/l	Significant	Not Significant
Copper	100	0.3	40.35	✓	
Filtered Copper	100	0.3	17.47	✓	
Zinc	100	0.6	139.19	✓	
Filtered Zinc	100	0.6	48.70	✓	
Cadmium	100	0.001	0.47	✓	
Aluminium (Total)	100	0.4	1216.58	*	
Lead	88	0.1	24.58	✓	
Platinum	3	0.15	24.00		✖
Palladium	30	0.5	0.43		✖
Nickel	92	0.01	5.81	✓	
Chromium	90	0.3	6.55	✓	
Simazine	28	0.1	0.08		✖
Amitrole	0	0.01	0.00		✖
Glyphosate	28	0.02	0.87	✓	
Diuron	3	0.02	0.33		✖
Bromacil	7	0.1	0.04		✖
Atrazine	16	0.1	0.02		✖

Table 4-5 continued

Determinand	% events detected	LOD µg/l	Average Concentration µg/l	Significant	Not Significant
Naphthalene	55	0.01-0.05	0.13	✓	
Acenaphthylene	32	0.01-0.05	0.02		✖
Acenaphthene	28	0.01-0.05	0.03		✖
Fluorene	38	0.01-0.05	0.02		✖
Phenanthrene	63	0.01-0.05	0.07		✖
Anthracene	55	0.01-0.05	0.05		✖
Fluoranthene	73	0.01-0.05	0.15	✓	
Pyrene	75	0.01-0.05	0.15	✓	
Benzoaanthracene	67	0.01-0.05	0.11	✓	
Chrysene	70	0.01-0.05	0.11	✓	
Benzobfluoranthene	70	0.01-0.05	0.14	✓	
Benzokfluoranthene	67	0.01-0.05	0.08	✓	
Benzoapyrene	75	0.01-0.05	0.14	✓	
Indeno123cdpyrene	63	0.01-0.05	0.10	✓	
Dibenzoahanthracene	43	0.01-0.05	0.07		✖
Benzoghiperylene	50	0.01-0.05	0.09	✓	
Na mg/l	100	0.5 mg/l	171.51	✓	
Hardness mg/l	100	0.5 mg/l	148.80	✓	
De-Icing Salts mg/l	15	0.2 mg/l	258.43	✓	
BOD mg/l	100	1.0 mg/l	6.59	✓	
COD mg/l	100	20.0 mg/l	88.62	✓	
TSS mg/l	100	1.0 mg/l	114.58	✓	
NH4-N mg/l	100	0.05 mg/l	0.25	✓	

*Aluminium analysis incompatible, see Section 4.1.

In addition to its abundance in runoff, the environmental impact of the contaminant should also be taken into consideration. DWS and EQS standards have been identified as providing some measure of the polluting nature of the contaminants in highway runoff. It should be noted that DWS and EQS standards are instream maximum allowable and annual average concentrations and percentiles. Therefore, no pass/fail judgement can be made. However, these standards provide the best available measure by which the polluting nature of highway runoff may be assessed.

Table 4-6 shows a ranking of determinands where individual sample maximum concentrations exceeded standards.

Table 4-6 Ranked Frequency of Standards Exceedence

	Drinking Water Standard	EQS		
Sample Code	**Prescribed concentration or values**	**Annual Average (AA)**	**Maximum allowable Concentration (MAC)**	**No of sites where standard values were exceeded**
	(Maximum)	"I" value	"I" value	
Cr	50	50	75	0
Amitrole	0.1			0
Naphthalene		10		0
Cd	5	5		0
Ni	20	50		1
Diuron	0.1			1
Simazine	0.1	2		2
Bromacil	0.1			2
Atrazine	0.1	2		2
Cu	2000		50	4
Fil Cu		28	112	4
Pb	25	50	75	4
Glyphosate	0.1			5
Zn		125	500	5
Benzo(b)fluoranthene	0.1			5
Indeno(12 3-cd)pyrene	0.1			5
Benzo(ghi)perylene	0.1			5
Benzo(a)pyrene	0.01			5
De-Icing Salts (mg/l)	200			5
Benzo(k)fluoranthene	0.1			6
BOD (mg/l)			3	6
TSS (mg/l)			25	6

All units µg/l unless stated

Comparison of Table 4-5 and Table 4-6 show a number of determinands that are identified as both significant and highly ranked in the respective tables. These determinands are given in Table 4-7 below:

Table 4-7 Key Determinands

Key Determinands
Copper
Filtered Cu
Zinc
Lead
Glyphosate
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(123-cd)pyrene
Benzo(ghi)perylene
BOD
TSS

4.5 Road Runoff Quality Relationship with Event Characteristics

Individual event concentrations have been plotted against the following selected event characteristics. The graphical plots produced for analysis of within site results are included in Appendix I of each of the site reports:

1. antecedent dry period,
2. total rainfall,
3. duration and,
4. average rainfall intensity.

4.5.1 Antecedent Dry Period (ADP)

There was no strong trend or relationship between ADP and metals, PAH and discrete determinand concentrations at any site. Plots of individual site event composite analysis and all site discrete analysis are given in Appendices I and J.

Possible relationships were noted at the M4/River Ray and A34/Gallos Brook site with peak concentrations of metals at c.100 to 200 hrs and 50 to 75 hrs respectively with corresponding peak concentrations in PAHs. However, regression analysis of individual determinands shows a random distribution of results. Cross reference to rainfall parameters showed that the peak concentrations at the A34/Gallos Brook site corresponded with high intensity rainfall but this did not correlate at the M4/River Ray site. At this site the peak values corresponded with winter events in January and February. Figure 4-1 illustrates the possible correlation at the

M4/River Ray site and Figure 4-2 shows the more typical random distribution illustrated by the M40/Souldern Brook site.

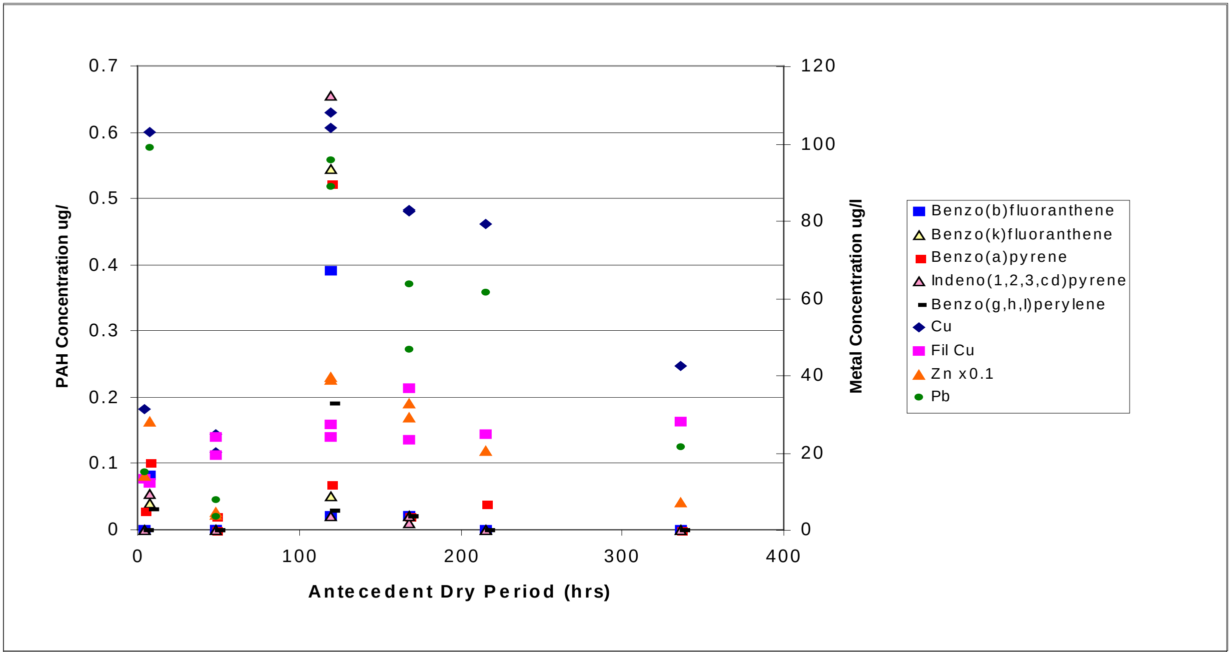


Figure 4-1 M4/River Ray Runoff Event Composite Key Determinands v ADP

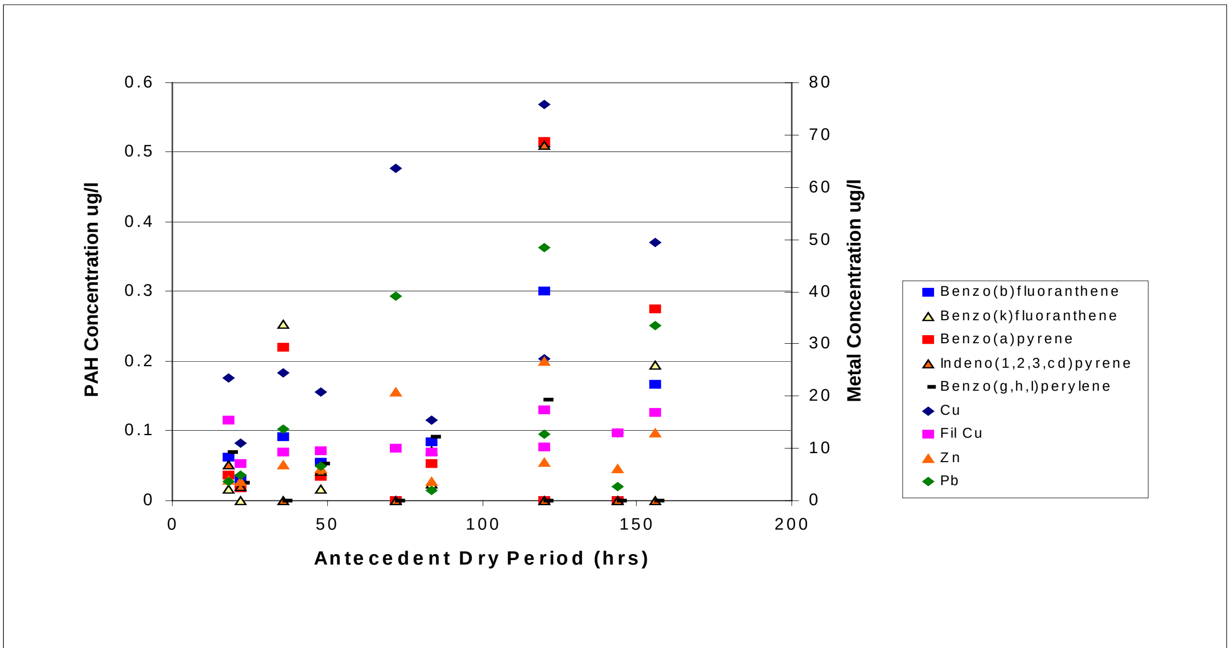


Figure 4-2 M40/Souldern Brook Runoff Event Composite Key Determinands v ADP

Peak values for Sodium and De-icing salts show no correlation between sites. Reference to event parameters at all individual sites show that although there is a superficial relationship with ADP the dry weather was due to winter high pressure and consequent cold weather. The peaks are directly correlated to the number of roadsalt applications in the ADP.

No relationship between ADP and BOD, COD, Ammonia and TSS could be identified other than a possible relationship showing higher concentrations of BOD and COD with a longer ADP at the M4/Brinkworth Brook site. Figure 4-3 and Figure 4-4 illustrate BOD and TSS average concentrations for all events respectively.

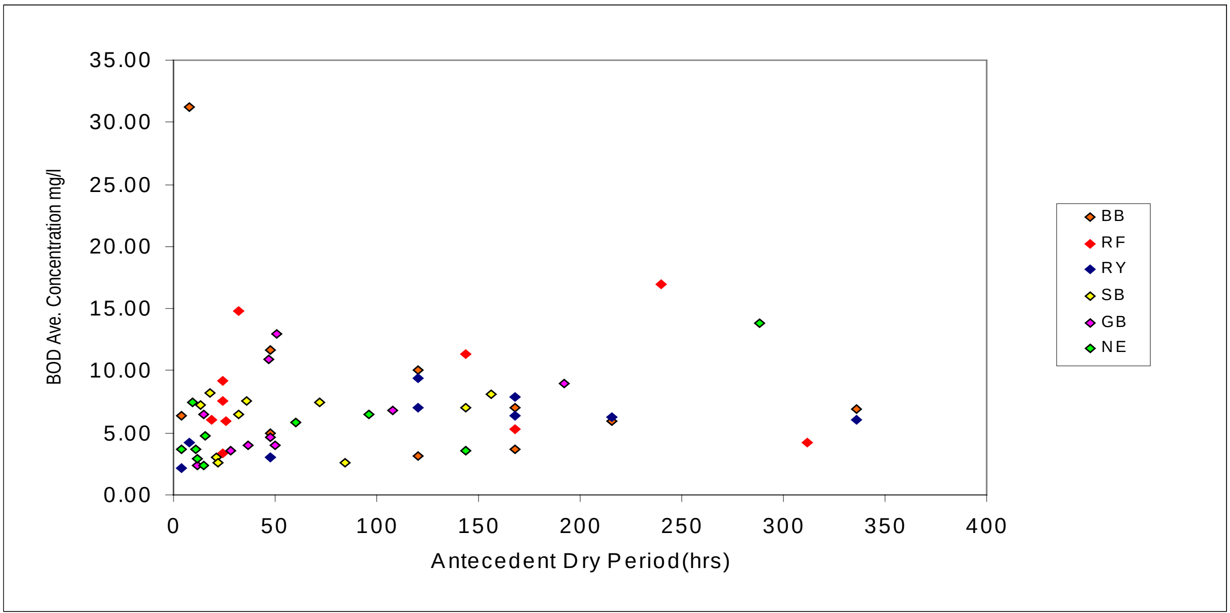


Figure 4-3 BOD v ADP – All monitored events

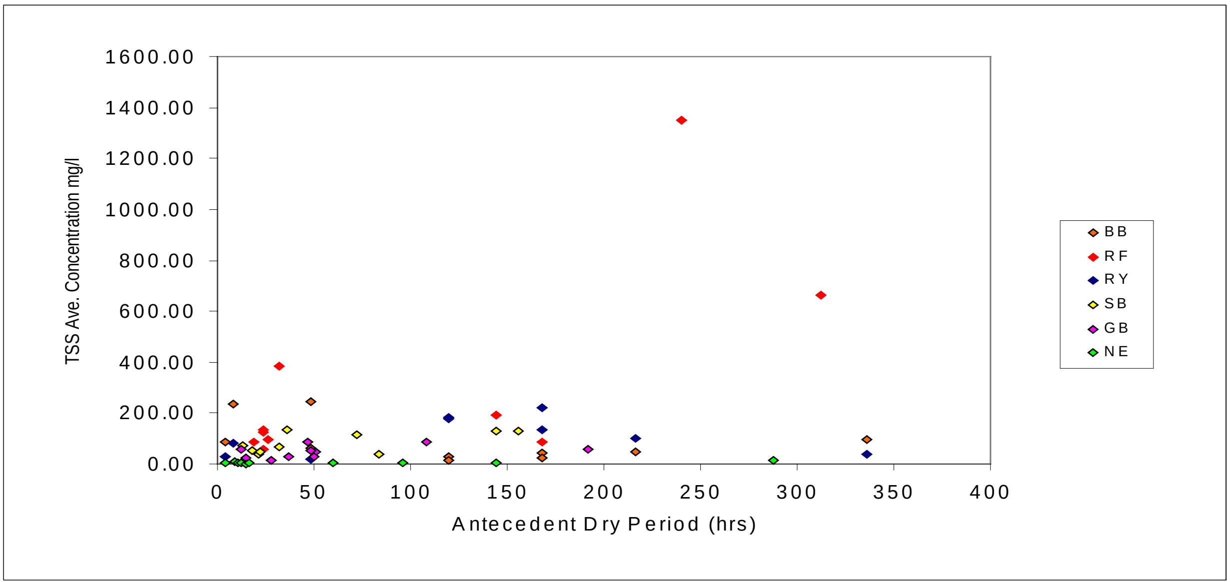


Figure 4-4 TSS v ADP – All monitored events

Examination of the relationships between event criteria and concentrations has been based on flow and rainfall data recorded from the beginning of the rainfall to the end of the sampling period only.

4.5.2 Total Rainfall

No relationship can be identified between total rainfall and runoff concentrations for any metal or PAH determinands. A peak for Aluminium (i.e. Total Aluminium) at the A417/River Frome site is coincidental with salting of the highway. An apparent trend for Na and de-icing salts at the A34/Newbury site showing a reduction in concentration with increased total rainfall is also coincidental with salting.

There was little evidence of any relationships between the discrete determinands (BOD, COD, NH_4-N, TSS) and Total rainfall.

4.5.3 Event Duration

No relationship can be identified between event duration and runoff concentrations for any determinands. There is a possible trend towards a reduction of concentration with time at the A34/Gallos Brook and A34/Newbury sites for PAHs

There is no relationship between the discrete determinands and rainfall duration. All sites showed a broad spread of data plots throughout the duration range.

4.5.4 Rainfall Intensity

A relationship is apparent between event average rainfall intensity and concentrations of metals and PAHs at all sites.

Average rainfall intensities are generally in the range 0.5 to 4.0mm/hr.

Over this range the relationship is for reduced concentrations with increased average intensity for five of the six sites. However at the A34/Newbury site the relationship is reversed with increased concentrations with increased average intensity over the same range of average intensities. The major difference in highway characteristics that distinguishes this site from the others is the porous asphalt carriageway surface and this may be a contributing factor to the different relationship.

There are possible relationships between average rainfall intensity and discrete determinands concentrations but these are not consistent between sites.

At the M4/Brinkworth Brook, A417/River Frome and A34/Gallos Brook sites the relationship is for higher concentrations associated with lower intensity rainfall (as for metals and PAHs). At the M4/River Ray and M40/Souldern Brook sites there is clustering of the data at low intensities and although generally concentrations are higher than at higher intensity rainfall, no reliable relationship can be inferred. At the A34/Newbury site there is a broad spread of data plots throughout the rainfall intensity range and no relationship can be identified.

4.6 Seasonal Relationships

A selection of the key determinands for each event has been plotted in chronological order for each site. These plots are presented in Appendix F.

A strong seasonal relationship with peak concentrations in key determinands during the winter months of February and March is noted at the M4/Brinkworth Brook and M4/River Ray sites.

The relationship is less well defined at the A417/River Frome site but this may be due in part to the distribution of events not representing the potential peak concentration period. (Limited winter sampling was undertaken due to high groundwater flows).

The M40/Souldern Brook and A34/Gallos Brook also show a relationship with peak values in December and January but the A34/Newbury site shows no seasonal relationship.

4.7 Treatment Efficiency

To assess the treatment efficiency of the individual devices and combinations of devices, tables showing average actual reduction in determinand concentrations and average percentage reduction in the liquid samples have been included in Appendix E.

These compare concentrations upstream and downstream of each device and reduction from highway runoff to discharge to watercourse. Negative values indicate an increase in concentration.

It should be noted that due to the low concentrations detected, some high percentage reductions or increases quoted may represent very small absolute differences in concentrations. Examination of the percentage reduction should, therefore, be referenced to the actual reduction.

The following comments are based on average reduction of all events at each site.

4.7.1 Bypass Oil Separator

Two bypass oil separators were monitored during the study. Both are to current standards and have been installed within 3 years of the monitoring.

The separator installed at the A417/River Frome site was a pre-cast GRP unit manufactured by Conder Limited of Hampshire. The separator was designed for a maximum drainage area of 25200 m^2 with a flow rate of 350 l/s, intercepting the first 10% of the flow, bypassing 90%.

The second at the A34/Newbury site was a pre-cast GRP unit manufactured by Klargester Environmental Engineering Limited of Aylesbury, Bucks. This separator is designed for a maximum drainage area of 31000m^2 with a peak flow rate of 550l/s. Full treatment is provided to 10% of the peak flow capacity, bypassing 90%.

The design performance of both separators is based on the requirements of prEN 858-1 1992 for class 2 separators where the residual oil at the outlet is less than 100 mg/l for the design event. The results indicate a similar performance for both separators with average residual oil at the outlet of 0.0017mg/l and 0.0013mg/l for monitored events at the A417/River Frome and A34/Newbury sites respectively. However it should be noted that total oils input concentration to the respective separators is 0.002mg/l and 0.0013mg/l, indicating little net benefit at these relatively low concentrations.

There is a beneficial reduction in metals of between 3.0% and 30% for both separators. A general but variable reduction is noted for the lighter PAHs but reduction of the heavier PAHs is ill defined, with a number of values indicating an increase below the separator.

Actual reduction of PAHs is at or below the determinand LODs.

Values for TSS show an average reduction of 56% and 37% through the separator at the A417/River Frome and A34/Newbury sites respectively.

4.7.2 Oil Trap Manhole

The oil trap manhole, constructed for the purposes of this study, was monitored at the M4/River Ray site. The oil trap was cleaned prior to monitoring.

There appears to be no beneficial reduction of any contaminants. This is consistent with observations of little accumulation of oils in the trap for the duration of the monitoring period. On-site observations would indicate that the gradient of the incoming pipe into the oil trap manhole was too great and this created turbulence and re-mixing within the oil trap allowing any contaminants to pass through the trap with the flow.

Actual reduction of PAHs is at or below the determinand LODs.

4.7.3 Full Retention Oil Separator

The Full Retention Oil Separator was monitored at the M40/Souldern Brook site. No design performance standards are available.

Percentage reduction shows reasonable reduction in the range 2.0% to 30% for metals and 14% to 97% reduction of the light PAHs. However there is an apparent increase for all key PAH determinand concentrations indicating re-entrainment of the heavier PAHs from the oil separator. This may be due in part to different turbulence and re-mixing within the oil separator during different flow regimes caused by the steep gradient of the incoming pipe. This poor design/installation is considered to impair the performance of the oil separator at this site where the highway is on a high embankment and the drain laid on a particularly steep gradient. Comparison of the reduction between Events 2, 4 and 6 with peak flows of 2.8l/s, 17.7l/s and 31.2l/s respectively, where results are above PAH LODs, are inconclusive.

Actual reduction of PAHs is at or below the determinand LODs.

4.7.4 Filter Drain

The filter drain was monitored at the A34/Gallos Brook site. Comparison of flows measured at the control untreated runoff, location 1, and the filter drain, location 2, showed a significant attenuation of flow at the filter drain location. The filter drain is unlined and some loss of runoff to the surrounding ground is suspected.

The effectiveness of the filter drain as a treatment device has been measured against the untreated runoff monitored at the control drainage system on the adjacent section of highway. The filter drain shows a good percentage reduction of metals in the range 11% to 50% reduction. Actual reduction values are well above LODs.

The percentage reduction for the PAHs is good across the full range with reductions of 60% to 70% achieved but with actual concentration reduction at and just above LOD.

4.7.5 Sedimentation Tank

The sedimentation tank provided a second treatment at the M4/River Ray site. The capacity of the tank is 10.5m^3 and the tank was cleaned prior to monitoring.

The sedimentation tank shows reduction levels for metals in the range 13% to 64%. There are no increased values.

Values for the light PAHs are unreliable as actual reduction is below the LOD. There is marginal reduction, generally <10%, for the mid range PAHs. TSS reduction is 43%.

4.7.6 Dry Balancing Pond

The Dry Balancing Pond provided secondary treatment at the A417/River Frome site. The capacity of the pond is an estimated 1800m^3 and was in as constructed condition at commencement of monitoring. The inlet and outlet structures are on adjacent sides of the pond c.16m apart. This arrangement allowed flows to pass through the pond with little retention as the pass forward flow limit of 150l/s exceeded the maximum flow for any of the monitored events. However some retention of flow was achieved by the natural build-up of sediments on the pond floor during the course of the monitoring which resulted in a delta like flow pattern across the pond floor.

The dry balancing pond shows a good average percentage reduction of metals in the range 5.8% to 59%. Nickel showed an average increase in concentration through the balancing pond but this was due to a single event value distorting an otherwise small percentage reduction. TSS showed an increase of 37%.

PAH reduction was inconsistent across the range with actual reduction well below LOD for all PAH determinands.

4.7.7 Wet Balancing Pond

The Wet Balancing Pond provided a second form treatment at the M40/Souldern Brook site. As at the dry balancing pond site, the inlet and outlet structures are on adjacent sides of the pond c.40m apart, approximately 30% of the full length of the pond.

The percentage reduction of metals is in the range 0 to 70%. TSS reduction is 62%

PAH reduction is high with percentage reduction in the range 22% to 94%. The reduction for the light PAHs is unreliable due to the low concentrations detected but the concentrations of the key PAHs is above the LODs and consistently show reductions between 71% and 94%.

4.7.8 Wet Balancing Pond/Surface Flow Wetland

The Wet Balancing Pond with planted reeds provided a second form of treatment at the A34/Newbury site. Flows enter the pond at one end and outfall c. 120m from the inlet, requiring flow through the full length of the pond.

All monitored metals concentrations are well above LODs but the average reduction percentages for metals are inconsistent, with Zinc, Chromium and Nickel showing an increase.

A significant reduction of typically 90%+ across the range of PAHs is observed. Values for the lightest PAHs are unreliable due to the low concentrations detected or in some cases not detected.

BOD and TSS reduction were the highest for all treatment devices at 29% and 73% respectively.

4.8 Treatment Combinations

The efficiency of combinations of treatment facilities strongly reflects the performance of the second form of treatment at each site. The Actual and Percentage Difference Road Runoff and Discharge to Watercourse spreadsheet in Appendix E summarises the reduction efficiency of the treatment combinations. Although as with the reduction at individual devices there is a variability in efficiency it is notable that combinations of treatment have resulted in overall reduction for the large majority of the 39 monitored determinands. This may suggest that a second form of treatment with a different set of design characteristics compensates for the design characteristics for the other device.

4.9 Sediments

The sediments are potentially a source of significant pollution in highway runoff as it acts as a transport medium for attached metals and PAHs and organic matter. It is the fine fraction of the particle size range to which a higher proportion of pollutants attach, previous research has indicated particles of less than 63µm, and it is also the fine fraction which remains in suspension and becomes dispersed in the environment. Discharge of non-polluting sediments to the environment may also change the physical nature of a habitat resulting in changes to fauna populations.

Sediment samples were taken on two occasions at each site, at the beginning and end of the monitoring periods.

Samples were taken upstream of highway runoff treatment (location 1) and at the point of discharge from the treatment facilities (location 3) to the watercourse. Additional samples were taken between the treatment devices (location 2) at the A34/Newbury site. Sediment samples were also taken from the watercourses upstream and downstream of the highway runoff discharge to watercourse. Sampling locations are illustrated in the schematic plans for each site in Section 3.

Sediments were analysed for particle size distribution, metals, PAHs and organic matter. Limits of detection are given in Appendix A and analytical method summaries in Appendix B.

Particle size analysis is carried out to BS 1377-pt2 with results presented as % passing the specified sieve size.

The results of the sediment analysis are presented in Section 4.3 of the individual site reports. It should be noted that Aluminium values are high at all sites due to the method analysing for total Aluminium releasing naturally occurring Aluminium.

The following comments give a brief summary of the sediment results presented in the site reports.

4.9.1 M4/Brinkworth Brook

A single set of two highway sediment samples were taken, as runoff receives no treatment at this site.

There was a large difference in the particle size distribution between the initial and final samples with 10% and 53% passing 63µm in the respective samples. (This difference was also reflected in the watercourse samples and would suggest different antecedent flow conditions prior to each sampling). Platinum and Palladium were not detected. Cadmium was detected at levels close to LOD and not detected in the two samples respectively. All other metals were detected showing similar concentrations in both samples. The key PAHs are an average 50-100% higher in the initial sample. Volatile Matter (VM) is consistent at c.5%.

Watercourse sediments show similar concentrations upstream and downstream with no apparent accumulation downstream of the highway discharge. The results do show an accumulation of Cadmium of 14.7 µg/g, that is greater upstream of the highway discharge indicating another source, possibly a discharge at Wooton Basset.

4.9.2 A417/River Frome

Runoff samples were taken upstream of treatment and from the dry balancing pond outlet.

Particle size analysis showed finer particles in the samples taken at the pond outlet than from the highway sample, on the ranges 29 to 74% and 35 to 44% passing 63µm. Platinum and Palladium were not detected. Cadmium was detected at levels close to LOD. Metals concentrations were similar at the two locations in the initial samples but were higher in the untreated final sediment sample. There is some retention in the pond but this is marginal. PAHs are consistently lower in the pond samples indicating no accumulation. VM is in the range 4 to 12% and is marginally higher in the samples from upstream of treatment.

The watercourse sediments are generally finer than the runoff sediments but there are greater accumulations of fine sediments at the downstream location, upto 80% compared to 56% at the upstream site passing 63µm. The final samples are notably courser across the size range than the initial samples. This is likely to be due to a flushing of fine sediments from the watercourse by high flows observed prior to the final sediment sampling. Metals concentrations are marginally higher at the downstream location but not significantly so. The PAHs are of similar concentrations upstream and downstream for the lighter oils but the key PAHs are significantly higher, at concentrations similar to the road runoff, at the downstream location for the initial sample. The final sample shows similar concentrations up and downstream. Both sets of samples were taken at the same time of the years. A possible explanation is that a summer storm flushed sediment from the highway and through the treatment devices with little reduction of contaminants and these were identified in the initial sediments. However, no long term rainfall data is available to confirm this. The watercourse samples show VM in the range 4 to 7% at both locations with the exception of the downstream initial sample that has a VM content of 16.7%. This pattern is consistent with the concentrations of metals and PAHs as discussed above.

4.9.3 M4/River Ray

Runoff samples were taken upstream of treatment and from the sedimentation tank outlet.

Runoff particle size analysis shows an accumulation of fine particles in the sedimentation tank with c.60 to 70% passing 63µm compared with 40 to 50% upstream of treatment.

Platinum and Palladium were not detected. All other metals were detected at levels well above LOD. Similar results were recorded for both initial and final samples, the initial samples were not accumulated sediments but taken after the sedimentation tank had been cleaned. There is an accumulation of PAHs in the tank samples compared with the untreated samples with concentrations 2 to 3 times greater for the key PAHs. VM is also 2 to 3 times greater in the tank at 12 to 17%.

The watercourse shows no significant difference in particle size, metals, PAHs or VM percentage between the upstream and downstream site. This is possibly due to highway runoff inputs upstream of the upstream watercourse location masking any small effect of the monitored discharge.

4.9.4 M40/Souldern Brook

Runoff samples were taken upstream of treatment and from the wet balancing pond outlet.

Runoff particle size analysis shows a very course sediment matrix upstream of treatment, 3% and 0% passing 63µm. This is due to a steep gradient on the drainage pipe work inducing turbulence and the washing out of the fine fraction. Accumulations of fine sediments were noted in the pond outlet samples with 75 to 80% passing 63µm.

There are small accumulations of metals in the pond samples with the exception of Platinum and Palladium that were not detected and Nickel and Chromium whose concentrations are lower than in the untreated sediments. Accumulations of key PAHs in the pond outlet samples were approximately twice the concentrations recorded in the untreated sample.

Volatile material in the untreated runoff sediments reflects the low fine particle fraction with c.3% VM. The pond outlet VM of 13 to 15% is high, due in part to breakdown of pond reeds.

The watercourse sediment particle size analysis shows 22% and 10% passing 63µm in the initial and final samples at both upstream and downstream locations. There is a small accumulation of metals noted in both the downstream location samples. Cadmium concentrations are low at only 50% above LOD. PAH concentrations are similar upstream and downstream in the initial sample but shows a significant increase at the downstream location in the final sample when key PAHs are up to 100 times greater than the upstream sample.

Organic matter is between c 4 and 8% at both watercourse locations.

4.9.5 A34/Gallos Brook

Runoff samples were taken from the untreated runoff and from the filter drain.

There was a notably smaller volume of sediments in the filter drain pipe than observed in any other drainage system monitored during the study, probably due to the infiltrating mode of entry of runoff into the pipe. For the final sediment there was insufficient sample to carry out particle size analysis. The analysis carried out showed the same percentage passing 63µm at both runoff locations.

Platinum was not detected. Palladium was detected in the initial samples. The Palladium concentration was high, 78µg/g, at the direct runoff location but at a much lower concentration of 1.0µg/g, at the downstream watercourse location. These results would suggest localised contamination of the highway from an incident with subsequent wash off into the watercourse. Palladium was not detected in the final samples.

All metals concentrations were well above LOD. Concentrations in the initial sample were c.50% lower in the filter drain but concentrations were similar in the final samples.

Key PAH concentrations are up to 20 times higher in the untreated samples compared to the filter drain samples.

There is no known highway runoff discharge upstream of the upstream watercourse monitoring location and particle size analysis shows virtually no fine material with 1% and 3% passing 63µgm.

The downstream location shows a wide disparity of particle size distribution between the two samples, with 100% and 16% passing 63µm. The high percentage of fine material identified in the initial sample was largely due to a stilling effect caused by vegetation and debris in the watercourse downstream of the sampling location. During the monitoring period the watercourse was cleared and the flow regime improved. The 16% passing 63µgm is a more representative value for the downstream sediments.

The downstream site shows an accumulation of metals and PAHs but concentrations are low compared with untreated runoff concentrations but similar to concentrations in the filter drain.

It should be noted that filter drains largely drain the highway runoff contributing to the watercourse. Sections where there are no filter drains are treated by trapped gullies. The untreated runoff has been arranged for the purposed of this study and represents a small proportion of the highway contributing area.

Organic content is < 2% at the upstream site and in the range c.6 to 10% at the downstream location.

4.9.6 A34/Newbury

Runoff samples were taken upstream of treatment, from an additional location at the pond inlet silt trap and from the wet balancing pond outlet. None of the locations were cleaned prior to monitoring.

Particle size distribution shows the accumulation of fine particles in the silt trap and wet pond relative to untreated runoff. The silt trap sample shows 70 to 80% passing 63µm, the pond outlet sample shows 50 to 60% passing 63µm relative to untreated runoff sample which shows 29 to 39% passing 63µm.

Platinum was not detected. Palladium was detected in the initial samples at the untreated runoff and silt trap locations only. All other concentrations are well above LOD and concentrations are compatible between the initial and final samples.

Results show a significant trapping of both metals and PAHs in the silt trap with further trapping of metals in the pond outlet samples.

Organic content is higher in the silt trap and pond sample at c.5 to 12 % compared to 3 to 7% in the untreated runoff sediments. Observations suggest this is due in part to breakdown of pond reeds.

The watercourse samples were taken from the culverted intermittent stream into which the pond discharges. Particle size is similar at both locations, with an average of 16% passing 63µm.

Metals concentrations are high at both upstream and downstream locations and are consistent with runoff concentrations.

PAH concentrations are very high at the upstream site consistent with concentrations in the silt trap. There are no highway inputs upstream of this location and the concentrations are not repeated at the downstream location. The source of the high concentrations is unknown.

Organic content is similar at the upstream and downstream sites with VM in the range 4 to 8%.

4.10 Watercourse background monitoring

Background monitoring of the watercourses was undertaken with liquid samples and in situ readings taken at quasi-monthly intervals during the monitoring period at each site. Results for each site are presented in Appendix E of the site reports.

Table 4-8 summarises the determinands monitored and the range of concentrations detected.

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.

Table 4-8 Background watercourse monitoring sample parameters

Sample Type	Determinands	Units	Range of Detection
Liquid	Biological Oxygen Demand	mg/l O_2	<1 – 4.8
	Chemical Oxygen Demand	mg/l O_2	<10 – 103
	Ammonia	mg/l N	<0.05 – 2.97
	Total Suspended Solids	mg/l	3 - 59
	Hardness	mg/l $CaCO_3$	111 - 500
In-situ measurement	Temperature	^oC	3 - 17
	pH	units	6.4 – 9.0
	Dissolved Oxygen	mg/l O_2	6 - 14

There are some values outside these ranges but for the majority of these the cause can be identified. Total suspended solids shows a relationship with rainfall events in the period immediately preceding the sampling and some elevated NH_4-N values were associated with activities on adjacent agricultural land. For the majority of samples NH_4-N was below LOD. Hardness was similar at four of the sites, in the range 253 to 390 mg/l $CaCO_3$. The exceptions were the M40/Souldern Brook site where the range was 410 to 500, thought to be due to the proximity of the limestone spring source of the brook, and the A34/Newbury site where the range was 111 to 220.

4.11 <u>Biological surveys</u>

The full presentation of results and discussion of the biological surveys for each site are given in Section 6 of the site reports.

Biological surveys have been undertaken at five sites receiving either treated or untreated highway drainage from major roads (No survey was undertaken at the A34/Newbury site due to the culverting of the receiving watercourse). In each case, a spatial control/impact survey design has been employed with one or more control sites located upstream of the discharge and one or more impact sites downstream of the discharge. Wherever possible, sites have been located on a similar substrate within the constraints of accessibility and within the supposed zone of effect. Samples have been sorted and results presented in a standard way (BMWP, ASPT biotic scores) which allows cross-comparison between sites and sampling occasions.

Table 4-9 Summary of Biological Effects

Site	Treatment	Biological effects
Brinkworth Brook (M4)	Untreated	Small reductions in Biotic (ASPT, BMWP) scores, but not sufficiently large to discount habitat and life cycle changes
River Frome (A417)	Bypass oil separator and dry balancing pond	No differences observed, sparse fauna at headland site, either treatment adequate or runoff not a problem.
River Ray (M4)	Oil trap manhole and sedimentation tank	No differences observed, sparse fauna – either treatment adequate or runoff is not a problem
Souldern Brook (M40)	Full retention oil separator and wet balancing pond	Few differences, possible habitat changes – treatment could be adequate or runoff not a problem
Gallos Brook (A34)	Untreated and filter drain	Small reductions in Biotic (ASPT, BMWP) scores but not sufficiently large to discount habitat and life cycle changes

Results suggest that:

- Macro-invertebrate communities located below the range of treatment options available at the five sites are not affected by treated runoff.

- Macro-invertebrate communities located below discharges of untreated runoff may be marginally affected but that changes are too small draw firm conclusions. It has not been possible to eliminate the possibility that confounding effects such changes in macro-invertebrate habitat quality and life cycle induced changes in community composition are responsible for the observed changes.

The overall conclusion is that highway drainage from these five sites appears not to have adversely affected the macro-invertebrate communities in receiving waters.

5. INTER SITE COMPARISONS

The type of road and traffic regimes will influence the quantity and quality of highway runoff during rainfall events. The variable character of the rainfall events will also be a major factor influencing the runoff and it is necessary to normalise one set of variables in order to determine the relationship between highway characteristics, event variability and the consequent runoff quality and quantity.

5.1 Highway Variability

The monitoring sites have a number of variable characteristics that it is considered may influence the rate and quality of the runoff and the efficiency of the treatment devices.

Table 5-1 shows the major highway variables between the sites.

Table 5-1 Major Highway Characteristics

Site	Lanes	Total Area m^2	Trafficked Area %	AADT	Surface
M4/Brinkworth Brook	3	8610	68	71929	Asphalt
A417/River Frome	2	20234	74	23647	Asphalt
M4/River Ray	3	4133	68	36107	Asphalt
M40/Souldern Brook	3	58600	62	83579	Asphalt
A34/Gallos Brook	2	24200	77	64953	Concrete
A34/Rriver Enborne (Newbury)	2	19420	74	37192	Porous Asphalt

In addition to these major variables there are a number of possibly less significant factors that may contribute to the variability in runoff quantity and quality, as shown in Table 5-2. These include highway slope, runoff access to the drainage system, proximity of junctions and the age/condition of surface. Although the site selection process attempted to exclude these variables, in some cases it was necessary to accept certain characteristics not found at other sites. Table 5-2 shows the sites at which these variables may influence road runoff quantity and quality.

Table 5-2 Additional Highway Characteristics

Site	Significant Slope	Runoff access to drainage system (m)	Proximity of junctions (km)	Age/condition of surface (years)
M4/Brinkworth Brook	-	30	6	2
A417/River Frome	-	5	0	0.5
M4/River Ray	-	40-60	3.5	2
M40/Souldern Brook	yes	continuous	5	8
A34/Gallos Brook	-	10/continuous	0	10
A34/Rriver Enborne (Newbury)	yes	50	0.7	3

No attempt has been made to normalise data for the above characteristics but these have been taken into consideration when assessing relationships between highway characteristics/event parameters and runoff quality.

5.1.1 Catchment area

The site selection process, in order to meet drainage type criteria, resulted in the selection of sites with large differences in catchment area as illustrated by Figure 5-1

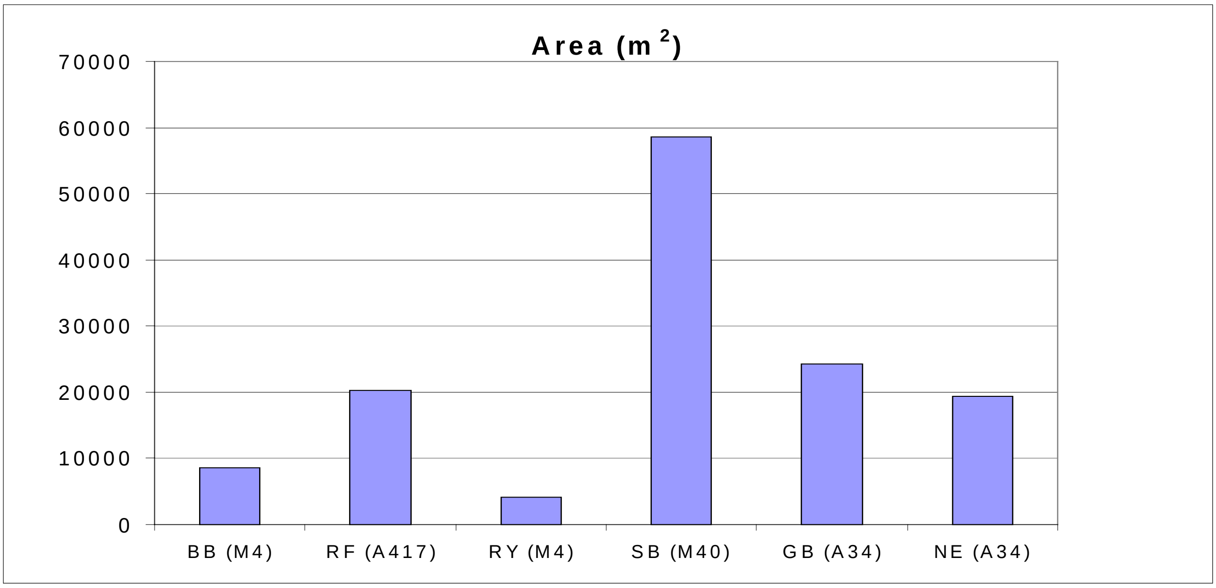


Figure 5-1 Catchment area (m^2) by site

The contributing area of each site has been factored to a unit area of $1000m^2$ to compare runoff and quality between sites. Comparison of load between sites is discussed in Section 5.3.

5.1.2 Traffic Density

Traffic density and consequently the availability of pollutants have been thought to have a large influence on the concentrations and loads recorded. Figure 5-2 and Figure 5-3 show the two way traffic density and HGV components respectively.

The three lane motorways monitored carry similar traffic flows. The two lane A34 has a large difference in traffic flows with total flows at the site north of Oxford similar to the motorway flows but with similar numbers of HGV at both A34 sites.

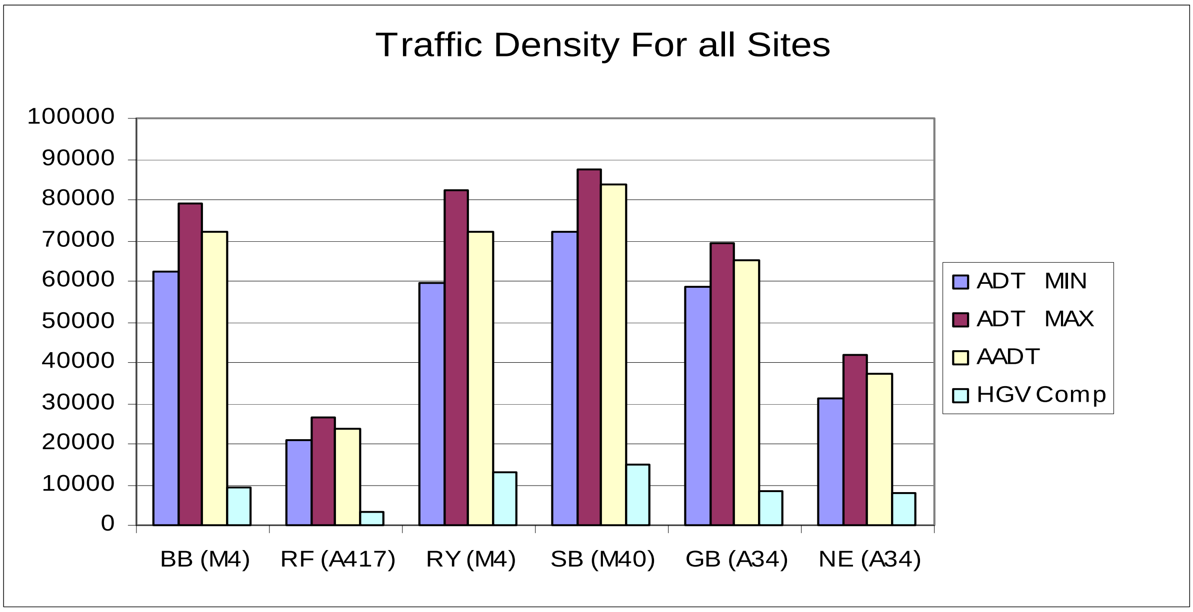


Figure 5-2 Traffic density

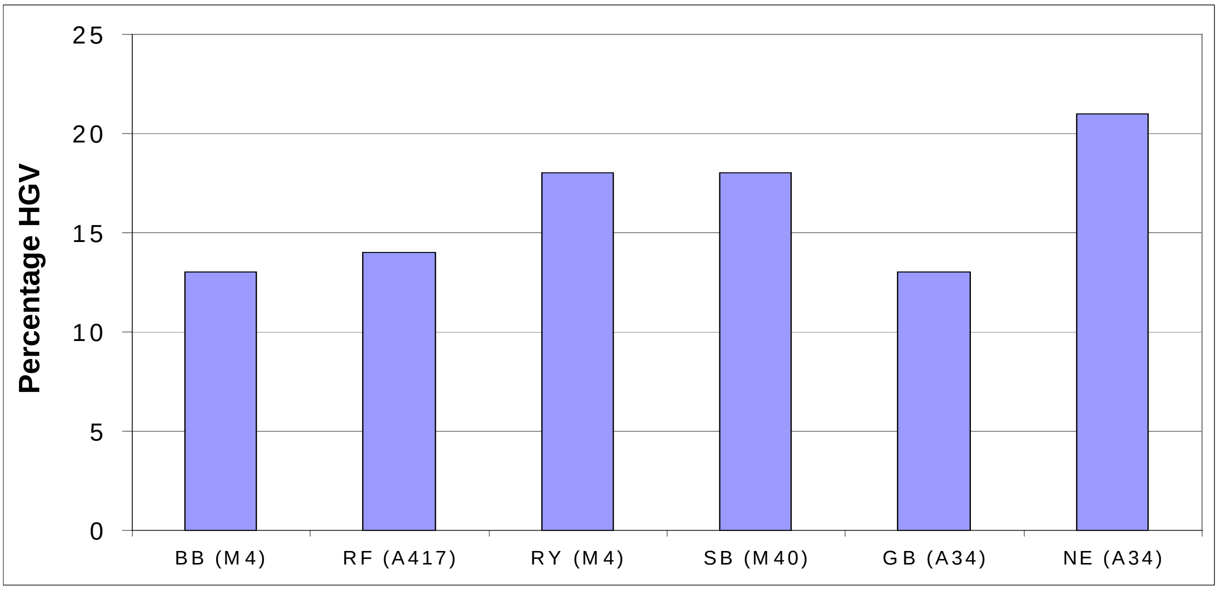


Figure 5-3 HGV percentage for all sites

5.1.3 Proportion of Trafficked Area

The proportion of paved area to trafficked area is in the range 62% to 77% at all sites. At the A34/Gallos Brook site, the paved area contributing to the control drainage system is 77% including the service area on/off slip lane and the area contributing to the filter drainage system is 75%. Four sites are within a 6% difference of trafficked area. This does not offer scope to attribute any observed differences reliably.

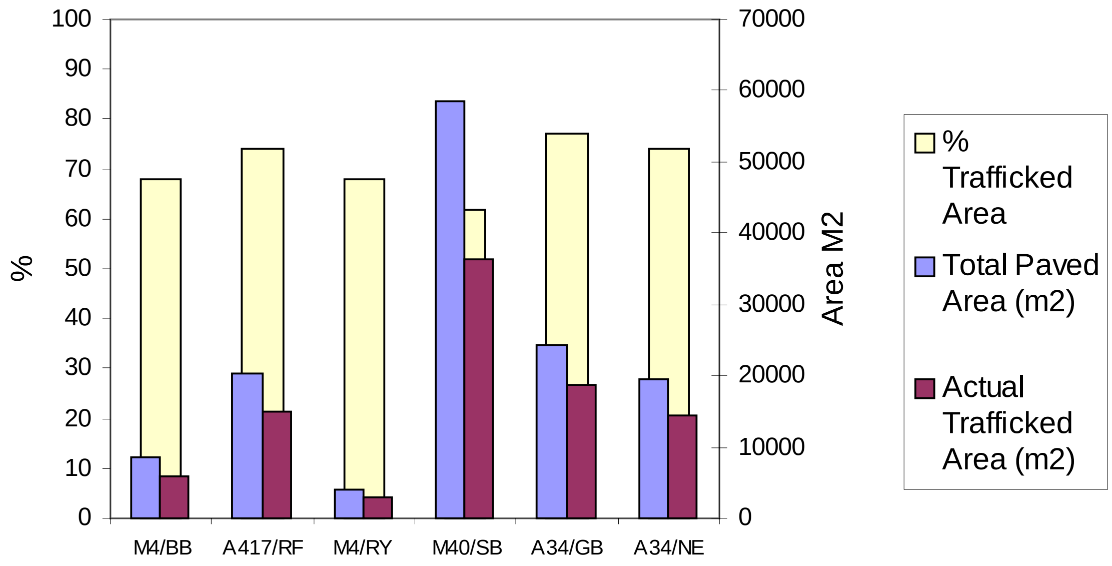


Figure 5-4 Paved and trafficked areas at each site

5.1.4 Surface Material

No detailed study of the highway surface storage capacity or drainage characteristics has been undertaken. Four of the six monitored sites are surfaced with non porous hot rolled asphalt and the contaminant accumulation, mobilisation and transport regimes have been accepted as being similar.

The porous asphalt surface at the A34/Newbury site and the concrete surface at the A34/Gallos Brook site are recognised as potentially having significantly different accumulation, mobilisation and transport regimes from the other sites and are likely to have an effect on the observed runoff quality at these sites.

5.2 <u>Event Characteristics</u>

Event selection attempted to capture a similar range of event types at each site. However, comparison of the event characteristics of monitored events at the six sites shows a matrix of events with a range of total rainfall from 1.0mm to 24.8mm, rainfall peak intensities from 1.2mm/hr to 84.0mm/hr and event durations from 9 minutes to 18 hours.

Storm event details for each site are presented in Section 4.4 of the site reports.

The combination of event characteristics is potentially infinite. Events have been grouped into total rainfall categories in order to correlate runoff characteristics with event characteristics. The categories are <5.0mm, 5mm to 10mm, and >10mm. Each category is subdivided into broad intensity groupings of low (<4mm/hr), medium (4mm/hr to 12mm/hr) and high intensity (>12mm/hr).

Table 5-3 shows the distribution of events in each category and the total rainfall recorded at each site.

Table 5-3 Event classification/distribution for each site

Event rainfall	<5mm			5mm to 10mm			>10mm		
Event intensity	Low	Med	High	Low	Med	High	Low	Med	High
M4/BB		2	3		3	1			1
A417/RF	4	1	3			1			1
M4/RY		4		1	1	2		2	
M40/SB	1		2	4		1			2
A34/GB	2	1	3		2	2			
A34/NE	1		1	2		1		1	4
	28			21			11		

The monitored event distribution shows the majority of events to be in the <5mm and <10mm categories. As Figure 5-5 shows, the events monitored are representative of the event profiles for each site during the monitoring period but with sufficient events in each category to examine for any event based relationships that exist.

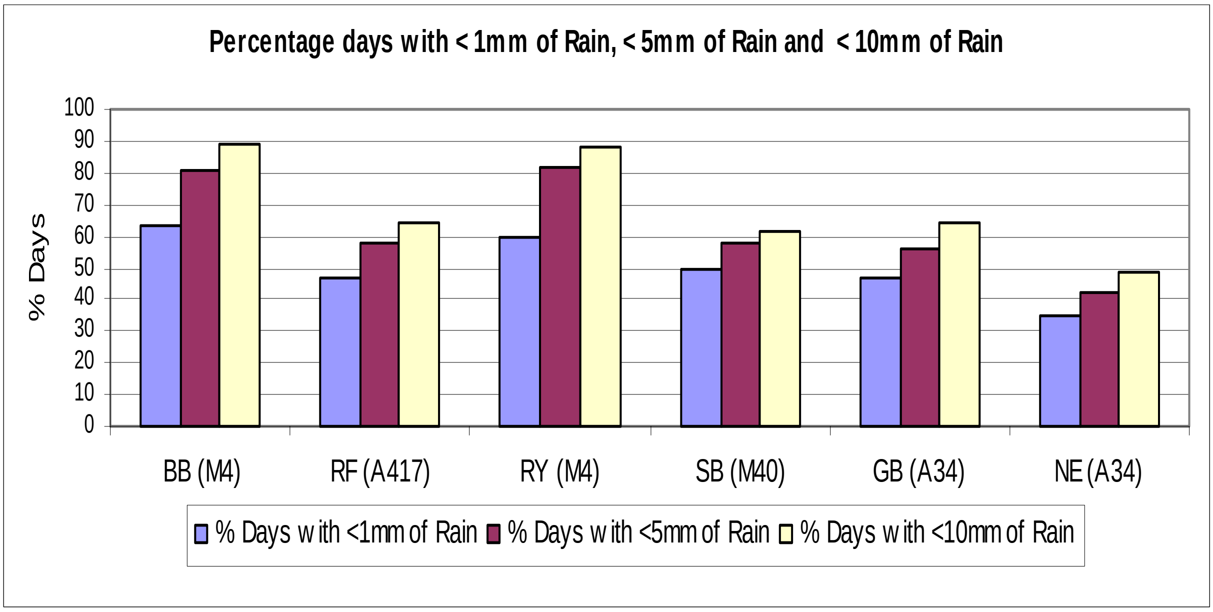


Figure 5-5 Percentage of days in event total rainfall categories

5.3 <u>Highway Runoff Quality</u>

The concentration of contaminants in highway runoff is controlled by a number of factors, as discussed previously. These factors will have greater or lesser effects subject to local conditions.

When comparing six sites with different characteristics with variable runoff quality resulting from rainfall events of different totals and intensities, any conclusions drawn will be, by necessity, subject to a degree of subjective interpretation. Assessments are, therefore, based on relative comparisons with explanations offered for the differences observed. A summary of untreated highway runoff average concentrations is given in Table 5-4.

Table 5-4 Summary highway runoff average concentrations

	Units	LOD	M4/BB Average	A417/RF Average	M4/RY Average	M40/SB Average	A34/GB Average	A34/NE Average	All sites Max	All sites Min	All sites Average
Copper	ug/l	0.3	24.40	54.61	67.92	32.41	42.65	23.99	67.92	23.99	41.00
Filtered Copper	ug/l	0.3	ND	33.62	23.32	11.82	17.61	16.53	33.62	11.82	20.58
Zinc	ug/l	0.6	100.70	221.60	219.73	97.98	149.31	62.60	221.60	62.60	140.30
Filtered Zinc	ug/l	0.6	8.60	163.42	66.79	29.01	55.74	21.37	163.42	8.60	57.49
Cadmium	ug/l	0.001	ND	0.99	0.56	0.25	0.43	0.21	0.99	0.21	0.49
Aluminium	ug/l	0.4	1185.00	2848.00	1995.90	739.25	520.00	101.98	2848.00	101.98	1231.69
Lead	ug/l	0.1	ND	51.39	50.45	16.73	15.36	4.38	51.39	4.38	23.06
Platinum	ug/l	0.15	24.00	ND	ND	ND	ND	ND	24.00	ND	4.00*
Palladium	ug/l	0.5	ND	0.90	0.21	0.42	0.42	0.34	0.90	0.21	0.38
Nickel	ug/l	0.01	ND	12.00	6.68	4.04	4.47	4.66	12.00	4.04	5.31
Chromium	ug/l	0.3	ND	11.60	9.08	7.73	4.82	2.72	11.60	2.72	6.98
Simazine	ug/l	0.02	0.02	0.00	ND	0.02	0.02	0.30	0.30	ND	0.06
Amitrole	ug/l	0.10	ND	ND	ND	ND	ND	ND	0.00	ND	ND
Glyphosate	ug/l	0.10	0.02	0.08	0.01	3.73	0.49	ND	3.73	ND	0.72
Diuron	ug/l	0.01	ND	0.33	ND	ND	ND	ND	0.33	ND	0.06
Bromacil	ug/l	0.02	ND	ND	0.04	0.07	ND	0.00	0.07	ND	0.02
Atrazine	ug/l	0.10	0.04	0.02	ND	0.01	0.00	0.02	0.04	ND	0.02
Naphthalene	ug/l	0.01-0.05	0.04	0.52	0.02	0.06	0.02	ND	0.52	ND	0.11
Acenaphthylene	ug/l	0.01-0.05	0.06	0.03	0.00	0.04	0.00	0.00	0.06	0.00	0.02
Acenaphthene	ug/l	0.01-0.05	0.08	0.01	0.00	0.05	0.01	ND	0.08	ND	0.02
Fluorene	ug/l	0.01-0.05	0.07	0.02	0.00	0.05	0.01	0.02	0.07	0.00	0.03
Phenanthrene	ug/l	0.01-0.05	0.19	0.10	0.02	0.06	0.03	0.05	0.19	0.02	0.08
Anthracene	ug/l	0.01-0.05	0.13	0.05	0.03	0.06	0.01	0.05	0.13	0.01	0.06
Fluoranthene	ug/l	0.01-0.05	0.18	0.16	0.08	0.17	0.12	0.23	0.23	0.08	0.16
Pyrene	ug/l	0.01-0.05	0.17	0.14	0.09	0.20	0.13	0.21	0.21	0.09	0.16
Benzo[a]anthracene	ug/l	0.01-0.05	0.16	0.11	0.05	0.15	0.09	0.13	0.16	0.05	0.11
Chrysene	ug/l	0.01-0.05	0.16	0.10	0.09	0.14	0.10	0.13	0.16	0.09	0.12
Benzo[b]fluoranthene	ug/l	0.01-0.05	0.20	0.16	0.05	0.12	0.20	0.14	0.20	0.05	0.14
Benzo[k]fluoranthene	ug/l	0.01-0.05	0.10	0.10	0.07	0.15	0.07	0.06	0.15	0.06	0.09
Benzo[a]pyrene	ug/l	0.01-0.05	0.16	0.24	0.08	0.19	0.13	0.13	0.24	0.08	0.16
Indeno[1,2,3-cd]pyrene	ug/l	0.01-0.05	0.11	0.10	0.08	0.13	0.12	0.12	0.13	0.08	0.11
Dibenzo[a,h]anthracene	ug/l	0.01-0.05	0.12	0.10	0.07	0.09	0.01	0.03	0.12	0.01	0.07
Benzo[g,h,i]perylene	ug/l	0.01-0.05	0.14	0.11	0.03	0.08	0.14	ND	0.14	ND	0.08
Na	mg/l	0.50	374.02	96.69	306.40	76.01	134.90	39.03	374.02	39.03	171.51
Hardness	mg/l	0.50	226.30	108.77	126.33	210.00	82.11	140.30	226.30	82.11	148.80
De-IcingSalts	mg/l	0.02	536.24	176.66	486.87	123.68	167.64	59.49	536.24	59.49	258.43
BOD	mg/l	1.00	9.10	8.36	5.54	5.99	5.26	5.30	9.10	5.26	6.59
COD	mg/l	20.00	87.52	137.66	95.40	75.30	61.19	74.62	137.66	61.19	88.62
TSS	mg/l	1.00	88.60	317.97	101.03	82.70	45.79	51.41	317.97	45.79	114.58
NH4-N	mg/l	0.05	0.33	0.35	0.29	0.13	0.21	0.20	0.35	0.13	0.25
ND = Not detected											
ND values used in averaging as zero											
Key Determinands											

Aluminium – see Section 4.1
*Platinum – only detected during two events at M4/BB site.

Table 5-4 and the graphical presentation of those results in Figure 5-6 show metals are all of similar values. The exception is with the Aluminium values which at the M4/Brinkworth Brook, A417/River Frome and M4/River Ray sites are significantly higher than the other sites. Reference to road salt application records shows an inconsistent relationship. At the A34/Newbury site, where no monitored events followed road salt application, Aluminium concentrations are low. Conversely, at the M4/River Ray site, five monitored events followed application of the road salt and at the A417/River Frome site the average concentration is high due to a single very high concentration monitored following a series of applications. However, at the M4/Brinkworth Brook site four individual high concentrations were recorded but only one of the events followed road salt application.

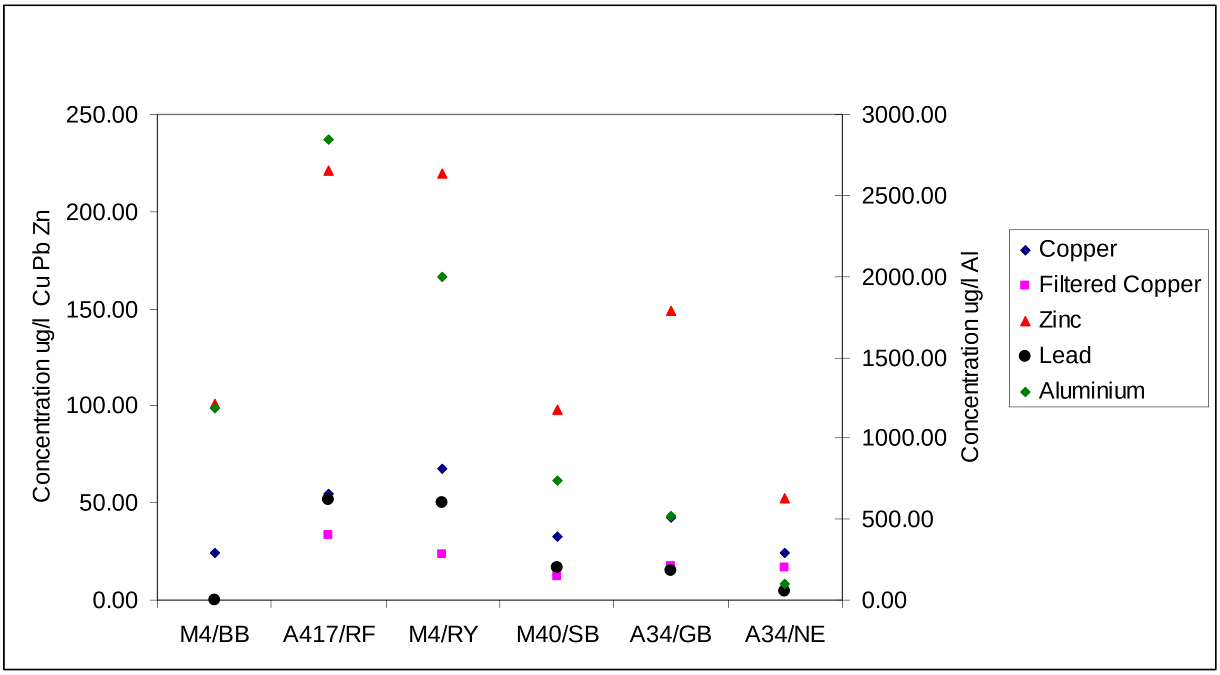


Figure 5-6 Comparison of the average metals concentrations between sites

Table 5-4 and Figure 5-7 show PAH concentrations of similar values at all sites except the M4/River Ray site where concentrations are c.50% less than those of other sites. Two characteristics distinguish this site from all others, the smallest contributing area and the types of events monitored. The runoff volume for the unit area is similar to other sites suggesting area is not a determining factor but a lower number of high intensity rainfall events were monitored at this site which may have reduced the mobilisation of contaminants relative to other sites. However, examination of relationships between individual event concentrations and event characteristics are inconclusive due to clustering of events.

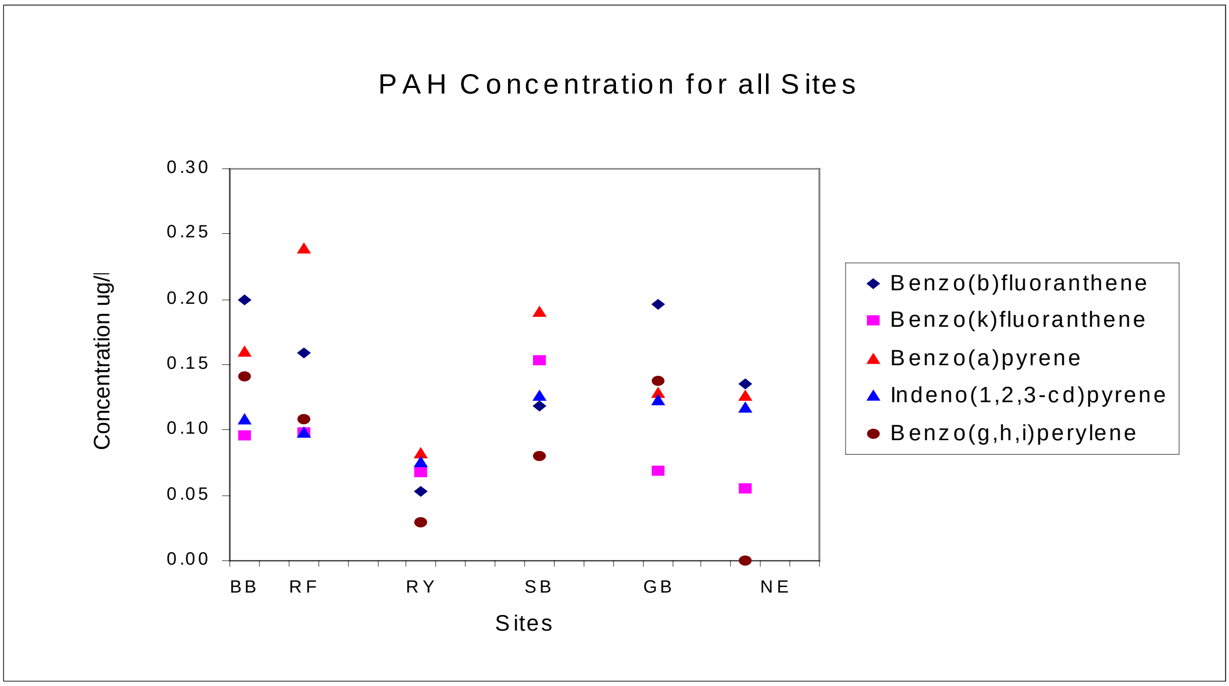


Figure 5-7 Comparison of the average PAH concentrations between sites

Comparison of BOD, COD, TSS and NH_4-N concentrations in Figure 5.8 shows similar values at all sites with the exception of the A417/River Frome site. TSS concentrations are significantly higher at this site.

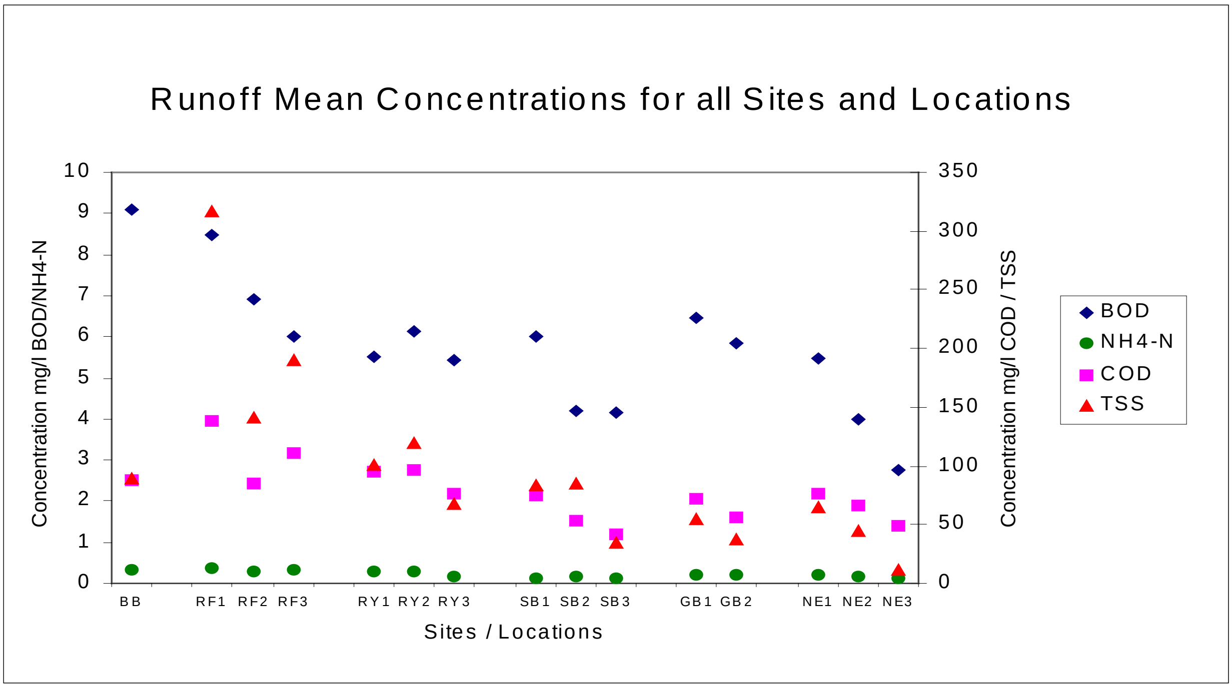


Figure 5-8 Comparison of the average discrete determinand concentrations between sites

Mean concentrations of discrete samples, metals and PAHs plotted against AADT are given in Figure 5-9, Figure 5-10 and Figure 5-11. No relationship can be identified between AADT and any determinand.

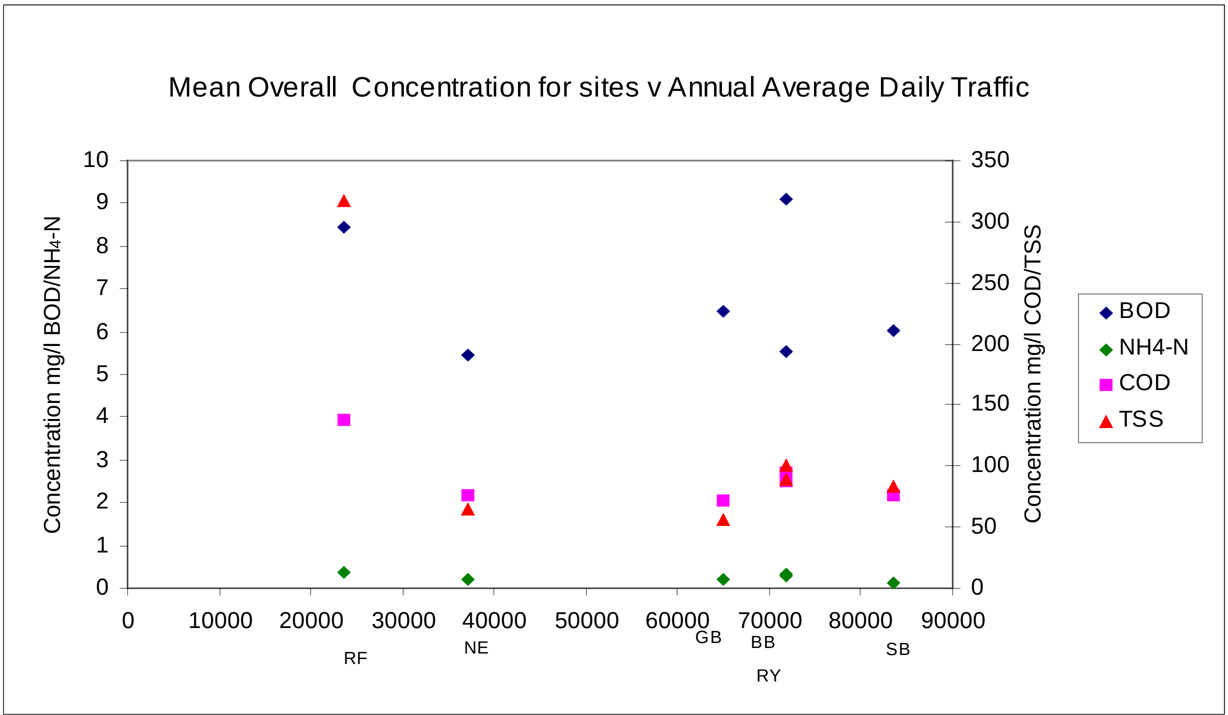


Figure 5-9 Discrete determinand mean concentration v AADT

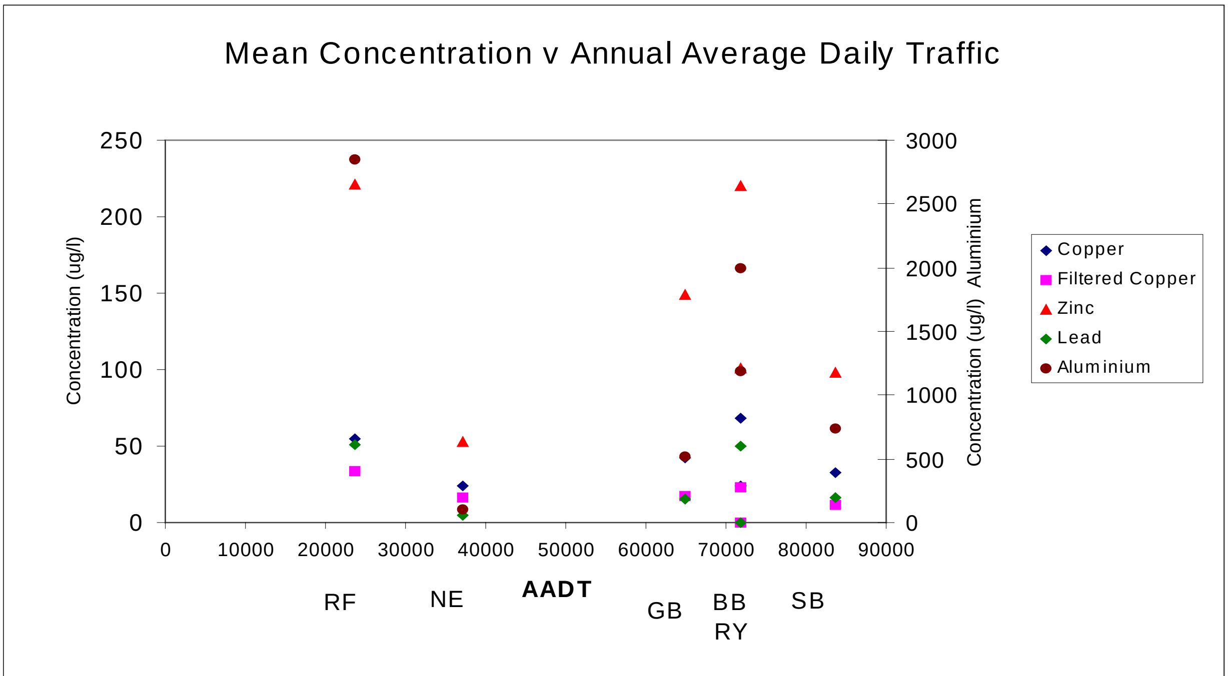


Figure 5-10 Metals mean concentration v AADT

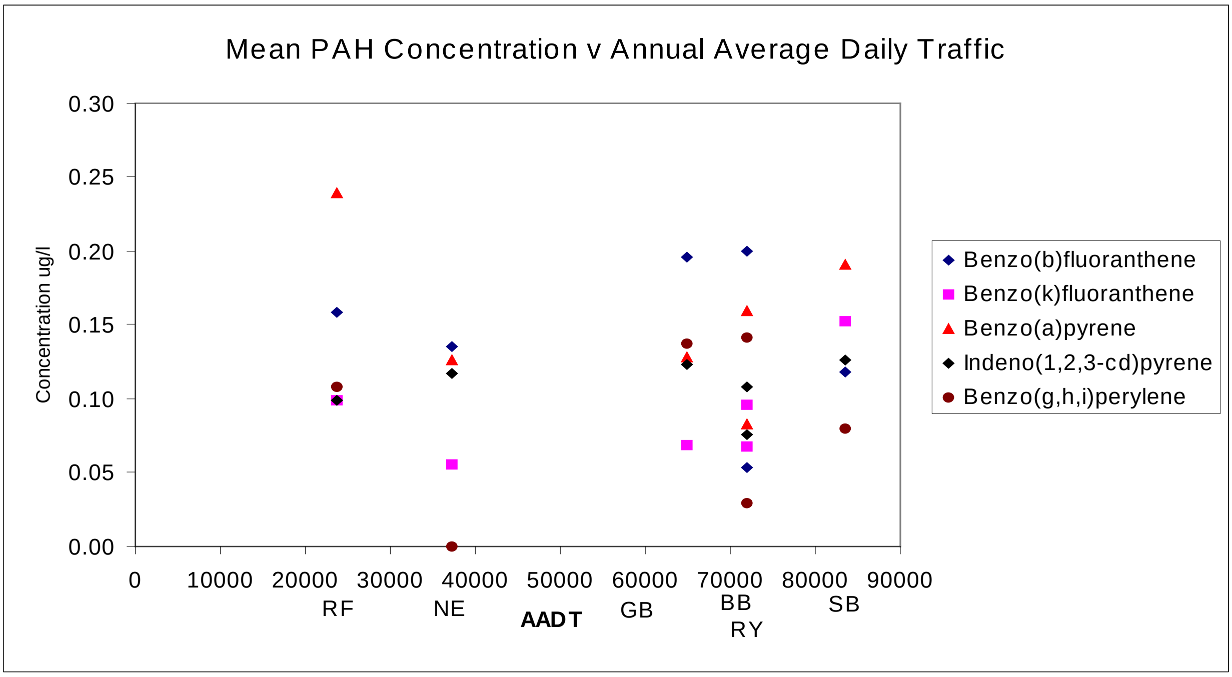


Figure 5-11 PAH mean concentration v AADT

Comparison of concentration of discrete determinands, metals and PAHs with Total Paved Area, as illustrated in Figure 5-12, Figure 5-13 and Figure 5-14 show no relationship.

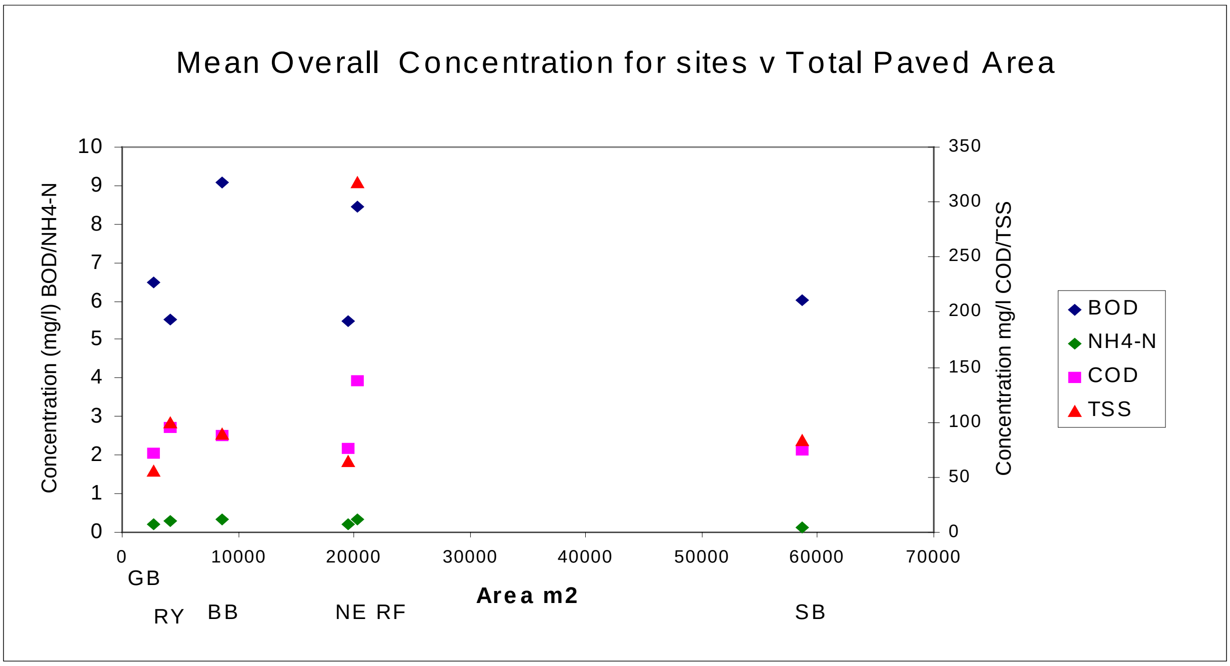


Figure 5-12 Discrete determinand mean concentration v Total paved area

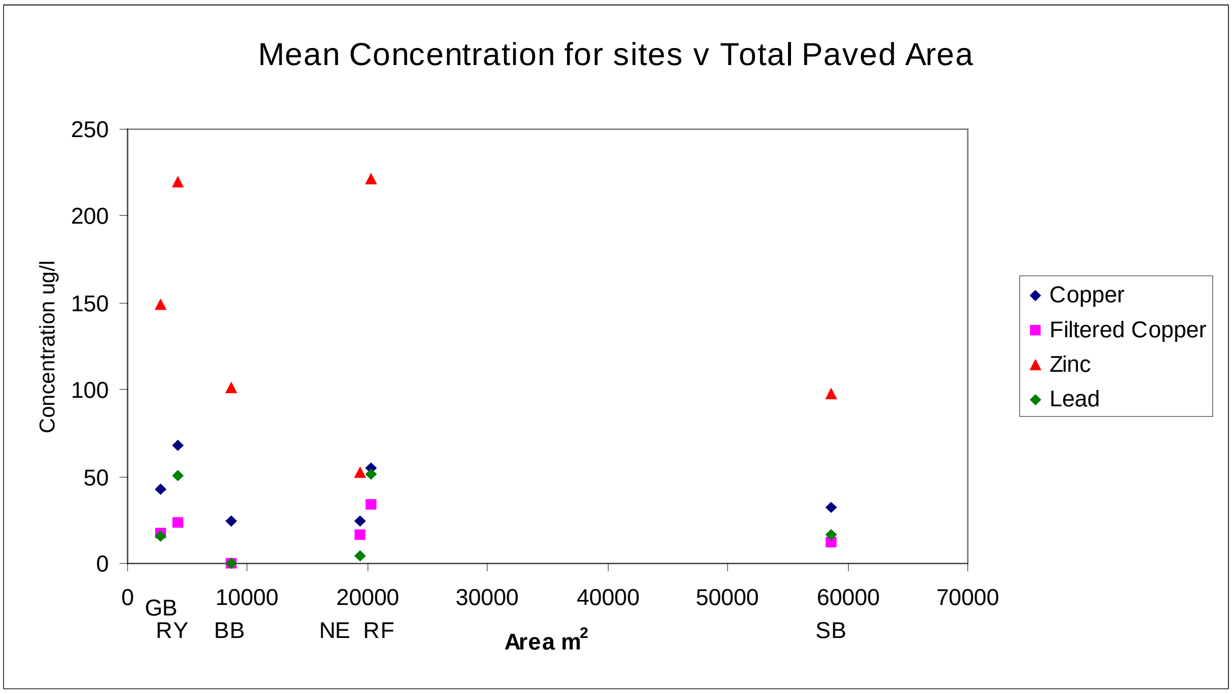


Figure 5-13 Metals mean concentration v Total paved area

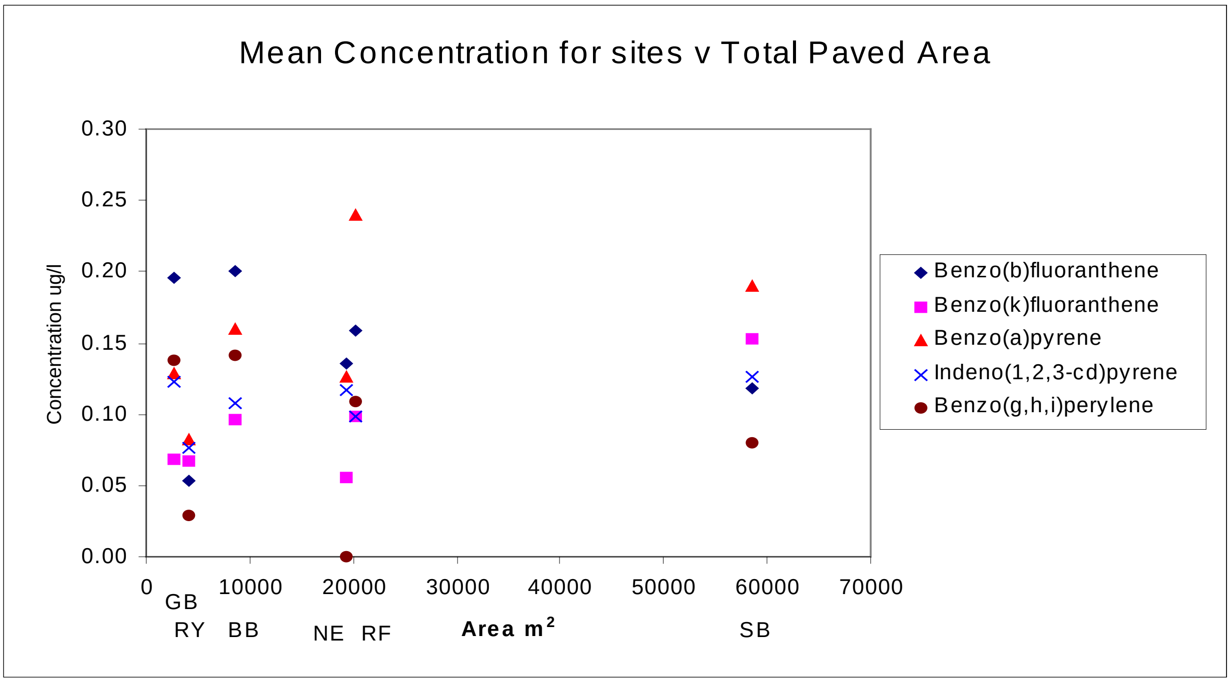


Figure 5-14 PAH mean concentration v Total paved area

Comparison of concentration of discrete determinands, metals and PAHs with Carriageway Width, as illustrated in Figure 5-15, Figure 5-16 and Figure 5-17, show no relationship. The higher values at the A417/River Frome site are believed to be related to the inclusion of a braking zone with 'rumble strips' increasing the quantity of solids deposited on the highway.

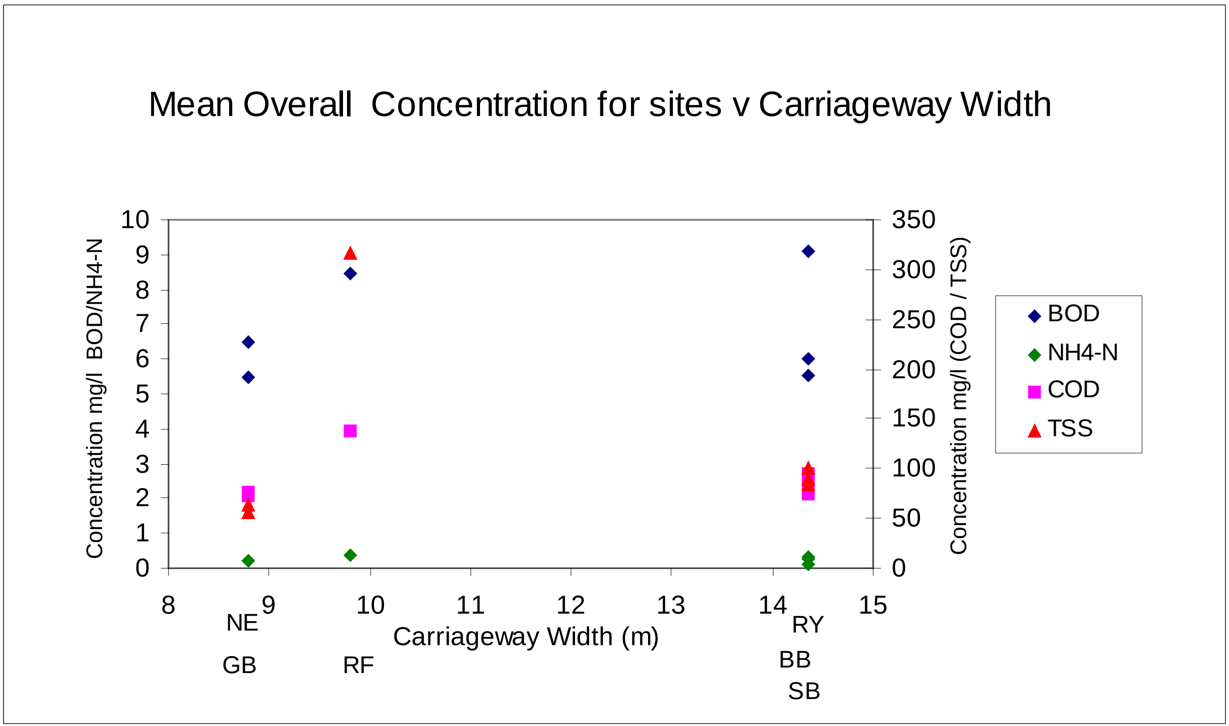


Figure 5-15 Discrete determinand mean concentration v Carriageway Width

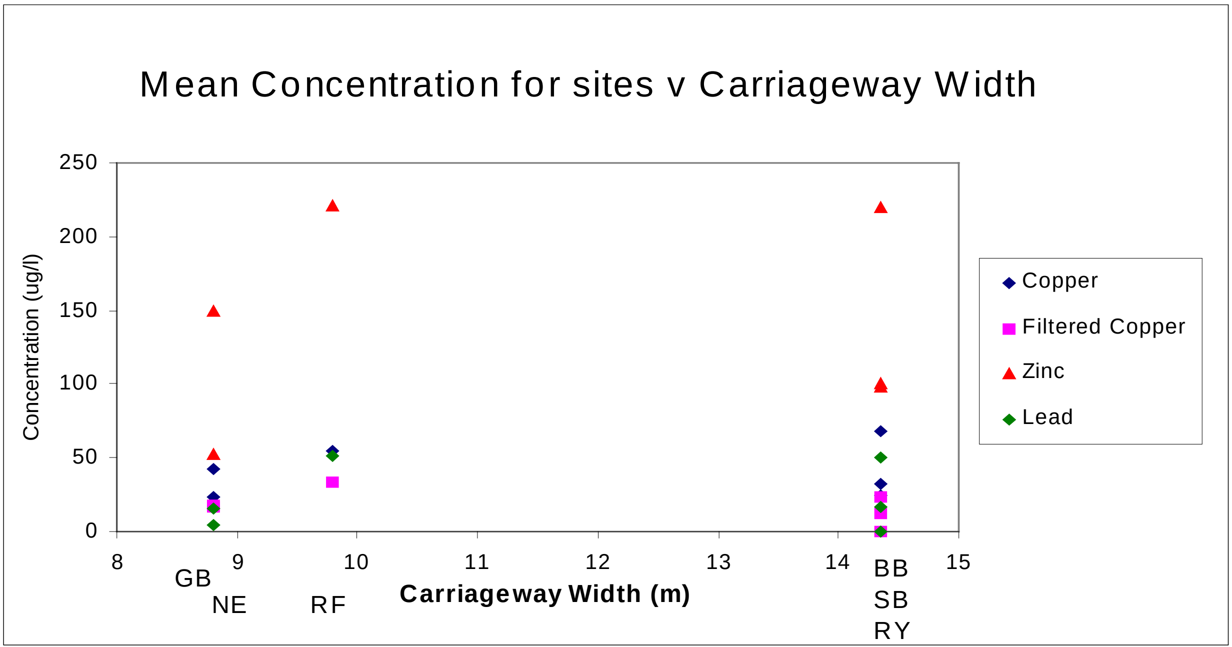


Figure 5-16 Metals mean concentration v Carriageway Width

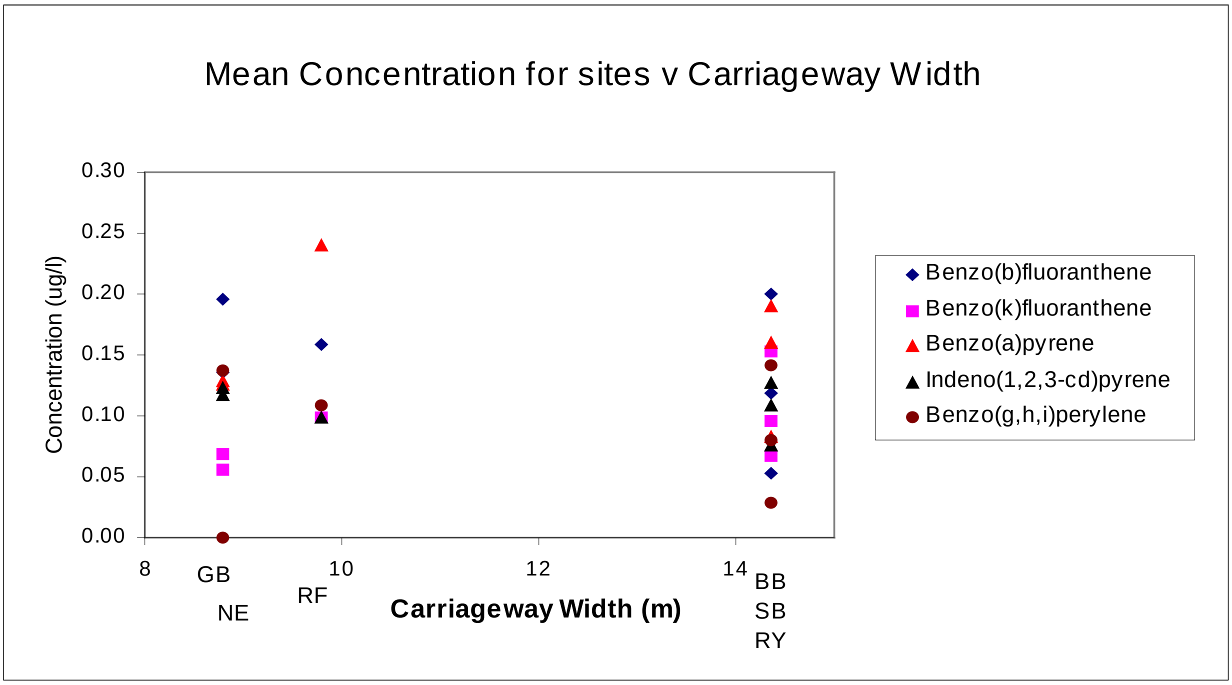


Figure 5-17 PAH mean concentration v Carriageway Width

Event load has been calculated per 1000m^2 highway surface area to normalise the data for one highway characteristic variable. The event load per 1000m^2 has been calculated as the composite sample concentration multiplied by the runoff during the sampling period.

Table 5-5 shows the average event load generated per 1000m^2 for each site.

Table 5-5 Sites Summary Average Load/1000m^2

		M4/BB	A417/RF	M4/RY	M40/SB	A34/GB	A34/New	All sites
								Average Load
	Load							
Copper	mg/1000m2	29.60	27.20	90.75	51.60	11.16	153.22	60.59
Filtered Copper	mg/1000m2	ND	14.83	37.61	24.63	4.77	92.40	29.04
Zinc	mg/1000m2	163.60	186.97	299.31	171.36	38.65	371.72	206.30
Filtered Zinc	mg/1000m2	42.31	98.57	77.83	73.29	16.40	136.14	74.09
Cadmium	mg/1000m2	ND	0.66	0.94	0.53	0.13	1.42	0.61
Aluminium (Total)	mg/1000m2	1747.44	1150.50	1583.14	2547.67	145.33	718.11	1315.36
Lead	mg/1000m2	ND	37.20	60.01	25.34	3.98	32.73	26.54
Platinum	mg/1000m2	5.17	ND	ND	ND	ND	ND	0.86
Palladium	mg/1000m2	ND	0.00	0.33	1.07	0.20	0.62	0.37
Nickel	mg/1000m2	ND	9.15	7.36	7.92	1.16	30.59	9.36
Chromium	mg/1000m2	ND	8.62	10.97	12.88	1.19	17.25	8.48
Simazine	ug/1000m2	7.92	ND	ND	11.44	ND	1176.52	199.31
Amitrole	ug/1000m2	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/1000m2	4.92	117.99	3.03	6729.04	0.16	ND	1142.52
Diuron	ug/1000m2	ND	834.52	ND	ND	ND	ND	139.09
Bromacil	ug/1000m2	ND	ND	26.14	81.66	ND	2.52	18.39
Atrazine	ug/1000m2	9.72	ND	ND	12.47	0.001	64.06	14.37
Naphthalene	ug/1000m2	91.19	0.33	13.38	88.66	0.01	ND	32.26
Acenaphthylene	ug/1000m2	43.79	39.24	0.22	7.25	0.001	0.60	15.18
Acenaphthene	ug/1000m2	115.54	10.05	0.34	57.29	0.002	ND	30.54
Fluorene	ug/1000m2	45.68	5.89	8.92	37.53	0.002	51.71	24.96
Phenanthrene	ug/1000m2	112.06	82.65	23.57	51.24	0.01	178.95	74.74
Anthracene	ug/1000m2	119.82	0.04	30.55	78.28	0.002	143.02	61.95
Fluoranthene	ug/1000m2	228.01	253.66	90.37	191.73	0.04	891.72	276.92
Pyrene	ug/1000m2	219.37	244.72	82.30	224.28	0.04	1074.64	307.56
Benzo(a)anthracene	ug/1000m2	222.81	0.12	35.44	184.81	0.03	520.29	160.59
Chrysene	ug/1000m2	226.50	222.44	92.39	180.88	0.03	479.78	200.34
Benzo(b)fluoranthene	ug/1000m2	301.47	281.35	50.89	120.37	0.07	547.88	217.00
Benzo(k)fluoranthene	ug/1000m2	137.53	0.09	64.70	167.01	0.03	192.61	93.66
Benzo(a)pyrene	ug/1000m2	246.08	398.30	75.73	184.91	0.05	488.55	232.27
Indeno(1,2,3-cd)pyrene	ug/1000m2	154.97	211.24	71.59	123.67	0.04	469.56	171.84
Dibenzo(a,h)anthracene	ug/1000m2	170.53	0.07	62.48	126.35	0.01	104.49	77.32
Benzo(g,h,i)perylene	ug/1000m2	222.16	0.09	31.47	54.63	0.05	ND	61.4
Na	g/1000m2	750.50	137.97	661.89	140.10	39.36	209.62	323.24
Hardness	g/1000m2	408.93	249.35	160.07	381.32	23.47	939.47	360.43
De-icingSalts	g/1000m2	1271.48	227.34	1035.26	238.35	38.51	343.42	526.73
BOD	g/1000m2	12.66	14.07	8.54	11.66	1.65	36.42	14.17
COD	g/1000m2	148.23	347.12	145.26	160.35	17.14	490.42	218.09
TSS	g/1000m2	130.03	877.98	166.79	183.01	12.64	284.66	275.92
NH4 N	g/1000m2	0.34	0.62	0.44	0.26	0.07	1.59	0.55
Average event runoff	ltr/1000m2	1873	1986	1476	2312	204	6977	

It can be seen in Table 5-5 that the average load/1000m^2 is significantly lower at the A34/Gallos Brook site than all other sites. Figure 5-18, Figure 5-19 and Figure 5-20 show metals, PAH and BOD/TSS load. The lower loads at this site occur in spite of runoff from a 9% greater proportion of the surface area trafficked compared to other sites.

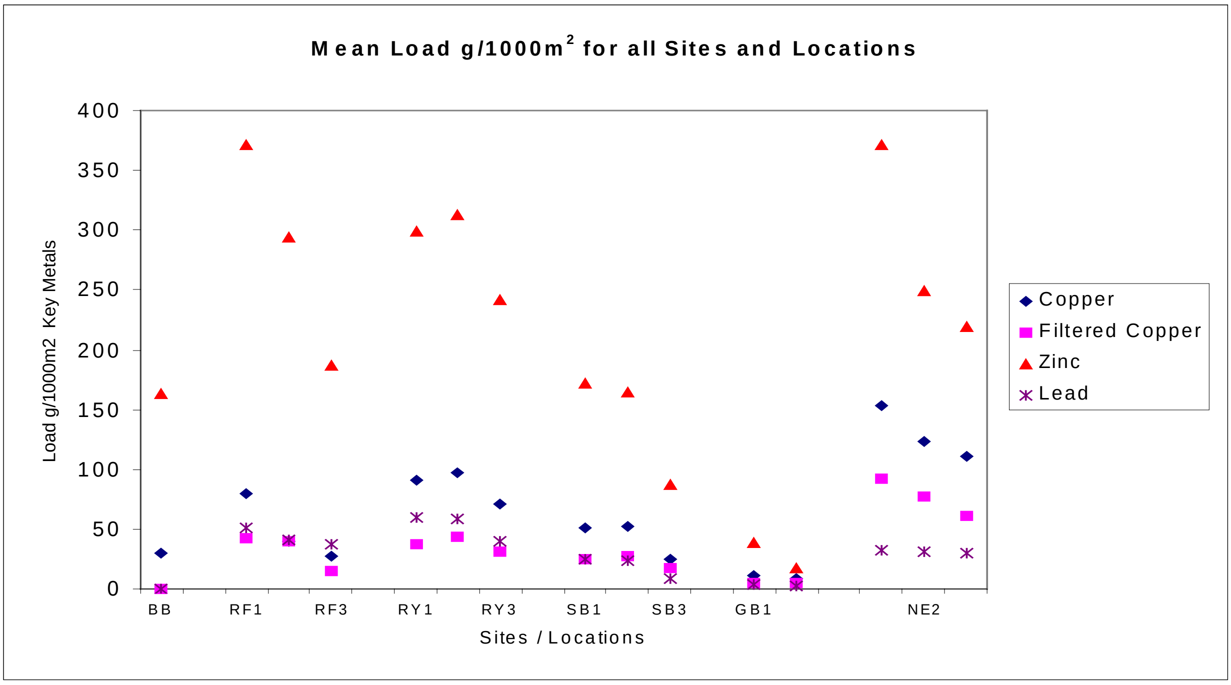


Figure 5-18 Metals load g/1000 m^2 by site/location

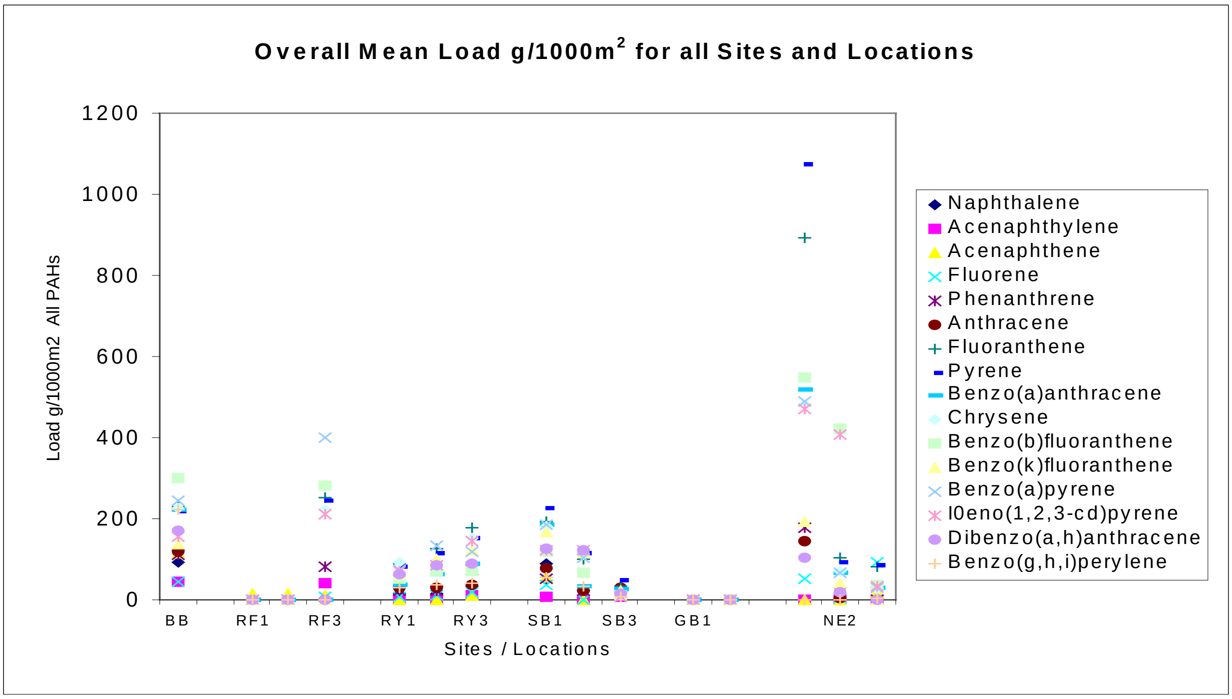


Figure 5-19 PAH load g/1000 m^2 by site/location

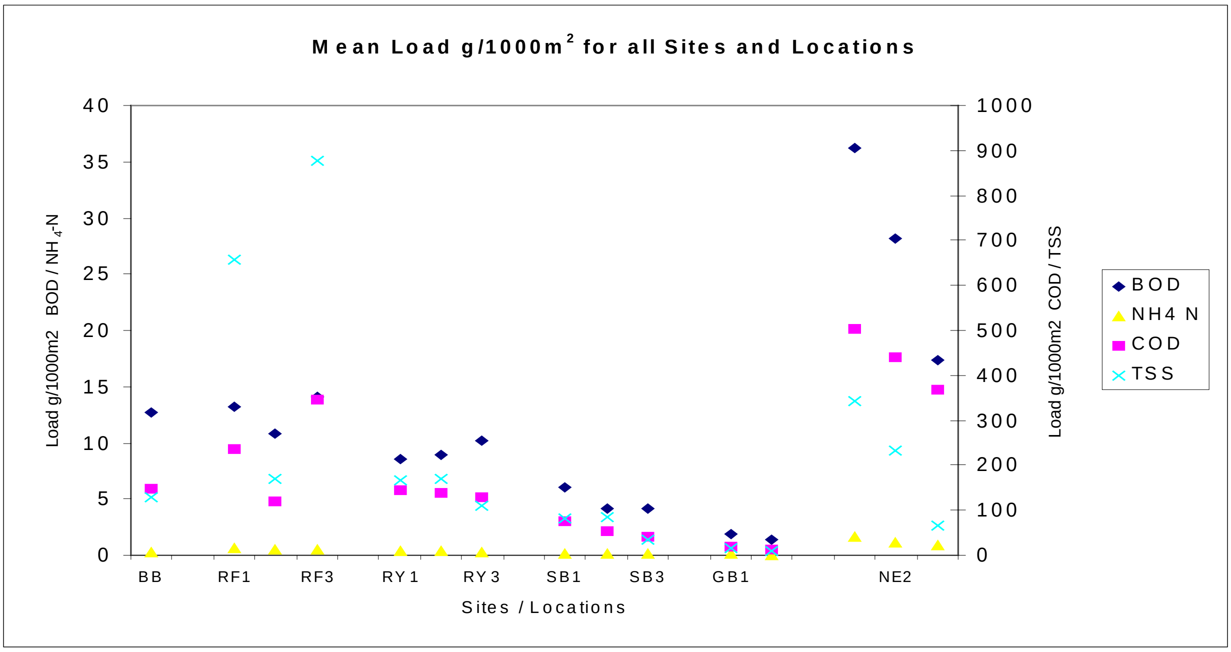


Figure 5-20 Discrete determinand load g/1000 m^2 by site/location

The reduced load may be due to disproportionate runoff from the paved area. As Figure 5-21 shows, the average runoff during the monitored events at the A34/Gallos Brook site is significantly lower than all other sites. The high average runoff at the Newbury site is due to a disproportionate number of long duration events compared with the other sites.

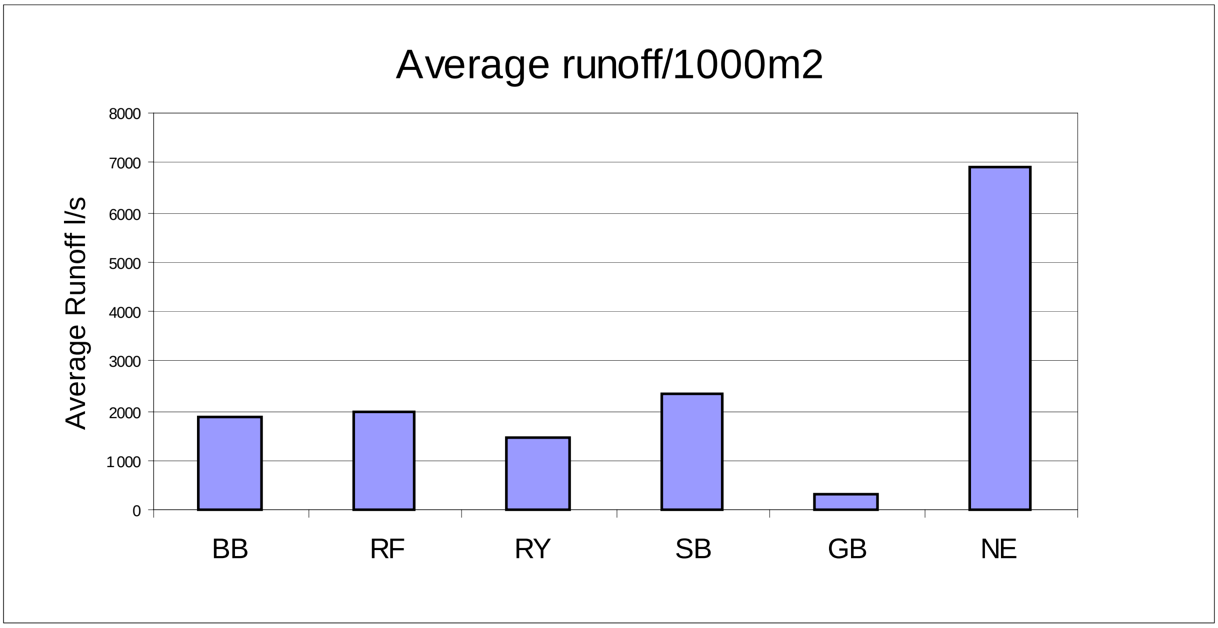


Figure 5-21 Average runoff/1000 m^2

A possible explanation is a combination of factors. 60% of the events were 5mm or less total rain, and 50% of these were low intensity events. The highway gradient is very shallow, 1:1000, reducing the speed of runoff from the surface to the drainage system. The surface material is concrete, c.11 years old. Traffic density is high, with AADT equivalent to the 3 lane motorways monitored, travelling on two lanes. It could, therefore, be argued that the low average runoff was a function of relatively light rainfall being removed from a non-porous surface by high traffic density.

5.4 Comparison of Treatment performance

Comparison of the efficiency of individual treatment devices is discussed in Section 4.7.

The comparison between monitored sites looks at the overall efficiency of the combinations of devices at the individual sites. A Table showing actual and percentage reduction for road runoff and discharge to watercourse samples, in addition to the reduction across individual treatment devices, is given in Appendix E.

A ranking of the combined efficiency of the treatment devices at the four sites where combinations were monitored is shown in Table 5-6.

Table 5-6 Combined treatment efficiency ranking

			%age reduction inlet to outlet		
Ranking	**Site/Treatment Devices**		**Initial form of treatment**	**Second form of treatment**	**Total system treatment**
1	A34/Newbury Bypass oil Separator/Wet Balancing Pond-Surface Flow Wetland	Metals	15	11	24
		PAH	-1	99	99
		TSS	37	73	83
2	M40/Souldern Brook Full retention Oil Separator/Wet Balancing Pond	Metals	19	35	48
		PAH	13	50	57
		TSS	-9	62	58
3	A417/River Frome Bypass oil separator/Dry Balancing Pond	Metals	27	39	56
		PAH	4	16	22
		TSS	56	-37	40
4	M4/River Ray Oil Trap Manhole/Sedimentation Tank	Metals	-7	41	30
		PAH	-30	-26	indeterminate
		TSS	-19	43	33

The greatest observed pollution removal efficiency was produced by a combination of a bypass oil separator and wet pond-surface flow wetland at the A34/Newbury Pond D site.

Although metals removal is less efficient than at other sites the high removal efficiency for PAHs and TSS gives and overall better performance than all other monitored sites.

A number of criteria influence the performance of the oil separators, including design, maintenance and event characteristics. The feature that is common to all sites and possibly compromised by all these criteria is the capacity of the oil separator. The smallest device, the oil trap manhole being the least efficient and the wet balancing ponds the largest and most efficient devices, supports this. The retention time is a function of the physical size of the device together with the flowpath characteristics. Table 5-7 shows the nominal hydraulic retention times of the secondary devices.

Table 5-7 Device nominal retention times

Device	Nominal Retention Time For:		
	Design - hrs	Peak Monitored flow - hrs	Average monitored flow - hrs
A417/River Frome Dry Balancing Pond	Not known	4.2	87.0
M4/River Ray Sedimentation Tank	Not known	0.5	4.0
M40/Souldern Brook Wet Balancing Pond	1.5	9.5	93.0
A34/Newbury Wet Balancing Pond with Reeds	0.75	4.5	27.0

Table 5-8 shows the similar performance for metals reduction of the oil separators and pond at both the M40/Souldern Brook and A34/Newbury Bypass Pond D sites. The full retention oil separator at the M40/Souldern Brook site performed significantly better for PAH reduction than the bypass oil separator at the A34/Newbury site. Conversely the pond at the A34/Newbury site performed significantly better for PAH reduction than the pond at the M40/Souldern Brook site. The ranking of these two systems would be subject to the priority of the treatment requirement but it is noteworthy that both systems are significantly more efficient than the other systems monitored.

Table 5-9 shows the treatment efficiency of the ponds and the overall systems at the two sites. This indicates that the treatment efficiency of the ponds represents a significant proportion of the treatment achieved by the overall systems. However, the treatment efficiency of the ponds was not assessed against typical runoff concentrations due to the presence of the upstream oil separation devices. Therefore, the performance of the ponds under highway runoff concentrations cannot be assessed.

At all sites the second form of treatment devices show variable concentration reduction, site to site, but all are generally more efficient than the initial devices. All primary devices are designed to intercept oil contaminants but comparison of average reduction efficiency between primary and secondary devices shows the secondary devices are more consistently efficient across the PAH range.

The TSS reduction efficiencies of the devices are not directly related to the nominal hydraulic retention times. For example, the efficiency of the A34/Newbury site is greater than the

M40/Souldern Brook site despite the shorter nominal retention time. Although the nominal hydraulic retention times control the volumetric discharge to the watercourse, the treatment efficiency is a function of the retention time of the runoff containing contaminants. In the case of the A417/ R Frome and M40/Souldern sites, this retention time is reduced by the proximity of the inlet to the outlet permitting a ‘short circuiting’ of flows from the inlet directly to the outfall.

The reduction of contaminated sediments by the treatment devices during a single event cannot be ascertained from the data collected other than by the reduction of TSS in the liquid sample. The bulk sediment samples taken represent deposition and accumulation over a period and as a measure of the efficiency of the treatment device in trapping sediment will be subject to the period of accumulation and the quantity and quality of the source sediments.

For example, the concentration of PAHs in the untreated runoff sediment samples at the M4/Brinkworth Brook, A417/River Frome and A34 Gallos Brook sites is much higher (on average 3 times higher), than at the M4/River Ray site and the M40/Souldern Brook site. This may be because the M4/River Ray silt trap was cleaned prior to monitoring and the M40/Souldern Brook site, has a high inlet gradient that precludes the build up of fine sediments within the system.

Sediment analysis results and reduction of determinands between the runoff sample and the discharge to watercourse sample are given in Appendix H.

Table 5-8 Device Treatment Efficiencies: M40/Souldern Brook and A34/Newbury Bypass

		Site 4 M40/Souldern Brook Location 1 & 2				Site 6 A34/Newbury Pond D Location 1 & 2				Site 4 M40/Souldern Brook Location 2 & 3				Site 6 A34/Newbury Pond D Location 2 & 3			
		Location 1 Road Runoff	Location 2 Full Retention Oil Separator			Location 1 Road Runoff	Location 2 Bypass Oil Separator			Location 2 Full Retention Oil Separator	Location 3 Discharge to Watercourse			Location 2 Bypass Oil Separator	Location 3 Discharge to Watercourse		
		Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction
	Units																
Copper	ug/l	32.41	28.51	3.90	12.03	23.99	20.83	3.16	13.17	28.51	12.79	15.72	55.14	20.83	14.60	6.23	29.91
Filtered Copper	ug/l	11.62	11.88	0.24	2.02	16.53	14.65	1.88	11.37	11.88	7.46	4.13	35.66	14.65	8.41	6.24	38.77
Zinc	ug/l	97.98	87.57	10.41	10.62	52.60	35.81	16.79	31.92	87.57	38.52	49.05	56.01	35.81	39.99	-4.18	-11.87
Filtered Zinc	ug/l	29.01	20.39	8.62	29.71	21.37	14.05	7.32	34.26	20.39	14.59	5.80	28.97	14.05	23.06	-9.01	-64.13
Cadmium	ug/l	0.25	0.32	-0.07	-28.57	0.21	1.32	-1.11	-548.75	0.32	0.31	0.02	4.69	1.32	0.22	1.11	83.71
Aluminium	ug/l	739.25	610.98	128.27	16.27	101.96	97.99	3.96	3.91	610.98	189.97	425.01	67.06	97.99	50.20	47.79	48.77
Lead	ug/l	16.72	14.19	2.55	15.22	4.26	3.60	0.66	17.34	14.19	4.27	9.91	69.87	3.60	3.86	0.21	5.84
Platinum	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Palladium	ug/l	0.42	0.00	0.42	100.00	0.34	0.13	0.21	61.76	0.00	0.02	-0.02	0.00	0.13	ND	ND	ND
Nickel	ug/l	4.04	4.18	-0.14	-3.47	4.66	4.83	-0.28	-5.95	4.18	3.86	0.27	7.86	4.83	5.47	-0.48	-8.79
Chromium	ug/l	7.72	4.83	2.90	37.52	2.72	3.16	-0.44	-16.16	4.83	3.54	1.29	26.71	3.16	3.22	-0.16	-5.95
Simazine	ug/l	0.01	0.22	-0.21	-2359.57	0.30	0.16	0.14	45.75	0.22	0.01	0.21	94.27	0.16	0.11	0.05	29.92
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	3.72	2.04	1.68	45.25	ND	ND	ND	ND	2.04	0.65	1.40	68.28	ND	ND	ND	ND
Diuron	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromacil	ug/l	0.07	0.07	0.00	-3.01	0.00	0.00	0.00	0.00	0.07	0.07	0.00	6.46	0.00	0.00	0.00	100.00
Atrazine	ug/l	0.01	0.01	-0.01	-95.08	0.02	0.01	0.00	28.57	0.01	0.01	0.01	39.66	0.01	0.01	0.01	58.90
Naphthalene	ug/l	0.08	0.02	0.04	67.67	ND	ND	ND	ND	0.02	0.02	0.00	-22.61	ND	0.00	ND	ND
Acenaphthylene	ug/l	0.03	ND	ND	ND	0.00	0.00	0.00	0.00	ND	0.02	ND	ND	0.00	0.00	0.00	100.00
Acenaphthene	ug/l	0.04	ND	ND	ND	ND	ND	ND	ND	ND	0.02	ND	ND	0.00	0.00	0.00	-47.50
Fluorene	ug/l	0.08	0.00	0.08	97.31	0.02	0.02	0.00	-28.76	0.00	0.00	0.00	-237.27	0.02	0.02	0.00	14.72
Phenanthrene	ug/l	0.04	0.03	0.01	25.97	0.06	0.04	0.00	5.56	0.03	0.024	0.01	22.16	0.04	ND	ND	ND
Anthracene	ug/l	0.08	0.02	0.04	65.21	0.06	0.04	0.01	19.75	0.02	0.032	-0.02	-66.21	0.04	ND	ND	ND
Fluoranthene	ug/l	0.12	0.10	0.02	13.93	0.23	0.22	0.01	5.09	0.10	0.03	0.07	66.55	0.22	0.01	0.20	93.24
Pyrene	ug/l	0.15	0.12	0.03	20.17	0.21	0.20	0.01	5.34	0.12	0.04	0.07	63.69	0.20	0.02	0.18	90.83
Benzo(a)anthracene	ug/l	0.12	0.04	0.08	66.73	0.13	0.13	0.01	3.79	0.04	0.03	0.02	35.14	0.13	0.01	0.12	95.27
Chrysene	ug/l	0.11	0.09	0.02	22.14	0.13	0.13	0.00	1.03	0.09	0.022	0.07	75.09	0.13	0.01	0.12	95.94
Benzo(b)fluoranthene	ug/l	0.09	0.09	0.00	-0.16	0.14	0.14	-0.01	-4.29	0.09	0.023	0.06	71.64	0.14	0.01	0.13	94.76
Benzo(k)fluoranthene	ug/l	0.10	0.09	0.01	11.16	0.06	0.06	-0.01	-11.35	0.09	0.02	0.07	74.56	0.06	ND	ND	ND
Benzo(a)pyrene	ug/l	0.12	0.12	-0.01	-6.67	0.13	0.13	0.00	-2.75	0.12	0.01	0.12	94.46	0.13	0.01	0.12	95.90
Indeno(1,2,3-cd)pyrene	ug/l	0.07	0.12	-0.05	-66.01	0.12	0.12	0.00	1.11	0.12	0.010	0.11	91.26	0.12	0.01	0.11	94.10
Dibenzo(a,h)anthracene	ug/l	0.06	0.09	-0.03	-41.76	0.03	0.03	0.00	-6.01	0.09	0.01	0.08	90.02	0.03	ND	ND	ND
Benzo(g,h,i)perylene	ug/l	0.04	0.06	-0.03	-64.97	ND	ND	ND	ND	0.06	0.01	0.05	83.56	ND	0.00	ND	ND
Na	mg/l	78.01	76.09	1.92	2.46	39.03	47.47	-8.44	-21.62	76.09	50.87	25.22	33.14	47.47	50.94	-3.47	-7.31
Hardness	mg/l	210.00	280.20	-60.20	-23.90	140.30	179.66	-39.36	-28.04	280.20	337.10	-66.90	-27.24	179.66	248.40	-60.71	-38.98
De-IcingSalts	mg/l	123.69	123.69	-0.01	-0.01	59.49	71.15	-11.66	-19.60	123.69	90.22	33.47	27.06	71.15	86.64	-15.49	-21.77
BOD	mg/l	14.67	4.21	10.76	71.66	4	2.66	1.66	38.14	4.21	3.78	0.43	10.24	2.66	2.75	1.11	28.72
COD	mg/l	71	54	17.34	24.36	77	63	13.97	18.11	53.69	38.52	15.06	28.18	63.16	49.69	13.48	21.34
TSS	mg/l	75	84	-8.69	-8.69	65	41	23.66	36.54	84.47	32.02	52.45	62.09	41.09	11.01	30.09	73.21
NH4-N	mg/l	0.13	0.17	-0.04	-31.72	0.05	0.13	-0.08	-165.96	0.17	0.18	-0.01	-7.63	0.12	0.12	0.00	0.00

ND = Not Detected

Table 5-9 Overall Treatment Efficiencies: M40/Souldern Brook and A34/Newbury Bypass

		Site 4 M40/Souldern Brook Location 2 & 3				Site 6 A34/Newbury Pond D Location 2 & 3				Site 4 M40/Souldern Brook Location 1 & 3				Site 6 A34/Newbury Pond D Location 1 & 3			
		Location 2 Full Retention Oil Separator	Location 3 Discharge to Watercourse			Location 2 Bypass Oil Separator	Location 3 Discharge to Watercourse			Location 1 Road Runoff	Location 3 Discharge to Watercourse			Location 1 Road Runoff	Location 3 Discharge to Watercourse		
		Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction
	Units																
Copper	ug/l	28.51	12.79	15.72	55.14	20.83	14.60	6.23	29.91	32.41	12.79	19.62	60.54	23.06	14.60	8.38	36.14
Filtered Copper	ug/l	11.58	7.48	4.10	35.86	14.65	9.41	5.24	35.77	11.82	7.48	4.37	36.97	16.53	9.41	7.12	43.07
Zinc	ug/l	87.57	38.52	49.05	55.91	35.81	39.98	-4.15	-11.67	97.99	38.52	59.46	60.69	52.60	39.99	12.61	23.97
Filtered Zinc	ug/l	20.39	14.89	5.50	26.97	14.05	23.06	-9.01	-64.13	29.01	14.89	14.12	48.67	21.37	23.06	-1.69	-7.91
Cadmium	ug/l	0.32	0.31	0.02	4.83	1.32	0.22	1.11	83.71	0.26	0.31	-0.06	-22.82	0.21	0.22	-0.01	-4.37
Aluminium	ug/l	618.98	198.97	420.01	67.86	97.99	50.20	47.79	48.77	739.25	198.97	540.28	73.08	101.98	50.20	51.78	50.77
Lead	ug/l	16.16	4.27	8.81	68.87	3.80	3.58	0.21	5.64	16.73	4.27	12.46	74.46	4.36	3.58	0.88	16.22
Platinum	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Palladium	ug/l	0.00	0.02	-0.02	0.00	0.13	ND	ND	ND	0.42	0.02	0.40	95.24	0.34	ND	ND	ND
Nickel	ug/l	4.16	3.86	0.32	7.66	4.93	5.47	-0.48	-9.79	4.04	3.86	0.18	4.46	4.68	5.47	-0.79	-16.92
Chromium	ug/l	4.80	3.54	1.26	26.71	3.16	3.32	-0.16	-5.06	7.73	3.54	4.19	54.20	2.72	3.32	-0.60	-22.06
Simazine	ug/l	0.22	0.01	0.21	94.27	0.16	0.11	0.05	29.62	0.01	0.01	ND	ND	0.30	0.11	0.19	61.60
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	2.04	0.65	1.40	68.39	ND	ND	ND	ND	3.73	0.65	3.08	82.59	ND	ND	ND	ND
Diuron	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bromacil	ug/l	0.07	0.07	0.00	5.46	0.00	0.00	0.00	100.00	0.07	0.07	ND	ND	0.00	ND	ND	ND
Atrazine	ug/l	0.01	0.01	0.01	39.86	0.01	0.01	0.01	50.00	0.01	0.01	ND	ND	0.02	0.01	0.01	62.26
Naphthalene	ug/l	0.02	0.02	0.00	-23.91	ND	0.00	ND	ND	0.06	0.02	0.04	66.16	ND	0.00	ND	ND
Acenaphthylene	ug/l	ND	0.02	ND	ND	0.00	0.00	0.00	100.00	0.03	0.02	ND	ND	0.00	0.00	0.00	100.00
Acenaphthene	ug/l	ND	0.02	ND	ND	0.00	0.00	0.00	-47.50	0.04	0.02	ND	ND	ND	0.00	ND	ND
Fluorene	ug/l	0.00	0.00	0.00	-227.27	0.03	0.02	0.00	14.72	0.06	0.05	ND	ND	0.02	0.02	0.00	-6.85
Phenanthrene	ug/l	0.03	0.024	0.01	22.16	0.04	ND	ND	ND	0.04	0.02	0.02	42.27	0.06	ND	ND	ND
Anthracene	ug/l	0.02	0.032	-0.02	-96.71	0.04	ND	ND	ND	0.05	0.03	0.02	37.83	0.06	ND	ND	ND
Fluoranthene	ug/l	0.10	0.03	0.07	66.50	0.22	0.01	0.20	93.24	0.12	0.03	0.09	71.20	0.23	0.01	0.22	93.85
Pyrene	ug/l	0.12	0.04	0.07	63.90	0.20	0.02	0.18	90.63	0.15	0.04	0.10	70.54	0.21	0.02	0.19	91.32
Benzo(a)anthracene	ug/l	0.04	0.03	0.02	39.14	0.13	0.01	0.12	95.27	0.12	0.03	0.10	79.42	0.13	0.01	0.13	95.34
Chrysene	ug/l	0.09	0.022	0.07	75.59	0.13	0.01	0.12	95.84	0.11	0.02	0.09	80.60	0.13	0.01	0.12	95.86
Benzo(b)fluoranthene	ug/l	0.08	0.023	0.06	71.64	0.14	0.01	0.13	94.78	0.08	0.02	0.06	71.59	0.14	0.01	0.13	94.53
Benzo(k)fluoranthene	ug/l	0.09	0.02	0.07	74.50	0.08	ND	ND	ND	0.10	0.02	0.08	77.40	0.06	ND	ND	ND
Benzo(a)pyrene	ug/l	0.12	0.01	0.12	94.45	0.13	0.01	0.12	95.69	0.12	0.01	0.11	94.14	0.13	0.01	0.12	95.46
Indeno(1,2,3-cd)pyrene	ug/l	0.12	0.010	0.11	91.30	0.12	0.01	0.11	94.18	0.07	0.01	0.06	85.21	0.12	0.01	0.11	94.21
Dibenzo(a,h)anthracene	ug/l	0.08	0.01	0.08	86.67	0.03	ND	ND	ND	0.06	0.01	0.05	83.02	0.03	ND	ND	ND
Benzo(g,h,i)perylene	ug/l	0.06	0.01	0.06	83.86	ND	0.00	ND	ND	0.04	0.01	0.03	73.38	ND	0.00	ND	ND
Na	mg/l	76.06	50.87	25.22	33.16	47.47	50.94	-3.47	-7.31	78.01	50.87	27.14	34.79	39.03	50.94	-11.91	-30.51
Hardness	mg/l	260.20	367.10	-86.90	-37.24	176.69	245.40	-68.71	-38.89	219.90	367.10	-147.10	-70.05	140.30	245.40	-105.10	-74.91
De-icing salts	mg/l	123.68	96.22	33.47	27.06	71.15	86.64	-15.49	-21.77	123.69	90.22	33.46	27.05	59.49	86.64	-27.15	-45.64
BOD	mg/l	4.21	3.79	0.43	10.24	3.89	2.79	1.11	28.72	14.97	3.79	11.18	74.78	5.52	2.79	2.77	50.21
COD	mg/l	53.58	38.52	15.06	28.10	63.16	49.66	13.49	21.34	70.82	38.52	32.30	45.61	77.10	49.60	27.48	35.59
TSS	mg/l	84.47	32.02	53.48	62.09	41.09	11.01	30.09	73.21	77.79	32.03	45.76	58.83	64.76	11.01	53.75	83.00
NH4-N	mg/l	0.17	0.18	-0.01	-7.63	0.13	0.13	0.00	0.06	0.13	0.18	-0.05	-41.84	0.08	0.13	-0.06	-165.96

ND = Not Detected

5.5 Treatment Efficiency Relationships with Event Characteristics

Graphs presented in Appendix G show treatment efficiency plotted for the key determinands, for each event, for the combinations of treatment facilities at each site. Anomalies have been examined to identify any relationship between treatment efficiency and event parameters.

Events where treatments have a better than average performance have been examined but no correlation between event characteristic and performance could be identified consistently.

Events where a negative performance was identified were also examined. A correlation with high total rainfall during the sampling period was identified at all sites with the exception of the A34/Newbury site. At this site there were also two events of 12.0mm and 11.0mm where treatment efficiency was better than average.

Plots of treatment efficiency for key determinands for each event at the M40/Souldern Brook site are presented in Figure 5-22, Figure 5-23 and Figure 5-24 for an illustration of the variable treatment efficiency at a single site for the monitored events. Events 1, 3 and 9 were identified as events during which little reduction in determinands was achieved. Correlation of poor treatment efficiency with event characteristics is shown in Table 5-10 for all monitored events.

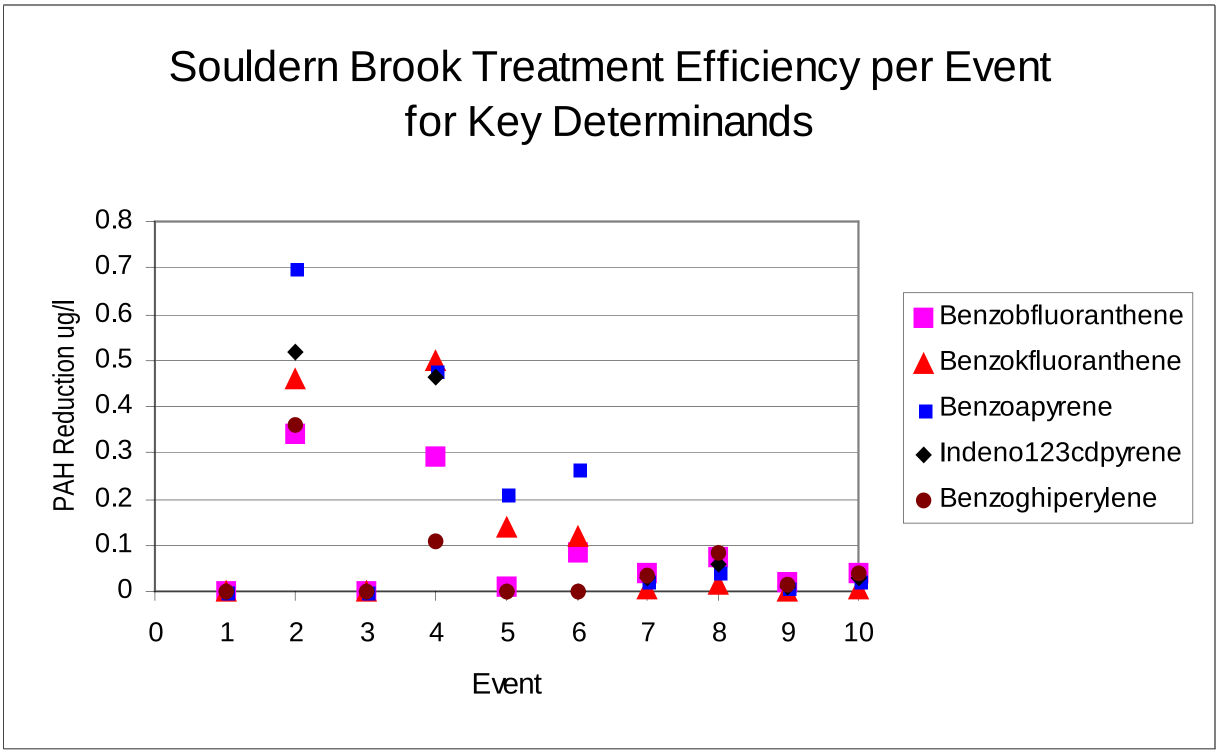


Figure 5-22 Reduction of key PAHs for each event - M40/Souldern Brook

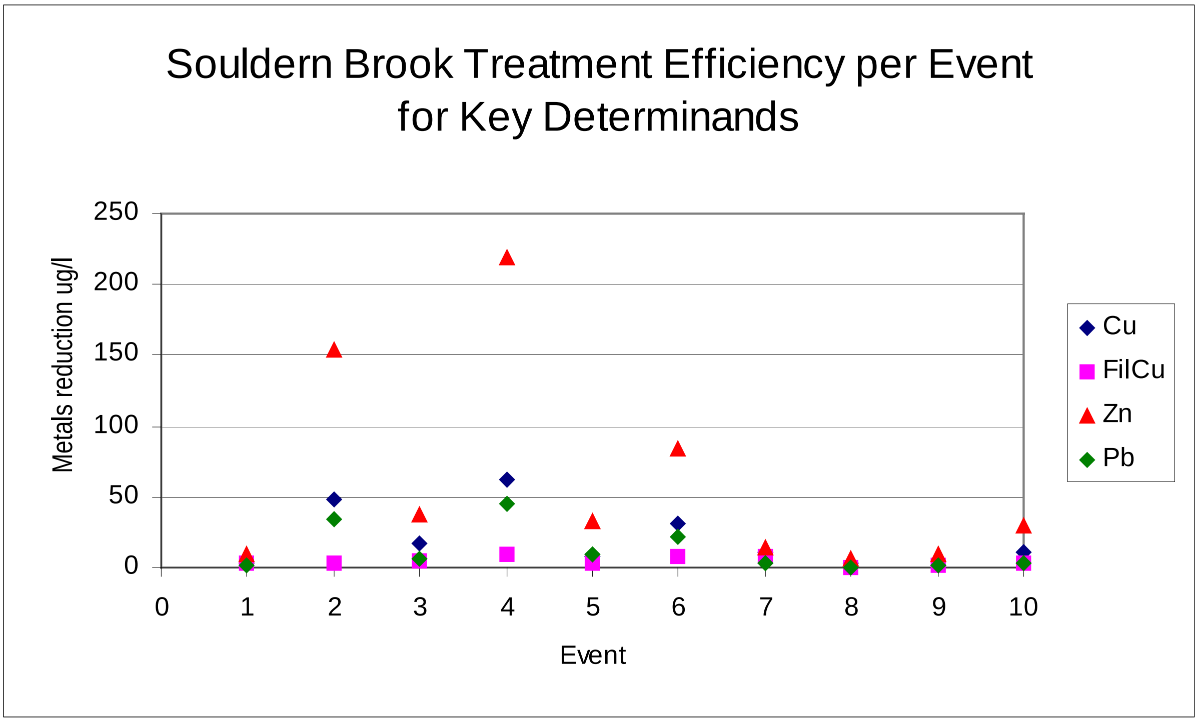


Figure 5-23 Reduction of key metals for each event - M40/Souldern Brook

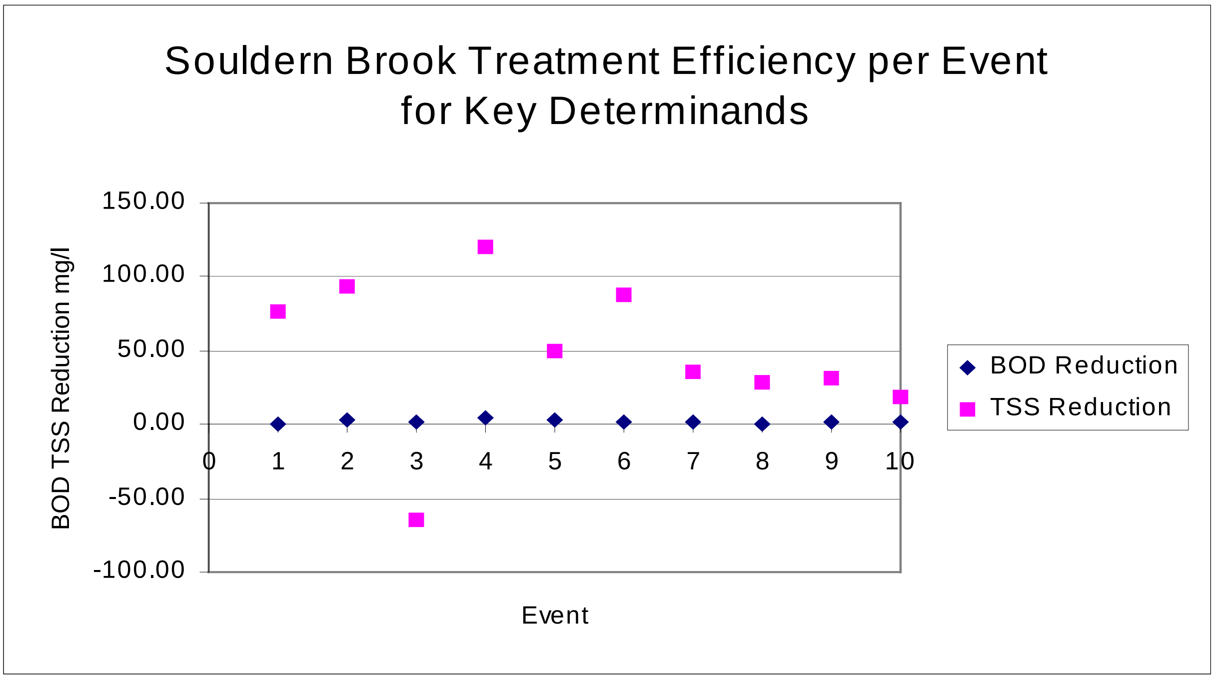


Figure 5-24 Reduction of BOD-TSS for each event - M40/Souldern Brook

Table 5-10 identifies the site, event and rainfall details of the events where poor treatment efficiency has been identified at all sites. For M40/Souldern Brook site, events 1, 3,and 9 were identified as resulting in a poor treatment efficiency. It can be seen that all event rainfall totals are greater than 5.2mm, but no correlation exists between poor performance and rainfall peak intensity.

Table 5-10 Event rainfall details associated with poor treatment efficiency

Site	Event	Total Rainfall	Peak Intensity
A417/River Frome	5	24.8	5.5
M4/River Ray	4	8.8	6.0
	9	13.0	6.3
	10	12.2	6.3
M40/Souldern Brook	1	13.4	84.0
	3	5.2	4.0
	9	15.0	12.0
A34/Gallos Brook	3	5.4	6.0
	4	9.8	36.0
	7	9.4	6.0
A34/Newbury	5	5.4	2.4
	6	8.8	12.0

Identification of an event total treatment efficiency threshold is not well defined due to the limited number of events and an unequal distribution of monitored event characteristics. However, from the data available a threshold of poor treatment efficiency of above c.5.0mm total event rainfall is indicated.

Comparison of treatment efficiency with event flow showed clustering of data due to the predominance of low flow and low intensity events. No consistent relationship could be reliably identified. Figure 5-25 and Figure 5-26, for the M40/Souldern Brook site, illustrate this clustering of event characteristics.

Figure 5-27 and Figure 5-28 for the M40/Souldern Brook site show that a consistent relationship between treatment efficiency and average rainfall intensity could not be identified.

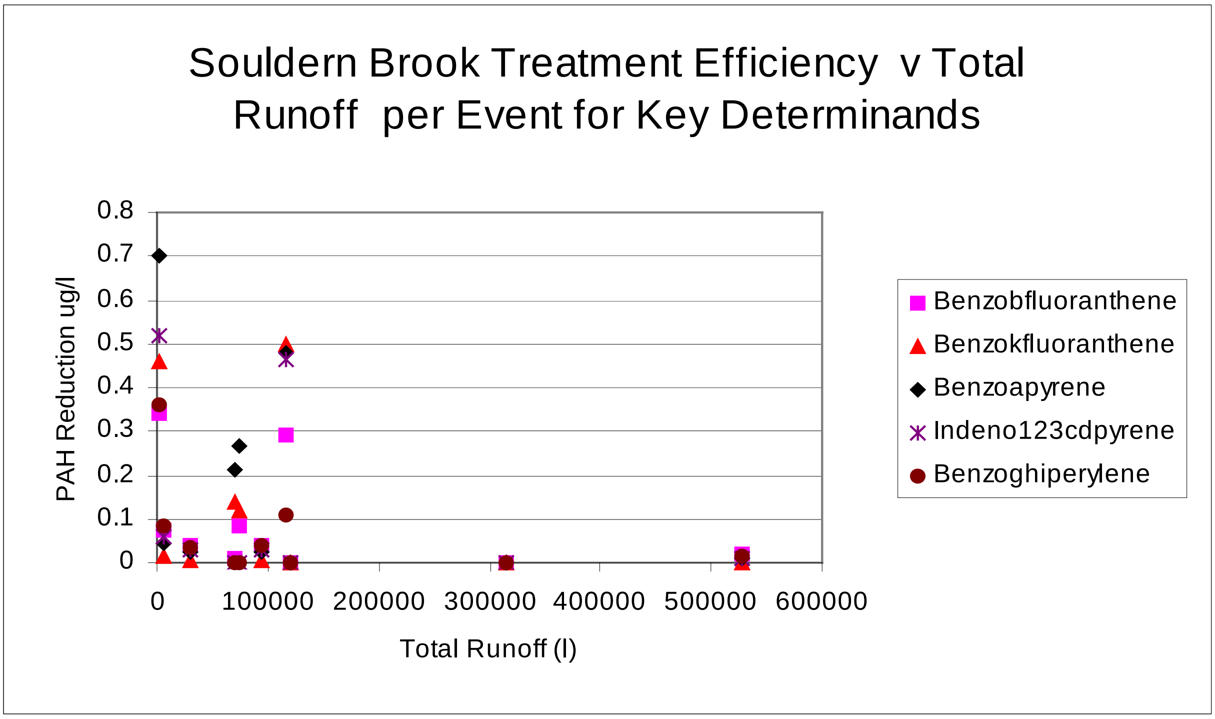


Figure 5-25 PAH Reduction v Total Runoff for each event - M40/Souldern Brook

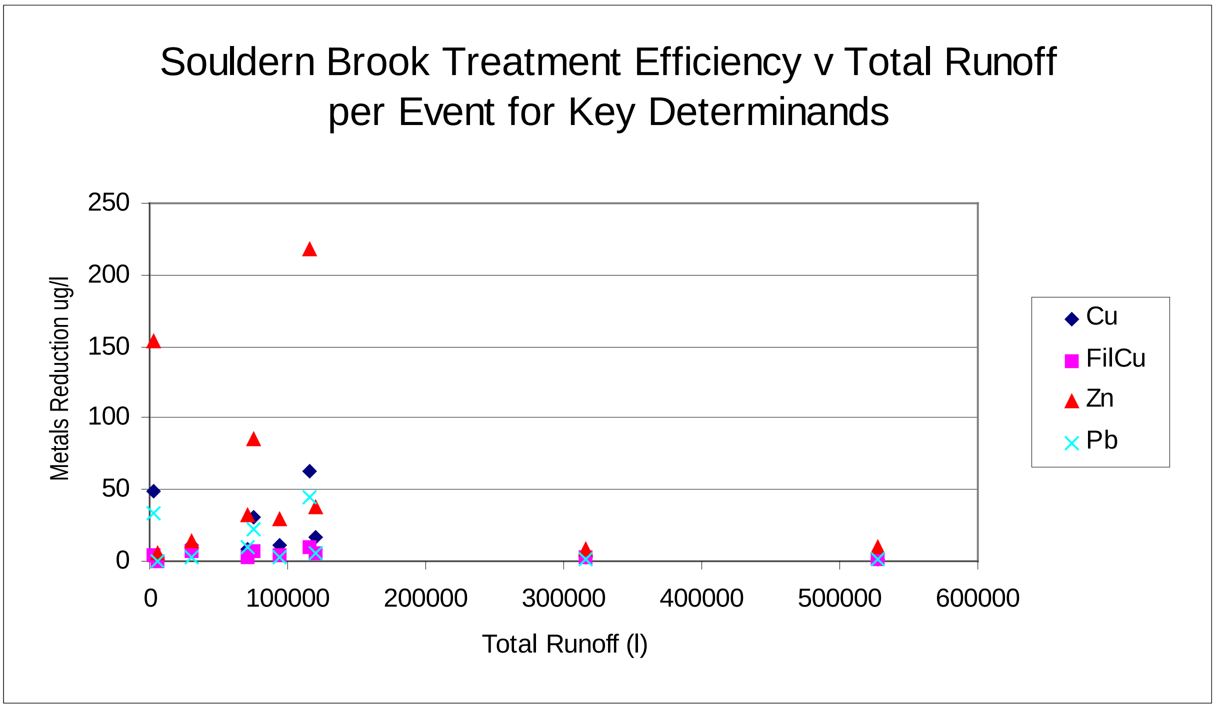


Figure 5-26 Metals Reduction v Total Runoff for each event - M40/Souldern Brook

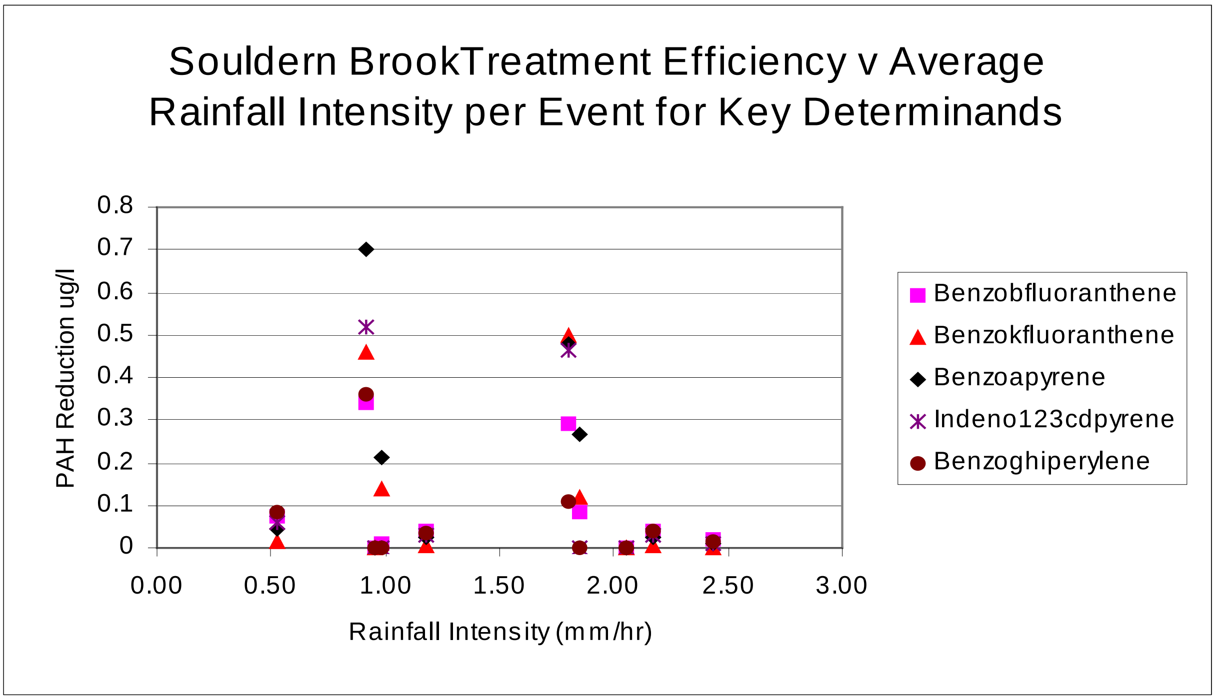


Figure 5-27 PAH Reduction v Average Rainfall Intensity for each event - M40/Souldern Brook

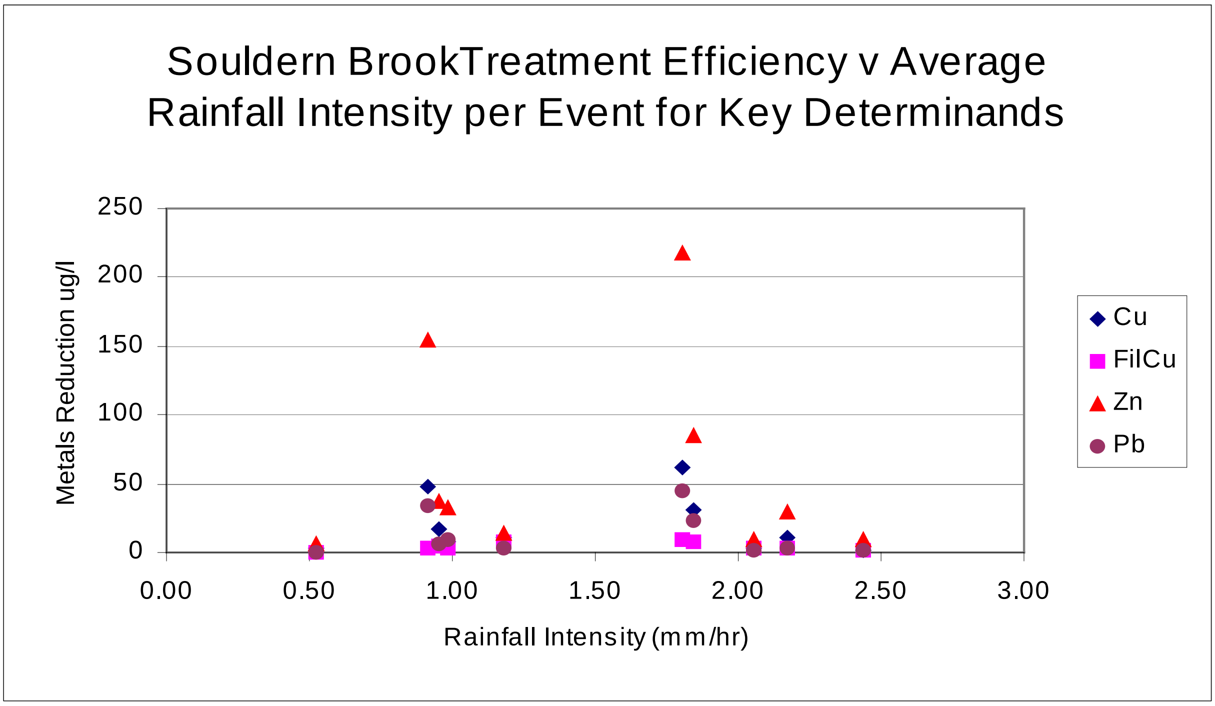


Figure 5-28 Metals Reduction v Average Rainfall Intensity for each event - M40/Souldern Brook

6. CONCLUSIONS

6.1 Highway Runoff Quality

A wide range of data have been collected for potential contaminants in highway runoff at six non urban highway locations in the central south of England over a four and a half year period from 1997 to 2002. Ten storm related runoff events have been captured at each site over a minimum one year monitoring period to represent a range of background highway and environmental conditions.

While the overall quantity of runoff data is large, with 60 events captured, the number of event data sets collected at individual sites is relatively small taking into consideration the observed variability of the events, background environmental conditions and highway characteristics. This has limited the identification of relationships between event and site characteristics and the resulting runoff quality at individual sites. In addition, the number of highway variables between sites has limited the conclusions that may be drawn from inter site comparisons of runoff, treatment device efficiency and environmental impact in the receiving watercourse.

A number of determinands were ‘Not Detected’ (Not present above the LOD) during a number of monitored rainfall events at one or more sites. These determinands have been identified as being not significant in non urban highway runoff as shown in Table 6-1. However, it is noted that the sites monitored do not represent the full range of characteristics across the highway network and, therefore, these determinands may not be ‘not significant’ elsewhere.

A number of determinands were detected at concentrations well above the LOD for all monitored rainfall events at all sites. Some determinands were detected at concentrations greater than the prescribed maximum and annual average concentrations identified for Drinking Water and Freshwater Environmental Quality Standards. These determinands have been identified as being ‘key determinands’ and are considered to be potentially significant pollutants in non urban highway runoff. These are also shown in Table 6-1.

The study identified a number of events at most sites where high concentrations of Aluminium were observed. These events appear to be related to winter salting. In general, levels of Aluminium were consistently higher than other metals. This is believed to be due to the total Aluminium analysis used that will have released Aluminium from clay mineral particles in suspension in the sample. Therefore, it is not possible to compare the results against water quality standards identified for soluble, or reactive Aluminium.

Table 6-1 Not significant and Key Determinands

Determinands	
Not significant	**Key**
Platinum	Copper (Total and Dissolved)
Palladium	Zinc
Simazine	Lead
Amitrole	Glyphosate
Diuron	Benzo(b)fluoranthene
Bromacil	Benzo(k)fluoranthene
Atrazine	Benzo(a)pyrene
Acenaphthylene	Indeno(123-cd)pyrene
Acenaphthene	Benzo(ghi)perylene
Fluorene	Na
Phenanthrene	BOD
Anthracene	TSS
Dibenzo(ah)anthracene	

The range of event mean flow weighted pollutant concentrations is higher than those quoted in the Design Manual for Roads and Bridges, Volume 11, Section 3:10, Water Quality and Drainage. The range of median concentrations quoted in Table 5 of the DMRB are derived from a study in the United States, published in 1990 and represent the median value calculated from event mean concentrations at a number of rural study sites.

The overall flow weighted event mean runoff quality for all the monitored determinands, and the range of individual event means at all sites, are summarised in Table 6-2.

Table 6-2 Observed event mean highway runoff quality

Determinand	EMC				Load/1000m^2	
	Units	Min	Max	Overall Mean	Units	Overall Mean
Copper	ug/l	23.98	67.92	41.00	mg/1000m2	60.59
Filtered Copper	ug/l	11.82	33.62	20.58	mg/1000m2	29.04
Zinc	ug/l	52.60	221.50	140.30	mg/1000m2	206.30
Filtered Zinc	ug/l	8.60	163.42	57.49	mg/1000m2	74.09
Cadmium	ug/l	0.21	0.99	0.49	mg/1000m2	0.61
Aluminium (Total)	ug/l	101.98	2848.00	1231.69	mg/1000m2	1315.36
Lead	ug/l	4.38	61.39	23.06	mg/1000m2	26.54
Platinum *	ug/l	ND	24.00	4.00	mg/1000m2	0.86
Palladium	ug/l	0.21	0.90	0.38	mg/1000m2	0.37
Nickel	ug/l	4.04	12.00	5.31	mg/1000m2	9.36
Chromium	ug/l	2.72	11.50	5.98	mg/1000m2	8.48
Simazine	ug/l	ND	0.30	0.06	ug/1000m2	199.31
Amitrole	ug/l	ND	0.00	ND	ug/1000m2	ND
Glyphosate	ug/l	ND	3.73	0.72	ug/1000m2	1142.52
Diuron	ug/l	ND	0.33	0.05	ug/1000m2	139.09
Bromacil	ug/l	ND	0.07	0.02	ug/1000m2	18.39
Atrazine	ug/l	ND	0.04	0.02	ug/1000m2	14.37
Naphthalene	ug/l	ND	0.52	0.11	ug/1000m2	32.26
Acenaphthylene	ug/l	0.00	0.06	0.02	ug/1000m2	16.18
Acenaphthene	ug/l	ND	0.08	0.02	ug/1000m2	30.54
Fluorene	ug/l	0.00	0.07	0.03	ug/1000m2	24.95
Phenanthrene	ug/l	0.02	0.19	0.08	ug/1000m2	74.74
Anthracene	ug/l	0.01	0.13	0.06	ug/1000m2	61.95
Fluoranthene	ug/l	0.08	0.23	0.16	ug/1000m2	276.92
Pyrene	ug/l	0.09	0.21	0.16	ug/1000m2	307.56
Benzo(a)anthracene	ug/l	0.05	0.16	0.11	ug/1000m2	160.59
Chrysene	ug/l	0.09	0.16	0.12	ug/1000m2	200.34
Benzo(b)fluoranthene	ug/l	0.05	0.20	0.14	ug/1000m2	217.00
Benzo(k)fluoranthene	ug/l	0.06	0.15	0.09	ug/1000m2	93.66
Benzo(a)pyrene	ug/l	0.08	0.24	0.15	ug/1000m2	232.27
Indeno(1,2,3-cd)pyrene	ug/l	0.08	0.13	0.11	ug/1000m2	171.84
Dibenzo(a,h)anthracene	ug/l	0.01	0.12	0.07	ug/1000m2	77.32
Benzo(g,h,i)perylene	ug/l	ND	0.14	0.08	ug/1000m2	51.40
Na	mg/l	39.03	374.02	171.51	g/1000m2	323.24
Hardness	mg/l	82.11	226.30	148.80	g/1000m2	360.43
De-icingSalts	mg/l	59.49	536.24	258.43	g/1000m2	526.73
BOD	mg/l	5.26	9.10	5.59	g/1000m2	14.17
COD	mg/l	61.19	137.66	88.62	g/1000m2	218.09
TSS	mg/l	45.79	317.97	114.68	g/1000m2	276.92
NH4-N	mg/l	0.36	0.13	0.25	g/1000m2	0.56

ND = Not detected
ND values used in averaging as zero
Key Determinands
Aluminium – see Section 4.1
*Platinum – only detected during two events at M4/BB site

A number of possible relationships associated with highway runoff quality can be proposed:

- There is a relationship between climatic season and highway runoff quality. Determinand concentrations, and in particular metals, appear in higher concentrations following winter salting. This may be a result of increased mobilisation of metals from vehicles and the highway surface, plus impurities in the salt applied, particularly Aluminium Silicate (Clay) particles.

- A relationship may exist between runoff concentration and rainfall intensity. Over the average rainfall intensity range of 0.5 to 4.0mm/hr, the relationship exists between reduced concentrations of metals and PAHs with increased average intensity for five of the six sites. At the sixth site, A34/Newbury, the relationship is reversed with increased concentrations and increased average intensity over the same range of average rainfall intensities. No reliable relationship can be inferred from BOD, COD, NH_4-N and TSS data.

However, the data did not exhibit the following potential relationships:

- No relationship can be identified between runoff concentrations and ADP. This finding is not consistent with previous studies. For example, CIRIA Report 142 states 'soluble species deposited by traffic……will collect more or less in proportion to the length of time since the last runoff event'. However, this is not specifically referenced to non urban highways. Further, Strecker et al (1990) state that 'the only factor that was demonstrated to have a statistically significant influence on pollutant concentrations is whether the site was in a rural or urban area' and that ambient air quality differences between urban and rural areas may be more important than the actual traffic density. In the latter case, traffic density can be considered to be a factor in relation to the effect of ADP in terms of the potential for the accumulation of pollutants between storm events.
- No relationship can be identified between runoff concentrations and event total rainfall.
- No relationship can be identified between runoff concentrations and event duration.
- No relationship can be identified between runoff concentrations and traffic flow, carriageway catchment area and carriageway width. However, runoff loads are, as can be expected, related to the carriageway catchment area and carriageway width.

6.2 Treatment Efficiency

Assessment of treatment efficiency indicates that there is a wide range of pollution removal efficiencies of the individual and combination treatment devices at the monitored sites. The following conclusions can be drawn from the monitoring exercise:

- There was insufficient information available on the original design and construction of the majority of devices to compare the observed performance against the original design criteria in terms of event characteristics, such as peak flows and residence times.

- Treatment efficiency could not be reliably determined for the bypass and full retention oil separators due to variability of results and site characteristics as the inflow pipes were steep, giving high flow velocities into the separators. In addition, the low observed treatment efficiency may also be a reflection of the low measured concentrations of PAHs in the highway runoff.

- The oil trap manhole provided no reduction of determinands. However, this could be a reflection of the characteristics of the monitored site.

- The sedimentation tank showed little reduction of determinands in the liquid samples but significant trapping of determinands attached to sediments.

- The dry balancing pond showed good reduction of metals but indeterminate PAH removal efficiency.

- The wet ponds showed a significant reduction of PAHs, metals and accumulation of contaminated sediments.

- A relationship exists between treatment efficiency of suspended determinands and retention time of contaminated runoff.

- Sediment analysis indicates significant accumulations of attached determinands within treatment devices.

The average treatment efficiencies of the monitored devices and combinations of devices are summarised in Table 6-3.

Table 6-3 Average treatment efficiency of devices and combinations

Site/Device		**Initial form of treatment** % Reduction	**Second form of treatment** % Reduction	**Total treatment** % Reduction
A34/Newbury Bypass oil Separator/Wet Balancing Pond with Reeds	Metals	15	11	24
	PAH	-1	99	99
	TSS	37	73	83
M40/Souldern Brook Full retention Oil Separator/Wet Balancing Pond	Metals	19	35	48
	PAH	13	50	57
	TSS	-9	62	58
Gallos Brook Filter Drain	Metals	7		7
	PAH	52	N/A	52
	TSS	38		38
A417/River Frome Bypass oil separator/Dry Balancing Pond	Metals	27	39	56
	PAH	4	16	22
	TSS	56	-37	40
M4/River Ray Oil Trap Manhole/Sedimentation Tank	Metals	-7	41	30
	PAH	-30	-26	indeterminate
	TSS	-19	43	33

6.3 Receiving Water Impact and Biological surveys

Event monitoring and background monitoring in the receiving waters at the five sites where data could be collected showed no apparent impact of highway runoff over background and upstream conditions.

Sediment analysis shows little significant accumulation of contaminated sediments downstream of highway runoff discharges in watercourses.

Biological surveys were undertaken at five sites receiving either treated or untreated highway drainage. The results suggest that:

- macro-invertebrate communities located below the range of treatment options available at the five sites are not affected by treated runoff.

- Macro-invertebrate communities located below discharges of untreated runoff may be marginally affected but that changes are too small to draw firm conclusions. It has not been possible to eliminate the possibility that confounding effects such as changes in macro-invertebrate habitat quality and life cycle induced changes in community composition are responsible for the observed changes.

- Highway drainage from the five sites appears not to have adversely affected macro-invertebrate communities in receiving waters. This differs from previous studies where impacts have been reported from sites impacted by runoff from urban highways.

6.4 Summary of Conclusions

- Key determinands have been identified in runoff from six non urban highway sites.

- Contaminants in highway runoff are higher in winter, possibly as a consequence of salting.

- Observed event mean flow weighted concentrations of key determinands appear to be greater than concentrations found in previous studies.

- The pollution removal/retention efficiency of runoff treatment in a range of drainage devices and systems has been quantified. The greatest monitored efficiencies were produced by the bypass oil separator and wet pond-surface flow wetland in combination, producing the best quality discharge to watercourse with a combined device efficiency of 24%, 99% and 83% for metals, PAHs and TSS respectively.

- Little impact on the river quality and ecology was identified at sites downstream of highway runoff discharges compared to upstream locations. The impact of the observed concentrations in highway runoff will be related to the physical characteristics and environmental requirements of the receiving water. The results differ from those of previous biological studies on the impact of runoff from urban highways.

- All data collected in the course of the study have been archived in a database that can be used to support further analysis, investigation and interpretation.

- There was little information available on the original designs and the design criteria of the drainage systems. In some cases, the actual systems were different to those proposed and shown on available drawings for the study sites.

Overall, the results from the study seem to differ from previous studies of runoff quality and receiving water impact that have largely been associated with urban highways, higher traffic densities and different regional climates and receiving water characteristics.

7. REFERENCES

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APPENDIX A DETERMINAND SUITES

STORM EVENT COMPOSITE LIQUID SAMPLES - ANALYSIS SUITE

Polyaromatic Hydrocarbons	**Units**	**LOD***
Napthalene	µg/l	0.01-0.05
Acenapthylene	µg/l	0.01-0.05
Acenapthene	µg/l	0.01-0.05
Fluorene	µg/l	0.01-0.05
Phenanthrene	µg/l	0.01-0.05
Anthracene	µg/l	0.01-0.05
Fluoranthene	µg/l	0.01-0.05
Pyrene	µg/l	0.01-0.05
Benzo(a)anthracene	µg/l	0.01-0.05
Chrysene	µg/l	0.01-0.05
Benzo(b)fluoranthene	µg/l	0.01-0.05
Benzo(k)fluoranthene	µg/l	0.01-0.05
Benzo(a)pyrene	µg/l	0.01-0.05
Indeno(1,2,3-cd)pyrene	µg/l	0.01-0.05
Dibenzo(a,h)anthracene	µg/l	0.01-0.05
Benzo(g,h,i)perylene	µg/l	0.01-0.05

Herbicides		
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

Metals	**Units**	**LOD***	**LOD ICPMS**
Copper (total)	µg/l	4.0	0.3
Copper (dissolved)	µg/l	4.0	0.3
Zinc (total)	µg/l	4.0	0.6
Zinc (dissolved)	µg/l	4.0	0.6
Cadmium	µg/l	4.0	0.001
Aluminium	µg/l	40.0	0.4
Lead	µg/l	50.0	0.1
Platinum	µg/l	0.1	0.15
Palladium	µg/l	0.1	0.5
Nickel	µg/l	10.0	0.01
Chromium	µg/l	10.0	0.3
Sodium	mg/l	0.5	
Hardness ($CaCo_3$)	mg/l	0.5	
Chloride	mg/l	0.2	0.2
BOD	mg/l	1.0	
COD	mg/l	**20.0**	
TSS	mg/l	1.0	
NH_4-N	mg/l	0.05	

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

SEDIMENT SAMPLES - ANALYSIS SUITE

Polyaromatic Hydrocarbons	Units	LOD*	Metals	Units	LOD*
Napthalene	$\mu g/gx10^3$	0.01-0.1	Copper	µg/g	0.25
Acenapthylene	$\mu g/gx10^3$	0.01-0.1	Zinc	µg/g	0.1
Acenapthene	$\mu g/gx10^3$	0.01-0.1	Cadmium	µg/g	0.1
Fluorene	$\mu g/gx10^3$	0.01-0.1	Aluminium	µg/g	1.0
Phenanthrene	$\mu g/gx10^3$	0.01-0.1	Lead	µg/g	1.0
Anthracene	$\mu g/gx10^3$	0.01-0.1	Platinum	µg/g	2.0
Fluoranthene	$\mu g/gx10^3$	0.01-0.1	Palladium	µg/g	2.0
Pyrene	$\mu g/gx10^3$	0.01-0.1	Nickel	µg/g	0.5
Benzo(a)anthracene	$\mu g/gx10^3$	0.01-0.1	Chromium	µg/g	0.1
Chrysene	$\mu g/gx10^3$	0.01-0.1			
Benzo(b)fluoranthene	$\mu g/gx10^3$	0.01-0.1			
Benzo(k)fluoranthene	$\mu g/gx10^3$	0.01-0.1	**Organic content**	%	0.1
Benzo(a)pyrene	$\mu g/gx10^3$	0.01-0.1			
Indeno(1,2,3-cd)pyrene	$\mu g/gx10^3$	0.01-0.1			
Dibenzo(a,h)anthracene	$\mu g/gx10^3$	0.01-0.1			
Benzo(g,h,i)perylene	$\mu g/gx10^3$	0.01-0.1			
Weathered Diesel/Carboxylic Acids	mg/kg	1.0			

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

APPENDIX B METHOD SUMMARIES

METHOD SUMMARY - PARTICLE SIZE ANALYSIS

Brixham Environmental Laboratory utilises a Malvern Mastersizer Microplus laser dispersion optical particle size analyser, from Malvern Instruments Limited, Spring Lane South, Malvern, Worcestershire, WR14 1AT, UK, model number MAF5001.

Specification

Principle	Laser diffraction with Mie scattering
Displayed size range	0.05µm - 556 µm
Result display resolution	61, optional 100 size bands logarithmically spaced
Samples	Powder or liquid samples in liquid dispersant
Sample quantities	Typically less than 5ml
Sample density	Typically 1 - 6 g cm^{-3}
Dispersant vessel	600 ml or 1 litre borosilicate glass
Particle suspension	Combined pump and stirrer, manual speed control 0-4000 rpm, digital readout
Particle dispersion	Ultrasonic probe in Dispersant vessel. Control of tip displacement 3 to 20µm, digital readout
Software control	External 486DX running Microsoft Windows and Mastersizer software

Principle of Operation

The Mastersizer is based on the principle of laser ensemble light scattering. It falls into the category of non-imaging optical systems due to the fact that size recognition is accomplished without forming an image of the particle onto a detector.

The Mastersizer employs two forms of optical configuration to provide measurement of Fraunhofer refraction. The first is the common optical method known as “conventional Fourier optics”. The second, “reverse Fourier optics”, is used in order to allow the measurement size range to be extended down to 0.05µm.

Typically 100 - 10,000 particles may be present in the analyser beam, produced by a low power Helium-Neon laser, at any one moment and an integral of the individual diffusion patterns from each particle is received at a detector for analysis of the particle size distribution. Time averaged observation of the scattering is used to ensure that a representative analysis of the bulk sample is achieved as the material is continuously passed through the analyser beam.

Measurement capabilities

Laser light scattering is an exceptionally flexible sizing technique able, in principle, to measure the size structure of any one material phase in another. The only qualification of the technique is that each phase must be optically distinct from the other and the medium must be transparent to laser light wavelength. This means, in practice, that the refractive index of the material must be different from that of the medium in which it is supported. The table below indicates the range of measurement potential open to laser scattering analysis, the blanks indicate that no common applications exist rather than a theoretical failure of the system to make a measurement.

		Particle material		
		Solid	Liquid	Gas
Suspension medium	Solid	Reference standards (reticules).		
	Liquid	Liquid dispersed powders. Cohesive powders.	Emulsions. 2-phasic fluids.	Bubbles.
	Gas	Powders not liquid dispersible. Pneumatic transport. Soluble powders.	Fuel sprays. Paints. Aerosols. Inhalers.	

The main benefits from use of the technique are:

- It is non-intrusive, using a low power laser beam to probe the particle size.
- It is fast, requiring typically less than 1 minute to take a measurement and analyse.
- It is precise, giving high resolution size discrimination.
- It is wide ranged. User selected ranges appropriate for each sample cover 18000:1.
- It is absolute. Calibration is not required since the instrumental principles are based on fundamental physical properties.
- It is simple.
- It is highly versatile.

Results are typically presented in phi or Witworth band divisions equating to the traditional sieve sizes. Eight phi band divisions allow analysis of particle distributions from 64mm to 63µm. Where fine particles are of interest, the sub-63µm fraction can be further analysed by use of a further four phi divisions allowing particles down to 4µm to be assessed. Custom analyses can be tailored to suit specific purposes, such as where critical size limits exist for acceptability criteria. The minimum size particle technically measurable is 0.05µm.

OTHER SEDIMENT ANALYSES

Measurement of organic matter content by loss on ignition, total carbonate and moisture content are available using standard methodology.

METHOD SUMMARY – ING 101 ICP-OES

Determinand	:	Ag, Al, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, P, Pb, S, Si, Sr, Ti, V, Zn, Zr
Method	:	Inductively Coupled Plasma Atomic Emission Spectrometry (ICPAES)
Sample Types	:	Potable and fresh waters, sewage effluents, industrial and waste waters
Principle	:	All aqueous samples are collected into nitric acid. Waste samples are pre-treated before analysis. The sample is introduced in aerosol form into an argon plasma which is maintained at a temperature of ca 7000K. The plasma is produced and sustained by electromagnetic coupling through a coil in an RF circuit. Determinands in the sample are exited in the plasma and emit radiation at characteristic wavelengths. The signals are measured and converted to a concentration for each individual determinand on the basis of standard calibration and interference corrections previously undertaken for these determinands.
Reference	:	SCA publication : “Inductively Coupled Plasma Spectrometry, 1996”, Methods for the Examination of Waters and Associated Materials, HMSO & Chemical Analysis - A Series of Monographs on Analytical Chemistry and its Applications, Volume 90, “Inductively Coupled Plasma Emission Spectroscopy”, PWJM Boumans, John Wiley and Sons, 1987

Approved	:	Carlo Frate
		Quality Manager
Date	:	17.9.01
UKAS Procedure	:	ING101

Performance Characteristics

Determinand	Reporting Limit (mg/l)	Range of Application (mg/l)	Precision Data	
			Concentration (mg/l)	R.S.D (%)
Ag	0.004	10.0	0.55	1.0
Al	0.040	10.0	5.50	0.9
* B	0.01	50.0		
Ba	0.002	5.0	0.55	1.0
Be	0.001	0.1	0.055	1.5
Ca	0.1	1000	5.50	0.9
Cd	0.004	10.0	0.55	2.0
Co	0.005	10.0	0.55	1.3
Cr	0.01	10.0	0.55	2.2
Cu	0.004	20.0	0.55	0.9
Fe	0.004	100.0	0.55	4.7
K	0.2	500.0	5.50	1.9
* Li	0.005	1.0		
Mg	0.01	200.0	5.50	1.4
Mn	0.002	20.0	0.55	1.3
Mo	0.005	10.0	0.55	1.9
Na	0.05	500.0	5.50	1.3
Ni	0.01	10.0	0.55	1.3
P	0.05	50.0	5.50	3.3
Pb	0.05	50.0	5.50	1.9
S	0.1	50.0	5.50	0.7
Si	0.03	50.0	0.55	1.3
Sr	0.002	10.0	0.55	1.2
* Ti	0.005	10.0		
V	0.004	10.0	0.55	1.4
Zn	0.004	50.0	0.55	2.3
* Zr	0.004	5.0		

All precision data based on estimates with at least 10 degrees of freedom

* Non-routine parameters

METHOD SUMMARY –ING 113 ICPMS

Determinands	:	Ag, Al, As, B, Ba, Be, Cd, Co, Cr, Cu, Fe, Li, Mn, Mo, Ni, Pb, Pd, Pt, Se, Sr, Tl, V, Zn
Method	:	Inductively Coupled Plasma - Mass Spectrometry – ING 113
Sample Types	:	Potable, raw, surface and groundwaters.
Principle	:	All aqueous samples are collected into nitric acid. The sample is spiked with internal standard and is introduced in aerosol form into an argon plasma which is maintained at a temperature of ca 7000K. The plasma is produced and sustained by electromagnetic coupling through a coil in an RF circuit. Determinands in the sample are ionised in the plasma, and a small portion of these ions are sampled and introduced into the mass spectrometer. The ions are separated (and identified) by their mass:charge ratio and are detected using a dynode array detector.
Reference	:	SCA Publication “Inductively Coupled Plasma Spectrometry 1996”, Methods for the Examination of Waters and Associated Materials, HMSO (ISBN 011 753244 4)

Approved	:	Carlo Frate
		Quality Manager
Date	:	17.9.01
UKAS Procedure	:	ING113

Performance Characteristics

Determ inand	Limit of Detection (a) (μg/l)	Range of Application (μg/l)	Precision Data (b)	
			Concentration (μg/l)	RSD (%)
Ag	0.10	200	20	1.5
Al	0.40	200	20	3.1
As	0.10	200	20	1.1
B	5.7	200	180	1.2
Ba	0.03	200	20	2.1
Be	0.03	200	20	2.8
Cd	0.01	200	20	1.1
Co	0.01	200	20	2.2
Cr	0.30	200	20	1.9
Cu	0.30	200	20	1.4
Fe	20	200	180	3.4
Li	0.06	200	20	3.5
Mn	0.04	200	20	1.8
Mo	1.2	200	20	2.6
Ni	0.01	200	20	1.3
Pb	0.10	200	20	2.6
Pd	0.5	200	20	1.5
Pt	0.15	200	20	1.8
Se	0.9	200	20	2.8
Sr	0.04	200	20	2.7
Tl	0.01	200	20	2.6
V	0.05	200	20	1.4
Zn	0.6	200	20	2.1

(a) As detailed in NS30 - ‘A Manual on Analytical Quality Control for the Water Industry’

(b) All precision data based on estimates with at least 10 degrees of freedom.

METHOD SUMMARY – ING 25

Determinands	:	Cl^-, SO_4^{2-}, NO_3^-, NO_2^-, PO_4^{3-}
Method	:	Ion Chromatography – ING 25
Sample Types	:	Surface waters, potable and treated waters, groundwaters, waste waters (e.g. leachates, industrial effluents)
Principle	:	The ions are separated by passing them through the anion-exchange column (AS9C) of an ion chromatograph (Dionex DX300) using a carbonate / bicarbonate eluent. The ions are detected, after chemical suppression of the eluent, with a conductivity detector. The system is calibrated using standards of known concentration.
Reference	:	SCA publication : “The Determination of Anions and Cations, Transition Metals, Other Complex Ions and Organic Acids and Bases in Water by Chromatography 1990” , Methods for the Examination of Waters and Associated Materials, HMSO

Approved	:	Carlo Frate Quality Manager
Date	:	17.9.01
UKAS Procedure	:	ING25

Performance Characteristics

Determinand	Reporting Limit (mg/l)	Range of Application (mg/l)	Precision Data	
			Concentration (mg/l)	Std. Devn. (mg/l)
Cl^-	0.2	60.0	13.6	1.9
NO_2^-	0.06	2.5	1.41	0.05
NO_3^-	0.05	20.0	0.54	0.02
PO_4^{3-}	0.13	5.0	2.6	0.05
SO_4^{2-}	0.2	80.0	13.0	0.27

All precision data based on estimates with at least 10 degrees of freedom

METHOD SUMMARY – ING 28

Determinand : Ca, Mg

Method : Flame Atomic Absorption Spectrometry

Sample Types : Waters : Potable, Raw, Groundwater's etc.

Wastes : Sewage and Industrial Effluents

Principle : All aqueous samples are collected into nitric acid. Waste waters are pre-treated to solubilise suspended material before analysis. Interference's which are caused by substances that produce refractory compounds (e.g. aluminium compounds, phosphates, sulphates and silicates) are minimised by the addition of a lanthanum salt

The treated liquid sample is aspirated into an air-acetylene flame where the determinands of interest absorb light of a characteristic wavelength.

Reference : SCA publications: "Lithium, Magnesium, Calcium, Strontium and Barium in Waters and Sewage Effluents by Atomic Absorption Spectrophotometry 1987", Methods for the Examination of Waters and Associated Materials, HMSO

Performance Characteristics

Determinand (UKAS Procedure)	**Reporting Limit (mg/l)**	**Range of Application (mg/l)**	**Precision Data**	
			Concentration	Standard Devn (mg/l)
Ca	0..01	4.0	2.50	0.04
Mg	0.01	10.0	0.625	0.006

All precision data based on estimates with at least 10 degrees of freedom

Approved : Carlo Frate Quality Manager

Date : 17.9.01

UKAS Procedure : ING 28

METHOD SUMMARY – ING 28

Determinand : Cd, Cu, Pb, Ni, Zn, Fe, Mn

Method : Flame Atomic Absorption Spectrometry – ING 28

Sample Types : Waters : Potable, Raw, Groundwaters etc

Wastes : Sewage and Industrial Effluents

Principle : All aqueous samples are collected into nitric acid. Waste waters are pre-treated to solubilise suspended material before analysis. The liquid sample is aspirated into an air-acetylene flame where the determinands of interest absorb light of a characteristic wavelength.

Reference : SCA publications: "Cadmium (1976), Lead (1976), Zinc (1980), Copper (1980), Nickel (1981), Iron and Manganese (1983) in Potable Waters by Atomic Absorption Spectrophotometry", Methods for the Examination of Waters and Associated Materials, HMSO

Performance Characteristics

Determinand (UKAS Procedure)	**Reporting Limit (mg/l)**	**Range of Application (mg/l)**	**Precision Data**	
			Concentration	R.S.D. (%)
Cd (ING28)	0.004	1.000	0.619	1.0
Cu (ING28)	0.010	4.00	2.44	1.7
Fe (ING28)	0.010	4.00	2.52	1.6
Mn (ING28)	0.004	1.000	0.626	1.1
Ni (ING28)	0.025	4.00	2.54	0.9
Pb (ING28)	0.05	4.00	2.50	1.5
Zn (ING28)	0.004	1.000	0.624	1.0

All precision data based on estimates with at least 10 degrees of freedom

Nominal values for the solutions are 2.50 mg/l and 0.625 mg/l

Approved : Carlo Frate Quality Manager

Date : 17.9.01

METHOD SUMMARY – ING 28

Determinand	:	Na, K, Li
Method	:	Flame Atomic Emission Spectrometry – ING 28
Sample Types	:	Waters : Potable, Raw, Groundwaters etc Wastes : Sewage and Industrial Effluents
Principle	:	All aqueous samples are collected into nitric acid. Waste waters are pre-treated to solubilise suspended material before analysis. The liquid sample is aspirated into an air-acetylene flame where the determinands of interest emit light of a characteristic wavelength.
Reference	:	SCA publications: “Dissolved Potassium...”, “Dissolved Sodium in Raw and Potable Waters 1980”, Methods for the Examination of Waters and Associated Materials, HMSO

Performance Characteristics

Determinand (UKAS Procedure)	**Reporting Limit (mg/l)**	**Range of Application (mg/l)**	**Precision Data**	
			Concentration	Standard Devn (mg/l)
Na	0.01	10.0	4.0	0.03
K	0.01	10.0	4.0	0.09
Li	0.001	1.0	0.625	0.006

All precision data based on estimates with at least 10 degrees of freedom

Approved	:	Carlo Frate Quality Manager
Date	:	17.9.01
UKAS Procedure	:	ING 28

METHOD SUMMARY - 77

Determinand	:	Suspended Solids
Method	:	Gravimetric
Sample Types	:	Potable and fresh waters, industrial effluents and sewage effluents
Principle	:	A measured volume of homogenous sample is filtered, under vacuum, through a GF/C glass fibre filter which has previously been washed, dried at 105'C and weighed. The filter with the collected solids is then dried at 105'C for 2 hours, allowed to cool in a desiccator and reweigh. The suspended solids of the sample is calculated from the weight difference and the volume of sample filtered and expressed in mg/l.
Reference	:	SCA publication: "Suspended, settable and total dissolved solids in waters and effluents, 1980", Methods for the Examination of Waters and Associated Materials, HMSO

Performance Characteristics

Range of Application : 0 - >10000 (dependent upon sample volume)

Reporting Limit : 2 mg/l

Precision Data :

	Concentration (mg/l)	Standard Deviation (mg/l)
Standards	100	1.3 (>10)
	200	4.8 (>30)
Samples	600	4.4 (>10)

Figures in brackets - degrees of freedom

Approved : Carlo Frate Quality Manager

Date : 17.9.01

UKAS Procedure : ING77

METHOD SUMMARY – ING 88

Determinand	:	Biochemical Oxygen Demand (BOD) 5-day
Method	:	Dissolved Oxygen Probe
Sample Types	:	Potable and fresh waters, industrial and waste waters, saline and estuarine samples, sewages and sewage sludges
Principle	:	BOD is an empirical test in which standardised laboratory procedures are used to determine the relative oxygen requirements of a sample. The aerated sample, diluted if necessary, is incubated for 5 days at 20°C in the dark. The amount of oxygen consumed is determined by measurement of the initial and final dissolved oxygen concentrations from which the BOD is calculated. Allyl thiourea (ATU) is added to suppress nitrification.
Reference	:	SCA Publication : "5-day Biochemical Oxygen Demand (BOD_5) Second Edition 1988 (with amendments to Dissolved Oxygen in waters)". Methods for the Examination of Waters and Associated Waters, HMSO

Performance Characteristics

Range of Application	:	ca 1.0 - 7.0 mg/l O_2 (undiluted sample)
Reporting Limit	:	ca 1.0 mg/l O_2 (undiluted sample)

Precision Data :

	Concentration (mg/l O_2)	Standard Deviation (mg/l O_2)
Standards	1.1	0.1 (>10)
	5.0	0.3 (>10)

Figures in brackets - degrees of freedom

Approved	:	Carlo Frate Quality Manager
Date	:	17.9.01
UKAS Procedure	:	ING88

METHOD SUMMARY – ING 89

Determinand	:	Chemical Oxygen Demand (COD)
Method	:	Digestion / Titration
Sample Types	:	Potable and fresh waters, industrial and waste waters, saline and estuarine samples, sewages and sewage sludges
Principle	:	COD is an empirical test in which standardised laboratory procedures are used to determine the relative oxygen requirements of a sample. The sample is oxidised by digestion with sulphuric acid and potassium dichromate in a sealed tube with a silver salt as catalyst. The amount of dichromate reduced after heating for 2 hours is expressed as mg/l O_2
Reference	:	SCA Publication : "Chemical Oxygen Demand (Dichromate Value) of Polluted and Waste Waters 1986 (Second Edition). Methods for the Examination of Waters and Associated Waters

Performance Characteristics

Range of Application	:	up to 400 mg/l O_2 (undiluted sample)
Reporting Limit	:	10 mg/l O_2 (undiluted sample)

Precision Data :

	Concentration (mg/l O_2)	Standard Deviation (mg/l O_2)
Standards	80	5.1(>10)
	360	5.9 (>10)

Figures in brackets - degrees of freedom

Approved	:	Carlo Frate Quality Manager
Date	:	17.9.01
UKAS Procedure	:	ING89

METHOD SUMMARY – ING 91

Determinand	:	Loss on Ignition at 550°C
Method	:	Gravimetric
Sample Types	:	Solid Samples
Principle	:	A representative portion of the sample is dried at 105°C. A known weight of this sample is then ashed at 550°C for a minimum of 30 minutes. The sample is then cooled and reweigh, the difference in weight is the loss on ignition.

Performance Characteristics

Range of Application	:	0-100%
Reporting Limit	:	0.1%
Precision Data	:	Not Applicable

Approved	:	Carlo Frate Quality Manager
Date	:	17.9.01
UKAS Procedure	:	ING91

APPENDIX C EVENT MEAN CONCENTRATIONS

		Site 1 M4/Brinkworth Brook Road Run Off Location 1			Site 2 A417/River Frome Road Run Off Location 1			Site 3 M4/River Ray Road Run Off Location 1			Site 4 M40/Souldern Brook Road Run Off Location 1			Site 5 A34/Gallos Brook Road Run Off Location 1			Site 6 A34/Newbury Pond D Road Run Off Location 1			Overall Minimum	Overall Maximum	Overall Average
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average			
	Units																					
Copper	ug/l	0.00	87	34.4	11	242	54.01	30.3	100.3	64.3	11	75.5	33.41	30.00	93.00	42.65	16.30	41.75	33.00	0.00	242.00	40.35
Filtered Copper	ug/l	NM	NM	NM	0.00	36	10.01	12.4	38.6	24.3	7.70	17.40	11.92	9.70	46.20	17.71	3.20	56.50	16.51	0.00	56.50	17.41
Zinc	ug/l	32	249	100.7	31	996	221.5	41.3	397.3	213.0	36.70	207.00	97.99	21.70	279.00	149.21	20.00	72.25	32.00	20.00	996.00	124.19
Filtered Zinc	ug/l	NM	NM	NM	0.00	536	81.71	38.3	97.1	66.7	8.80	80.00	28.01	21.10	112.00	66.74	7.45	37.00	21.37	0.00	536.00	48.72
Cadmium	ug/l	ND	ND	ND	0.00	6.4	0.888	0.2	1.1	0.6	0.09	0.84	0.26	0.14	0.78	0.42	0.10	0.40	0.21	0.00	6.40	0.47
Aluminium	ug/l	130	4130	1185	41	20000	2995	276.0	5300.0	1603.7	61.60	1840.00	799.25	167.00	1080.00	670.00	17.60	161.00	101.06	17.60	20000.00	1214.66
Lead	ug/l	ND	ND	ND	0.00	175	41.75	3.1	95.0	41.1	2.04	48.40	16.73	4.80	50.00	15.19	0.20	7.44	4.15	0.00	175.00	24.50
Platinum	ug/l	0.00	120	24	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00	120.00	24.00
Palladium	ug/l	ND	ND	ND	0.00	7	0.886	0.00	0.00	0.00	0.00	1.40	0.42	0.00	3.20	0.43	0.00	1.75	0.34	0.00	7.00	0.42
Nickel	ug/l	ND	ND	ND	0.00	40	8.74	1.90	9.80	6.15	2.40	7.15	4.04	1.91	17.30	4.47	2.94	7.87	4.66	0.00	40.00	5.61
Chromium	ug/l	ND	ND	ND	0.00	49.9	8.96	4.84	15.80	8.60	1.80	30.00	7.72	1.80	9.40	4.82	0.90	4.30	2.72	0.00	49.90	6.66
Simazine	ug/l	0.00	0.15	0.014	0.00	0.03	0.003	ND	ND	ND	ND	ND	ND	0.00	0.04	0.01	0.00	0.85	0.30	0.00	0.85	0.08
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	0.00	0.11	0.022	0.00	1.4	0.072	0.00	0.30	0.05	0.00	17.50	3.72	0.00	3.00	0.44	ND	ND	ND	0.00	17.50	0.97
Diuron	ug/l	ND	ND	ND	0.00	2.02	0.126	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00	2.02	0.22
Bromacil	ug/l	ND	ND	ND	ND	ND	ND	0.00	0.26	0.04	0.02	0.18	0.07	ND	ND	ND	0.00	0.02	0.00	0.00	0.26	0.04
Atrazine	ug/l	0.00	0.18	0.035	0.00	0.2	0.01	ND	ND	ND	0.00	0.08	0.01	0.00	0.03	0.00	0.00	0.08	0.02	0.00	0.20	0.02
Total Herbicides	ug/l																					
Naphthalene	ug/l	0.00	0.18	0.061	0.00	4.75	0.514	0.00	0.06	0.02	0.00	0.13	0.02	0.00	0.04	0.01	ND	ND	ND	0.00	4.75	0.12
Acenaphthylene	ug/l	0.00	0.22	0.056	0.00	0.13	0.027	0.00	0.02	0.00	0.00	0.15	0.02	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.22	0.02
Acenaphthene	ug/l	0.00	0.31	0.083	0.00	0.03	0.008	0.00	0.03	0.00	0.00	0.21	0.04	0.00	0.03	0.01	ND	ND	ND	0.00	0.31	0.03
Fluorene	ug/l	0.00	0.26	0.065	0.00	0.05	0.015	0.00	0.03	0.01	0.00	0.18	0.04	0.00	0.07	0.01	0.00	0.08	0.03	0.00	0.26	0.03
Phenanthrene	ug/l	0.00	0.8	0.187	0.00	0.11	0.046	0.00	0.11	0.03	0.00	0.18	0.04	0.00	0.15	0.03	0.00	0.38	0.05	0.00	0.80	0.07
Anthracene	ug/l	0.00	0.36	0.127	0.00	0.12	0.047	0.00	0.11	0.02	0.00	0.21	0.05	0.00	0.03	0.01	0.00	0.15	0.05	0.00	0.36	0.05
Fluoranthene	ug/l	0.00	0.61	0.175	0.00	0.38	0.152	0.00	0.57	0.09	0.00	0.57	0.12	0.00	0.38	0.12	0.00	1.27	0.23	0.00	1.27	0.15
Pyrene	ug/l	0.00	0.53	0.194	0.00	0.36	0.126	0.00	0.66	0.09	0.00	0.75	0.15	0.00	0.46	0.12	0.00	1.26	0.21	0.00	1.26	0.15
Benzo(a)anthracene	ug/l	0.00	0.86	0.188	0.00	0.48	0.107	0.00	0.32	0.04	0.00	0.61	0.12	0.00	0.38	0.09	0.00	0.78	0.13	0.00	0.86	0.11
Chrysene	ug/l	0.00	0.83	0.155	0.00	0.39	0.093	0.00	0.74	0.06	0.00	0.46	0.11	0.00	0.38	0.10	0.00	0.83	0.13	0.00	0.83	0.11
Benzo(b)fluoranthene	ug/l	0.00	1.1	0.209	0.00	0.6	0.147	0.00	0.39	0.05	0.00	0.39	0.08	0.00	0.86	0.20	0.00	0.72	0.14	0.00	1.10	0.14
Benzo(k)fluoranthene	ug/l	0.00	0.35	0.095	0.00	0.25	0.062	0.00	0.85	0.07	0.00	0.61	0.10	0.00	0.36	0.07	0.00	0.25	0.05	0.00	0.85	0.08
Benzo(a)pyrene	ug/l	0.00	0.6	0.101	0.00	0.6	0.226	0.00	0.53	0.09	0.00	0.52	0.12	0.00	0.56	0.12	0.00	0.70	0.12	0.00	0.70	0.14
Indeno(1,2,3-cd)pyrene	ug/l	0.00	0.5	0.105	0.00	0.25	0.095	0.00	0.66	0.09	0.00	0.51	0.07	0.00	0.51	0.12	0.00	0.72	0.12	0.00	0.72	0.10
Dibenzo(a,h)anthracene	ug/l	0.00	0.88	0.119	0.00	0.26	0.088	0.00	0.86	0.07	0.00	0.60	0.08	0.00	0.11	0.01	0.00	0.11	0.03	0.00	0.88	0.07
Benzo(g,h,i)perylene	ug/l	0.00	0.87	0.139	0.00	0.39	0.104	0.00	0.18	0.03	0.00	0.14	0.04	0.00	0.86	0.14	ND	ND	ND	0.00	0.87	0.08
Na	mg/l	0.00	2100	236.07	5.5	727	105.01	10.00	1300.00	257.07	1.4	79.00	19.01	5.61	164.00	134.9	1.82	80.55	39.01	0.00	2100.00	175.37
Hardness	mg/l	0.00	615	200.07	57	246	109.72	27.80	291.00	124.91	120.00	300.00	210.00	44.2	14	9	61.75	217.00	140.21	0.00	615.00	144.94
De-icing Salts	mg/l	19.6	2120	530.24	5.4	1220	176.60	17.90	1902.00	517.74	22.40	400.00	122.66	4.40	122	100	25	142	50	4.40	2120.00	263.58
BOD	mg/l	3.13	31.27	8.1	3	17	8.4	2.10	9.80	6.94	2.80	8.21	14.97	2.40	13	6	2	14	6	2.10	31.27	8.28
COD	mg/l	28.09	189.82	87.82	41	488	137.7	38.80	173.00	95.40	28.23	114.80	70.82	37.02	172	72	30	182	77	28.23	488.00	90.16
TSS	mg/l	16.15	348.4	88.8	87	1980	318	18.40	231.00	101.03	58.61	138.64	77.79	29.27	87	63	16	186	68	16.15	1980.00	117.15
NM = Not Measured																						
ND = Not Detected																						

Event Mean Concentrations – Location 1   Road Runoff

		Site 2 A417/River Frome Location 2			Site 3 M4/River Ray Location 2			Site 4 M40/Souldern Brook Location 2			Site 6 A34/Newbury Pond D Location2			Overall Minimum	Overall Maximum	Overall Average
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average			
	Units															
Copper	ug/l	0.00	146.00	37.34	21.10	104.00	63.16	9.90	67.30	28.51	9.2	38.7	20.83	0.00	146.00	37.47
Filtered Copper	ug/l	0.00	95.00	14.74	9.62	39.50	25.18	8.40	19.00	11.56	4.1	45.7	14.65	0.00	95.00	16.54
Zinc	ug/l	44.00	622.00	167.93	40.20	385.00	202.44	30.00	240.00	87.57	25.1	50.6	35.61	25.10	622.00	123.44
Filtered Zinc	ug/l	0.00	488.00	68.46	24.40	119.00	59.78	9.00	51.00	20.39	6.1	25.8	14.05	0.00	488.00	40.67
Cadmium	ug/l	0.00	4.39	0.819	0.00	1.90	0.77	0.08	0.80	0.30	0.07	12	1.32	0.00	12.00	0.91
Aluminium	ug/l	0.00	15100.00	2546	241.00	6260.00	2207.6	61.40	2480.00	618.98	14.3	212	97.99	0.00	15100.00	1367.38
Lead	ug/l	0.00	137.00	28.89	3.80	80.40	43.05	1.38	43.30	14.16	0.1	10.7	3.795	0.00	137.00	22.48
Platinum	ug/l	ND	ND	ND	0.00	0.15	0.02	ND	ND	ND	ND	ND	ND	0.00	0.15	0.02
Palladium	ug/l	0.00	0.67	0.067	0.00	0.50	0.10	ND	ND	ND	0	0.7	0.13	0.00	0.70	0.10
Nickel	ug/l	0.00	20.00	6.68	1.90	16.10	6.44	2.40	6.90	4.16	3.2	7.17	4.833	0.00	20.00	5.56
Chromium	ug/l	0.00	36.80	8.26	3.75	26.50	9.02	0.40	12.30	4.83	0.8	6.2	3.16	0.00	36.80	6.32
Simazine	ug/l	0.00	0.10	0.01	ND	ND	ND	0.00	2.06	0.22	0.00	0.693	0.1603	0.00	2.06	0.13
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	0.00	0.49	0.116	0.00	0.14	0.02	0.00	13.70	2.04	ND	ND	ND	0.00	13.70	0.73
Diuron	ug/l	0.00	1.39	0.299	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00	1.39	0.20
Bromacil	ug/l	ND	ND	ND	0.00	0.19	0.02	0.00	0.17	0.07	0.00	0.023	0.0023	0.00	0.19	0.03
Atrazine	ug/l	0.00	0.1	0.01	ND	ND	ND	0.00	0.08	0.01	0.00	0.047	0.012	0.00	0.10	0.01
Total Herbicides	ug/l															
								0.00	0.09	0.02						
Naphthalene	ug/l	0.00	1.98	0.22	0.00	0.03	0.01	ND	ND	ND	ND	ND	ND	0.00	1.98	0.12
Acenaphthylene	ug/l	0.00	0.05	0.02	0.00	0.02	0.002	ND	ND	ND	0.00	0.016	0.0034	0.00	0.05	0.01
Acenaphthene	ug/l	0.00	0.03	0.01	0.00	0.03	0.003	0.00	0.01	0.00	0.00	0.034	0.0034	0.00	0.03	0.00
Fluorene	ug/l	0.00	0.03	0.01	0.00	0.02	0.004	0.00	0.13	0.03	0.00	0.041	0.0197	0.00	0.13	0.02
Phenanthrene	ug/l	0.00	0.17	0.06	0.00	0.14	0.04	0.00	0.10	0.02	0.00	0.194	0.0435	0.00	0.19	0.04
Anthracene	ug/l	0.00	0.38	0.07	0.00	0.13	0.02	0.00	0.49	0.10	0.00	0.18	0.0383	0.00	0.49	0.06
Fluoranthene	ug/l	0.00	0.36	0.15	0.00	0.75	0.13	0.00	0.57	0.12	0.02	0.861	0.2174	0.00	0.86	0.15
Pyrene	ug/l	0.00	0.38	0.13	0.00	0.73	0.13	0.00	0.17	0.04	0.00	0.851	0.1864	0.00	0.85	0.12
Benzo(a)anthracene	ug/l	0.00	0.42	0.09	0.00	0.28	0.07	0.00	0.56	0.08	0.00	0.482	0.1288	0.00	0.56	0.09
Chrysene	ug/l	0.00	0.39	0.10	0.00	0.78	0.12	0.00	0.31	0.06	0.00	0.402	0.1255	0.00	0.78	0.10
Benzo(b)fluoranthene	ug/l	0.00	0.47	0.13	0.00	0.56	0.08	0.00	0.57	0.09	0.00	0.534	0.1411	0.00	0.57	0.11
Benzo(k)fluoranthene	ug/l	0.00	0.34	0.10	0.00	0.72	0.11	0.00	0.55	0.12	0	0.158	0.0618	0.00	0.72	0.10
Benzo(a)pyrene	ug/l	0.00	0.78	0.22	0.00	1.03	0.15	0.00	0.80	0.12	0.00	0.488	0.1298	0.00	1.03	0.15
Indeno(1,2,3-cd)pyrene	ug/l	0.00	0.45	0.10	0.00	0.69	0.09	0.00	0.62	0.09	0.00	0.428	0.1162	0.00	0.69	0.10
Dibenzo(a,h)anthracene	ug/l	0.00	0.85	0.11	0.00	0.68	0.08	0.00	0.22	0.06	0.00	0.12	0.0346	0.00	0.68	0.07
Benzo(g,h,i)perylene	ug/l	0.00	0.83	0.16	0.00	0.19	0.04	0.00	0.00	0.00	ND	ND	ND	0.00	0.83	0.07
								12.10	290.00	78.09						
Na	mg/l	4.90	688.00	94.098	15.50	1710.00	403.77	134.00	456.00	280.20	37.10	86.60	47.47	4.90	1710.00	201.37
Hardness	mg/l	46.00	281.00	123.3	44.90	277.00	143.70	24.20	465.00	123.69	82.90	259.00	178.69	24.20	465.00	141.85
De-icingSalts	mg/l	5.60	1155.00	159.48	20.10	2353.00	674.46	24.20	465.00	123.69	42.80	149.00	71.16	5.60	2353.00	257.19
BOD	mg/l	3.53	14.85	8.80	2.88	10.03	6.13	1.93	8.37	4.21	1.04	7.48	3.88	1.04	14.85	5.25
COD	mg/l	31.90	201.75	83.14	28.59	192.71	97.02	30.25	88.05	53.56	17.08	105.18	63.16	17.08	201.75	74.22
TSS	mg/l	29.82	303.57	139.27	16.56	359.13	120.04	43.18	162.38	84.47	10.83	121.98	41.09	10.83	359.13	96.22
NM = Not Measured																
ND = Not Detected																

Event Mean Concentration – Location 2

		Site 1 M4/Brinkworth Brook Location 3 Discharge To Watercourse			Site 2 A417/River Frome Location 3 Discharge To Watercourse			Site 3 M4/River Ray Location 3 Discharge To Watercourse			Site 4 M40/Souldern Brook Location 3 Discharge To Watercourse			Site 5 A34/Gallos Brook Location 2 Discharge To Watercourse			Site 6 A34/Newbury Pond D Location 3 Discharge To Watercourse			Overall Minimum	Overall Maximum	Overall Average
		Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average			
	Units																					
Total Copper	ug/l	0.00	67	24.4	0.00	84	27.42	13.00	60	30.38	0.00	10.00	11.76	10.00	61.90	34.40	5.80	28.00	11	0.00	91.90	25.35
Filtered Copper	ug/l	NM	NM	NM	0.00	15.6	0.84	8.10	34.4	10.00	5.10	10.00	7.45	10.50	28.30	19.71	2.70	18.40	7	0.00	38.30	11.07
Total Zinc	ug/l	32.00	246	100.7	34.00	238	100.69	42.80	288	127.62	24.00	94.00	38.62	27.80	209.00	74.67	13.40	172.00	40	13.40	288.00	93.36
Filtered Zinc	ug/l	0.00	66	8.6	0.00	178	34.42	13.80	70.3	38.07	7.10	61.00	14.88	16.10	66.90	34.88	4.10	104.00	25	0.00	178.00	26.68
Cadmium	ug/l	NM	NM	NM	0.00	7.4	0.16	0.16	1.6	0.67	0.06	0.50	0.31	0.16	0.61	0.35	0.08	0.75	0	0.00	7.40	0.36
Aluminium	ug/l	130.00	4130	1165	0.00	6040	1346	100.00	3150	761.33	10.60	560.00	169.97	140.00	1570.00	467.63	2.50	100.00	50	0.00	6040.00	658.60
Lead	ug/l	ND	ND	ND	0.00	100	27.2	1.40	62.8	21.98	0.71	11.00	4.27	2.34	24.30	11.54	0.20	16.10	4	0.00	100.00	13.27
Platinum	ug/l	0.00	120	24	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00	10.00	ND	ND	ND	ND	0.00	120.00	24.00
Palladium	ug/l	ND	ND	ND	ND	ND	ND	0.00	0.61	0.08	0.00	0.20	0.02	0.00	2.00	0.80	ND	ND	ND	0.00	2.00	0.30
Nickel	ug/l	ND	ND	ND	0.00	40	7.16	0.00	8.6	4.85	1.70	7.10	3.80	1.94	5.40	3.16	5.40	8.69	6	0.00	40.00	4.69
Chromium	ug/l	ND	ND	ND	0.00	20	6.62	0.00	11.8	7.11	1.90	6.00	3.54	2.90	12.10	4.70	1.10	7.10	5	0.00	20.00	5.17
Simazine	ug/l	0.00	0.15	0.015	ND	ND	ND	ND	ND	ND	0.00	0.04	0.01	0.00	0.02	0.07	0.00	3.92	0	0.00	3.92	0.04
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	0.00	0.11	0.022	0.00	0.22	0.084	0.00	0.27	0.04	0.00	2.80	0.60	0.00	0.75	0.13	ND	ND	ND	0.00	2.80	0.16
Diuron	ug/l	ND	ND	ND	0.00	1.75	0.11	ND	ND	ND	ND	ND	ND	0.00	0.09	0.01	ND	ND	ND	0.00	1.75	0.16
Bromacil	ug/l	ND	ND	ND	ND	ND	ND	0.00	0.270546275	0.030066697	0.00	0.29	0.07	ND	ND	ND	ND	ND	ND	0.00	0.29	0.05
Atrazine	ug/l	0.00	0.10	0.005	ND	ND	ND	ND	ND	ND	0.00	0.02	0.01	ND	ND	ND	0.00	0.02	0	0.00	0.10	0.02
Total Herbicides	ug/l																					
Naphthalene	ug/l	0.00	0.16	0.061	0.00	1.06	0.139	0.00	0.08	0.03	0.00	0.11	0.02	0.00	0.03	0.01	0.00	0.02	0	0.00	1.06	0.06
Acenaphthylene	ug/l	0.00	0.77	0.056	0.00	0.06	0.016	0.00	0.05	0.01	0.00	0.09	0.02	0.00	0.01	0.00	0.00	0.00	0	0.00	0.77	0.02
Acenaphthene	ug/l	0.00	0.31	0.032	0.00	0.03	0.006	0.00	0.06	0.01	0.00	0.12	0.02	0.00	0.01	0.00	0.00	0.03	0	0.00	0.31	0.02
Fluorene	ug/l	0.00	0.30	0.065	0.00	0.03	0.007	0.00	0.07	0.01	0.00	0.02	0.00	0.00	0.02	0.01	0.00	0.07	0	0.00	0.30	0.02
Phenanthrene	ug/l	0.00	0.8	0.167	0.00	0.12	0.041	0.00	0.18	0.06	0.00	0.10	0.024	0.00	0.06	0.01	ND	ND	ND	0.00	0.80	0.06
Anthracene	ug/l	0.00	0.38	0.127	0.00	0.08	0.032	0.00	0.12	0.03	0.00	0.11	0.032	0.00	0.01	0.00	ND	ND	ND	0.00	0.38	0.04
Fluoranthene	ug/l	0.00	0.61	0.170	0.00	0.11	0.142	0.00	0.67	0.11	0.00	0.12	0.03	0.00	0.14	0.05	0.00	0.03	0	0.00	0.67	0.08
Pyrene	ug/l	0.00	0.53	0.164	0.00	0.57	0.124	0.00	0.64	0.12	0.00	0.13	0.04	0.00	0.14	0.04	0.00	0.05	0	0.00	0.64	0.08
Benzo(a)anthracene	ug/l	0.00	0.96	0.150	0.00	0.56	0.122	0.00	0.45	0.08	0.00	0.10	0.03	0.00	0.14	0.03	0.00	0.02	0	0.00	0.96	0.07
Chrysene	ug/l	0.00	0.83	0.155	0.00	0.56	0.114	0.00	0.82	0.13	0.00	0.10	0.02	0.00	0.15	0.03	0.00	0.02	0	0.00	0.83	0.08
Benzo(b)fluoranthene	ug/l	0.00	1.1	0.208	0.00	0.38	0.111	0.00	0.31	0.08	0.00	0.08	0.02	0.00	0.37	0.06	0.00	0.02	0	0.00	1.10	0.08
Benzo(k)fluoranthene	ug/l	0.00	0.36	0.096	0.00	0.18	0.084	0.00	0.72	0.10	0.00	0.12	0.02	0.00	0.12	0.02	ND	ND	ND	0.00	0.72	0.06
Benzo(a)pyrene	ug/l	0.00	0.6	0.163	0.00	0.32	0.156	0.00	0.72	0.10	0.00	0.05	0.01	0.00	0.29	0.04	0.00	0.02	0	0.00	0.72	0.08
Indeno(1,2,3-cd)pyrene	ug/l	0.00	0.5	0.125	0.00	0.18	0.094	0.00	0.62	0.12	0.00	0.05	0.01	0.00	0.25	0.04	0.00	0.02	0	0.00	0.62	0.06
Dibenzo(a,h)anthracene	ug/l	0.00	0.56	0.116	0.00	0.25	0.082	0.00	0.79	0.09	0.00	0.06	0.01	0.00	0.03	0.01	ND	ND	ND	0.00	0.79	0.06
Benzo(g,h,i)perylene	ug/l	0.00	0.87	0.139	0.00	0.3	0.081	0.00	0.18	0.03	0.00	0.08	0.01	0.00	0.33	0.06	0.00	0.02	0	0.00	0.87	0.06
Na	mg/l	0.00	7100	336.67	5.90	691	94.74	17.90	1170.00	174.64	15.70	127.00	65.07	25.70	604.00	161.64	17.30	60.60	61	0.00	7100.00	176.63
Hardness	mg/l	0.00	619	203.67	81.00	266	132.7	83.90	389.00	302.76	246.00	466.00	317.10	64.00	287	154	132.00	368.00	242	0.00	619.00	237.56
De-icing Salts	mg/l	16.00	3120	536.24	0.00	1145	150.04	30.10	1772.00	460.90	37.00	325	90	15.30	964	244	54	14	61	0.00	3120.00	267.22
BOD	mg/l	2.13	31.27	9.1	2.00	11.6	6	2.00	8.00	6.00	1.00	7	4	2.3	8	5	1	6	3	1.00	31.27	5.41
COD	mg/l	49.88	189.83	87.62	17.60	281.4	107.4	36.00	131.00	76.00	26.00	60	39	40.40	96	60	26	60	60	17.60	281.40	68.22
TSS	mg/l	16.19	348.6	88.6	16.60	667	188.8	16.00	136.00	65.00	11.00	131	37	8.60	47	29	0.00	27	11	0.00	667.00	70.42
NM = Not Measured																						
ND = Not Detected																						

Event Mean Concentration - Location 3 Discharge to Watercourse

APPENDIX D COMPARISON OF RUNOFF CONCENTRATIONS WITH WATER QUALITY STANDARDS

						Drinking Water Standard	EQS							
				MAX	LOD	Prescribed Conc.	Annual Average (AA)	Maximum Allowable	Max - DWS Standard	Max - EQS (AA) Standard	Max - EQS (MAC) Standard	Average - DWS Standard	Average - EQS (AA) Standard	Average - EQS (MAC) Standard
SampleCode	BB-1					or Values	"T" value	Concentration (MAC)						
	MIN	MAX	AVERAGE			(Maximum)		"T" value						
Cu	0	67	24.4	67	4	2000		50	-1933		17	-1975.6		-25.6
FiltCu	0	0	0	0	4		20	112		-20	-112		-20	-112
Zn	32	246	100.7	246	4		125	500		121	-254		-24.3	-399.3
FiltZn	0	86	8.6	86	4									
Cd	0	0	0	0	4	5	5		-5	-5		-5	-5	
Al	130	4130	1185	4130	40	200			3930			985		
Pb	0	0	0	0	50	25	50	75	-25	-50	-75	-25	-50	-75
Pt	0	120	24	120	0.1									
Pd	0	0	0	0	0.1									
Ni	0	0	0	0	10	20	50		-20	-50		-20	-50	
Cr	0	0	0	0	10	50	50	75	-50	-50	-75	-50	-50	-75
Simazine	0	0.15	0.015	0.15	0.03	0.1	2		0.05	-1.85		-0.085	-1.985	
Amitrole	0	0	0	0	0.1	0.1			-0.1			-0.1		
Glyphosate	0	0.11	0.022	0.11	0.1	0.1			0.01			-0.078		
Diuron	0	0	0	0	0.01	0.1			-0.1			-0.1		
Bromacil	0	0	0	0	0.02	0.1			-0.1			-0.1		
Atrazine	0	0.18	0.035	0.18	0.02	0.1	2		0.08	-1.82		-0.065	-1.965	
				0		0.5			-0.5			-0.5		
Naphthalene	0	0.16	0.061	0.16	0.01-0.05		10			-9.84			-9.939	
Acenaphthylene	0	0.22	0.050	0.22	0.01-0.05									
Acenaphthene	0	0.31	0.083	0.31	0.01-0.05									
Fluorene	0	0.26	0.065	0.26	0.01-0.05									
Phenanthrene	0	0.8	0.187	0.8	0.01-0.05									
Anthracene	0	0.39	0.127	0.39	0.01-0.05									
Fluoranthene	0	0.61	0.179	0.61	0.01-0.05									
Pyrene	0	0.53	0.184	0.53	0.01-0.05									
Benzoaanthracene	0	0.96	0.159	0.96	0.01-0.05									
Chrysene	0	0.83	0.155	0.83	0.01-0.05									
Benzobfluoranthene	0	1.1	0.208	1.1	0.01-0.05	0.1			1			0.108		
Benzokfluoranthene	0	0.35	0.095	0.35	0.01-0.05	0.1			0.25			-0.005		
Benzoapyrene	0	0.6	0.163	0.6	0.01-0.05	0.010			0.59			0.153		
Indeno123cdpyrene	0	0.5	0.105	0.5	0.01-0.05	0.1			0.4			0.005		
Dibenzoahanthracene	0	0.58	0.118	0.58	0.01-0.05									
Benzoghiperylene	0	0.87	0.139	0.87	0.01-0.05	0.1			0.77			0.039		
Na	0	2100	336.622	2100	0.5									
Hardness	0	619	203.67	619	0.5									
DeicingSalts	16.6	3120	536.24	3120	0.2	200			2920			336.24		
BOD	3.13	31.27	9.1	31.27	1			3			28.27			6.1
COD	49.6	189.8	87.52	189.83	20									
TSS	15.2	246.5	88.6	246.5	1.00			25			221.5			63.6
NH4 N	0.07	0.69	0.33	0.6909	0.05			0.78			-0.09			-0.45
	Green = concentrations meet standards													

M4/Brinkworth Brook – Highway Runoff

						Drinking Water	EQS							
				MAX	LOD	Prescribed Conc. or Values (Maximum)	Annual Average (AA) "I" value	Maximum Allowable Concentration (MAC) "I" value	Max - DWS Standard	Max - EQS (AA) Standard	Max - EQS (MAC) Standard	Average - DWS Standard	Average - EQS (AA) Standard	Average - EQS (MAC) Standard
SampleCode	RF-1													
	MIN	MAX	AVERAGE											
Cu	13	242	54.61	242	4	2000		50	-1758		192	-1945.39		4.61
FiltCu	0	90	16.81	90	4		28	112		62	-22		-11.19	-95.19
Zn	51	688	221.5	688	4		125	500		563	188		96.5	-278.5
FiltZn	0	536	81.71	536	4									
Cd	0	5.4	0.886	5.4	4	5	5		0.4	0.4		-4.114	-4.114	
Al	40	20700	2850	20700	40	200			20500			2650		
Pb	0	178	41.39	178	50	25	50	75	153	128	103	16.39	-8.61	-33.61
Pt	0	0	0	0	0.1									
Pd	0	7	0.056	7	0.1									
Ni	0	40	9.74	40	10	20	50		20	-10		-10.26	-40.26	
Cr	0	49.9	8.96	49.9	10	50	50	75	-0.1	-0.1	-25.1	-41.04	-41.04	-66.04
Simazine	0	0.03	0.003	0.03	0.03	0.1	2		-0.07	-1.97		-0.097	-1.997	
Amitrole	0	0	0	0	0.1	0.1			-0.1			-0.1		
Glyphosate	0	0.4	0.075	0.4	0.1	0.1			0.3			-0.025		
Diuron	0	2.02	0.326	2.02	0.01	0.1			1.92			0.226		
Bromacil	0	0	0	0	0.02	0.1			-0.1			-0.1		
Atrazine	0	0.2	0.02	0.2	0.02	0.1	2		0.1	-1.8		-0.08	-1.98	
						0.5			-0.5			-0.5		
Naphthalene	0	4.75	0.514	4.75	0.01-0.05		10			-5.25			-9.486	
Acenaphthylene	0	0.13	0.027	0.13	0.01-0.05									
Acenaphthene	0	0.03	0.008	0.03	0.01-0.05									
Fluorene	0	0.05	0.015	0.05	0.01-0.05									
Phenanthrene	0	0.31	0.096	0.31	0.01-0.05									
Anthracene	0	0.12	0.047	0.12	0.01-0.05									
Fluoranthene	0	0.36	0.153	0.36	0.01-0.05									
Pyrene	0	0.38	0.139	0.38	0.01-0.05									
Benzoaanthracene	0	0.48	0.107	0.48	0.01-0.05									
Chrysene	0	0.26	0.093	0.26	0.01-0.05									
Benzobfluoranthene	0	0.6	0.152	0.6	0.01-0.05	0.1			0.5			0.052		
Benzokfluoranthene	0	0.25	0.092	0.25	0.01-0.05	0.1			0.15			-0.008		
Benzoapyrene	0	0.6	0.235	0.6	0.01-0.05	0.010			0.59			0.225		
Indeno123cdpyrene	0	0.25	0.095	0.25	0.01-0.05	0.1			0.15			-0.005		
Dibenzoahanthracene	0	0.26	0.098	0.26	0.01-0.05									
Benzoghiperylene	0	0.29	0.104	0.29	0.01-0.05	0.1			0.19			0.004		
Na	5.5	727	105.81	727	0.5									
Hardness	52	245	108.77	245	0.5									
DeicingSalts	5.4	1220	176.66	1220	0.2	200			1020			-23.34		
BOD	3	17	8.4	17	1			3			14			5.4
COD	41	458	137.2	458	20									
TSS	62	1350	318	1350	1.00			25			1325			293
NH4 N	0.00	0.73	0.35	0.73	0.05			0.78			-0.78			-0.78

Green = concentrations meet standards

A417/River Frome – Highway Runoff

						Drinking Water Standard	EQS							
				MAX	LOD	Prescribed Conc. or Values (Maximum)	Annual Average (AA) "T" value	Maximum Allowable Concentration (MAC) "T" value	Max - DWS Standard	Max - EQS (AA) Standard	Max - EQS (MAC) Standard	Average - DWS Standard	Average - EQS (AA) Standard	Average - EQS (MAC) Standard
SampleCode	RY.1													
	MIN	MAX	AVERAGE											
Cu	20.7	108	67.92	108	4	2000		50	1892		58	1932.08		17.92
FilCu	12.1	36.8	23.32	36.8	4		28	112		8.8	75.2		4.68	88.68
Zn	41	397	219.73	397	4		125	500		272	103		94.73	280.27
FilZn	38	167	66.79	167	4									
Cd	0.16	1.11	0.575	1.11	4	5	5		3.89	3.89		4.425	4.425	
Al	225	5300	1995.9	5300	40	200			5100			1795.9		
Pb	3.5	99	50.45	99	50	25	50	75	74	49	24	25.45	0.45	24.55
Pt	0	0	0	0	0.1									
Pd	0	0.8	0.16	0.8	0.1									
Ni	1.9	11.4	6.683	11.4	10	20	50		8.6	38.6		13.317	43.317	
Cr	4.44	15.8	9.084	15.8	10	50	50	75	34.2	34.2	59.2	40.916	40.916	65.916
Simazine	0	0	0	0	0.03	0.1	2		0.1	2		0.1	2	
Amitrole	0	0	0	0	0.1	0.1			0.1			0.1		
Glyphosate	0	0.36	0.045	0.36	0.1	0.1			0.26			0.055		
Diuron	0	0	0	0	0.01	0.1			0.1			0.1		
Bromacil	0	0.2	0.03	0.2	0.02	0.1			0.1			0.07		
Atrazine	0	0	0	0	0.02	0.1	2		0.1	2		0.1	2	
				0		0.5			0.5			0.5		
Naphthalene	0	0.1	0.028	0.1	0.01-0.05		10			9.9			9.972	
Acenaphthylene	0	0.02	0.002	0.02	0.01-0.05									
Acenaphthene	0	0.03	0.003	0.03	0.01-0.05									
Fluorene	0	0.03	0.005	0.03	0.01-0.05									
Phenanthrene	0	0.2	0.042	0.2	0.01-0.05									
Anthracene	0	0.2	0.04	0.2	0.01-0.05									
Fluoranthene	0	1.4	0.261	1.4	0.01-0.05									
Pyrene	0	1.3	0.242	1.3	0.01-0.05									
Benzoaanthracene	0	1.3	0.186	1.3	0.01-0.05									
Chrysene	0	1	0.17	1	0.01-0.05									
Benzobfluoranthene	0	0.9	0.126	0.9	0.01-0.05	0.1			0.8			0.026		
Benzokfluoranthene	0	0.7	0.139	0.7	0.01-0.05	0.1			0.6			0.039		
Benzoapyrene	0	0.7	0.15	0.7	0.01-0.05	0.010			0.69			0.14		
Indeno123cdpyrene	0	0.9	0.095	0.9	0.01-0.05	0.1			0.8			0.005		
Dibenzoahanthracene	0	0.2	0.041	0.2	0.01-0.05									
Benzoghiperylene	0	0.9	0.147	0.9	0.01-0.05	0.1			0.8			0.047		
Na	16.6	1350	335.38	1350	0.5									
Hardness	37.8	281	125.33	281	0.5									
DeicingSalts	17.9	1902	406.87	1902	0.2	200			1702			206.87		
BOD	2.1	9	5.54	9	1			3			6			2.54
COD	39.8	173	95.4	173	20									
TSS	10.4	231	101.03	231	1.00			25			206			76.03
NH4 N	0.05	0.52	0.29	0.52	0.05			0.78			0.26			0.49

Green = concentrations fall within standards

M4/River Ray - Highway Runoff

				MAX	LOD	Drinking Water Prescribed Conc. or Values (Maximum)	EQS Annual Average (AA) "I" value	EQS Maximum Allowable Concentration (MAC) "I" value	Max - DWS Standard	Max - EQS (AA) Standard	Max - EQS (MAC) Standard	Average - DWS Standard	Average - EQS (AA) Standard	Average - EQS (MAC) Standard
SampleCode	SB-1													
	MIN	MAX	AVERAGE											
Cu	11.00	75.90	32.41	75.9	4	2000		50	-1924.1		25.9	-1967.59		-17.59
FilCu	7.10	17.40	11.82	17.4	4		28	112		-10.6	-94.6		-16.18	-100.18
Zn	36.70	267.00	97.98	267	4		125	500		142	-233		-27.02	-402.02
FilZn	8.50	60.00	29.01	60	4									
Cd	0.09	0.64	0.25	0.64	4	5	5		-4.36	-4.36		-4.748	-4.748	
Al	83.50	2940.00	739.25	2940	40	200			2740			539.25		
Pb	2.04	48.40	16.73	48.4	50	25	50	75	23.4	-1.6	-26.6	-8.267	-33.267	-58.27
Pt	0.00	0.00	0.00	0	0.1									
Pd	0.00	1.40	0.42	1.4	0.1									
Ni	2.40	7.10	4.04	7.1	10	20	50		-12.9	-42.9		-15.96	-45.96	
Cr	1.50	30.00	7.73	30	10	50	50	75	-20	-20	-45	-42.27	-42.27	-67.27
Simazine	0.00	0.00	0.00	0	0.03	0.1	2		-0.1	-2		-0.1	-2	
Amitrole	0.00	0.00	0.00	0	0.1	0.1			-0.1			-0.1		
Glyphosate	0.00	17.50	3.73	17.5	0.1	0.1			17.4			3.632		
Diuron	0.00	0.00	0.00	0	0.01	0.1			-0.1			-0.1		
Bromacil	0.00	0.20	0.02	0.2	0.02	0.1			0.1			-0.08		
Atrazine	0.00	0.00	0.00	0	0.02	0.1	2		-0.1	-2		-0.1	-2.00	
				0		0.5			-0.5			-0.5		
Naphthalene	0.00	0.30	0.06	0.3	0.01-0.05		10			-9.7			-9.939	
Acenaphthylene	0.00	0.00	0.00	0	0.01-0.05									
Acenaphthene	0.00	0.10	0.01	0.1	0.01-0.05									
Fluorene	0.00	0.00	0.00	0	0.01-0.05									
Phenanthrene	0.00	0.20	0.05	0.2	0.01-0.05									
Anthracene	0.00	0.20	0.05	0.2	0.01-0.05									
Fluoranthene	0.00	0.60	0.12	0.6	0.01-0.05									
Pyrene	0.00	0.70	0.12	0.7	0.01-0.05									
Benzoaanthracene	0.00	0.50	0.12	0.5	0.01-0.05									
Chrysene	0.00	0.60	0.11	0.6	0.01-0.05									
Benzobfluoranthene	0.00	0.30	0.06	0.3	0.01-0.05	0.1			0.2			-0.04		
Benzokfluoranthene	0.00	0.50	0.10	0.5	0.01-0.05	0.1			0.4			0		
Benzoapyrene	0.00	0.50	0.10	0.5	0.01-0.05	0.010			0.49			0.09		
Indeno123cdpyrene	0.00	0.50	0.05	0.5	0.01-0.05	0.1			0.4			-0.05		
Dibenzoahanthracene	0.00	0.20	0.02	0.2	0.01-0.05									
Benzoghiperylene	0.00	0.60	0.06	0.6	0.01-0.05	0.1			0.5			-0.04		
Na	11.40	279.00	78.01	279	0.5									
Hardness	126.00	368.00	210.00	368	0.5									
DeicingSalts	22.40	430.00	123.68	430	0.2	200			230			-76.32		
BOD	3	8	15	15	1			3			11.97			11.97
COD	20	115	71	115	20									
TSS	39	137	78	137	1.00			25			111.55			52.78
NH4 N	0.05	0.20	0.13	0.20	0.05			0.70			-0.50			-0.65

Green = concentrations meet standards

M40/Souldern Brook - Highway Runoff

				MAX	LOD	Drinking Water Prescribed Conc. or Values (Maximum)	EQS Annual Average (AA) "T" value	EQS Maximum Allowable Concentration (MAC) "T" value	Max - DWS Standard	Max - EQS (AA) Standard	Max - EQS (MAC) Standard	Average - DWS Standard	Average - EQS (AA) Standard	Average - EQS (MAC) Standard
SampleCode	GB-1													
	MIN	MAX	AVERAGE											
Cu	20.90	93.80	42.65	93.8	4	2000		50	-1906.2		43.8	-1957.35		-7.35
FiltCu	0.70	49.30	17.61	49.3	4		28	112		21.3	-62.7		-10.39	-94.39
Zn	21.10	379.00	149.31	379	4		125	500		254	-121		24.31	-350.69
FiltZn	21.10	112.00	55.74	112	4									
Cd	0.14	0.79	0.43	0.79	4	5	5		-4.21	-4.21		-4.566	-4.566	
Al	157.00	1080.00	520.00	1080	40	200			880			320		
Pb	4.83	38.00	15.36	38	50	25	50	75	13	-12	-37	-9.64	-34.64	-59.64
Pt	0.00	0.00	0.00	0	0.1									
Pd	0.00	2.20	0.42	2.2	0.1									
Ni	1.81	17.30	4.47	17.3	10	20	50		-2.7	-32.7		-15.535	-45.535	
Cr	1.90	9.50	4.82	9.5	10	50	50	75	-40.5	-40.5	-65.5	-45.18	-45.18	-70.18
Simazine	0.00	0.00	0.00	0	0.03	0.1	2		-0.1	-2		-0.1	-2	
Amitrole	0.00	0.00	0.00	0	0.1	0.1			-0.1			-0.1		
Glyphosate	0.00	2.65	0.49	2.65	0.1	0.1			2.55			0.3895		
Diuron	0.00	0.00	0.00	0	0.01	0.1			-0.1			-0.1		
Bromacil	0.00	0.00	0.00	0	0.02	0.1			-0.1			-0.1		
Atrazine	0.00	0.00	0.00	0	0.02	0.1	2		-0.1	-2		-0.1	-2	
						0.5			-0.5			-0.5		
Naphthalene	0.00	0.00	0.00	0	0.01-0.05		10			-10			-10	
Acenaphthylene	0.00	0.00	0.00	0	0.01-0.05									
Acenaphthene	0.00	0.00	0.00	0	0.01-0.05									
Fluorene	0.00	0.00	0.00	0	0.01-0.05									
Phenanthrene	0.00	0.10	0.02	0.1	0.01-0.05									
Anthracene	0.00	0.00	0.00	0	0.01-0.05									
Fluoranthene	0.00	0.40	0.08	0.4	0.01-0.05									
Pyrene	0.00	0.50	0.10	0.5	0.01-0.05									
Benzoaanthracene	0.00	0.30	0.04	0.3	0.01-0.05									
Chrysene	0.00	0.40	0.06	0.4	0.01-0.05									
Benzobfluoranthene	0.00	0.90	0.15	0.9	0.01-0.05	0.1			0.8			0.05		
Benzokfluoranthene	0.00	0.30	0.04	0.3	0.01-0.05	0.1			0.2			-0.06		
Benzoapyrene	0.00	0.60	0.08	0.6	0.01-0.05	0.010			0.59			0.073		
Indeno123cdpyrene	0.00	0.50	0.08	0.5	0.01-0.05	0.1			0.4			-0.017		
Dibenzoahanthracene	0.00	0.00	0.00	0	0.01-0.05									
Benzoghiperylene	0.00	0.60	0.10	0.6	0.01-0.05	0.1			0.5			-0.004		
Na	5.67	684.00	134.90	684	0.5									
Hardness	44.20	140.00	82.11	140	0.5									
DeicingSalts	4.48	1229.00	167.64	1229	0.2	200			1029			-32.361		
BOD	2.48	13	6	13	1			3			9.90			3.10
COD	37.62	122	72	122	20									
TSS	29.27	87	53	87.4	1.00			25			62.41			27.64
NH4 N	0.05	1	0	0.52	0.05			0.78			-0.26			-0.57

Green = concentrations meet standards

A34/Gallos Brook – Highway Runoff

						Drinking Water	EQS							
				MAX	LOD	Prescribed Conc. or Values (Maximum)	Annual Average (AA) "I" value	Maximum Allowable Concentration (MAC) "I" value	Max - DWS Standard	Max - EQS (AA) Standard	Max - EQS (MAC) Standard	Average - DWS Standard	Average - EQS (AA) Standard	Average - EQS (MAC) Standard
SampleCode	NE-1													
	MIN	MAX	AVERAGE											
Cu	10.2	49.7	24.0	49.7	4	2000		50	-1950.3		-0.3	-1976.01		-26.01
FilCu	5.3	56.5	16.5	56.5	4		28	112		28.5	-55.5		-11.47	-95.47
Zn	20.5	72.2	52.6	72.2	4		125	500		-52.8	-427.8		-72.4	-447.4
FilZn	7.4	37.0	21.4	37	4									
Cd	0.1	0.4	0.2	0.4	4	5	5		-4.6	-4.6		-4.794	-4.794	
Al	17.5	101.0	102.0	101	40	200			-99			-98.02		
Pb	0.2	7.4	4.4	7.44	50	25	50	75	-17.56	-42.56	-67.56	-20.621	-45.621	-70.621
Pt	0.0	0.0	0.0	0	0.1									
Pd	0.0	1.7	0.0	1.7	0.1									
Ni	2.8	8.0	4.7	7.97	10	20	50		-12.03	-42.03		-15.344	-45.344	
Cr	0.9	4.3	2.7	4.3	10	50	50	75	-45.7	-45.7	-70.7	-47.28	-47.28	-72.28
Simazine	0.0	0.9	0.4	0.9	0.03	0.1	2		0.8	-1.1		0.25	-1.65	
Amitrole	0.0	0.0	0.0	0	0.1	0.1			-0.1			-0.1		
Glyphosate	0.0	0.0	0.0	0	0.1	0.1			-0.1			-0.1		
Diuron	0.0	0.0	0.0	0	0.01	0.1			-0.1			-0.1		
Bromacil	0.0	0.0	0.0	0	0.02	0.1			-0.1			-0.1		
Atrazine	0.0	0.0	0.0	0	0.02	0.1	2		-0.1	-2		-0.1	-2	
						0.5			-0.5			-0.5		
Naphthalene	0.0	0.0	0.0	0	0.01-0.05		10			-10			-10	
Acenaphthylene	0.0	0.0	0.0	0	0.01-0.05									
Acenaphthene	0.0	0.0	0.0	0	0.01-0.05									
Fluorene	0.0	0.0	0.0	0	0.01-0.05									
Phenanthrene	0.0	0.0	0.0	0	0.01-0.05									
Anthracene	0.0	0.0	0.0	0	0.01-0.05									
Fluoranthene	0.0	0.0	0.0	0	0.01-0.05									
Pyrene	0.0	0.2	0.0	0.2	0.01-0.05									
Benzoaanthracene	0.0	0.2	0.0	0.2	0.01-0.05									
Chrysene	0.0	0.0	0.0	0	0.01-0.05									
Benzobfluoranthene	0.0	0.0	0.0	0	0.01-0.05	0.1			-0.1			-0.1		
Benzokfluoranthene	0.0	0.2	0.0	0.2	0.01-0.05	0.1			0.1			-0.08		
Benzoapyrene	0.0	0.0	0.0	0	0.01-0.05	0.010			-0.01			-0.01		
Indeno123cdpyrene	0.0	0.0	0.0	0	0.01-0.05	0.1			-0.1			-0.1		
Dibenzoahanthracene	0.0	0.0	0.0	0	0.01-0.05									
Benzoghiperylene	0.0	0.0	0.0	0	0.01-0.05	0.1			-0.1			-0.1		
Na	3.5	90.5	39.0	90.5	0.5									
Hardness	82.7	217.0	140.3	217	0.5									
DeicingSalts	27.5	142.0	59.5	142	0.2	200			-58			-140.51		
BOD	2.4	13.8	5.5	13.8	1			3			10.83			2.52
COD	37.6	160.5	77.1	160	20									
TSS	16.3	184.8	64.8	185	1.00			25			159.83			39.75
NH4 N	0.1	0.4	0.2	0.35	0.05			0.78			-0.78			-0.78
	Green = concentrations meet standards													

A34/Newbury Bypass – Highway Runoff

APPENDIX E TREATMENT DEVICE REDUCTION EFFICIENCY – LIQUID SAMPLES

	Units	Site 1 M6/Bricklesworth Brook Location 1 Road Run Off / Discharge To Watercourse: Road Run Off & Discharge To Water Course Average	Site 2 A417/River Frome Location 1 & 2: Road Run Off Average	Location 2 Oil Trap (Bypass Oil Separator) Average	Actual Reduction	% Reduction
Copper	ug/l	24.4	54.01	37.34	17.27	31.60
Filtered Copper	ug/l	NM	16.81	14.74	2.07	12.31
Zinc	ug/l	183.7	221.6	167.90	63.67	24.18
Filtered Zinc	ug/l	9.8	81.71	68.46	13.26	16.22
Cadmium	ug/l	NM	0.866	0.816	0.067	7.68
Aluminium	ug/l	1180	3660	2848	808	10.18
Lead	ug/l	ND	41.90	33.66	17.5	30.16
Platinum	ug/l	24	ND	ND	ND	ND
Palladium	ug/l	ND	0.095	0.007	0.028	82.52
Nickel	ug/l	ND	8.74	9.06	3.08	31.42
Chromium	ug/l	ND	8.90	8.20	0.7	1.61
Simazine	ug/l	0.019	0.003	0.01	ND	ND
Amitrole	ug/l	ND	ND	ND	ND	ND
Glyphosate	ug/l	0.022	0.076	0.115	-2.04	-30.30
Diuron	ug/l	ND	0.030	0.208	0.211	84.17
Bromacil	ug/l	ND	ND	ND	ND	ND
Atrazine	ug/l	0.025	0.02	0.01	ND	ND
Total Herbicides	ug/l					
Naphthalene	ug/l	0.081	0.514	0.221	0.293	57.06
Acenaphthylene	ug/l	0.080	0.027	0.017	0.01	37.04
Acenaphthene	ug/l	0.080	0.008	0.008	0	0.00
Fluorene	ug/l	0.080	0.019	0.011	0.008	36.67
Phenanthrene	ug/l	0.181	0.096	0.059	0.037	38.54
Anthracene	ug/l	0.177	0.041	0.07	-0.029	-40.04
Fluoranthene	ug/l	0.179	0.150	0.150	0	0.00
Pyrene	ug/l	0.184	0.126	0.120	0.011	7.91
Benzo(a)anthracene	ug/l	0.159	0.107	0.085	0.022	20.56
Chrysene	ug/l	0.183	0.050	0.095	-0.005	-5.26
Benzo(b)fluoranthene	ug/l	0.288	0.152	0.121	0.029	19.46
Benzo(k)fluoranthene	ug/l	0.086	0.082	0.109	-0.012	-13.08
Benzo(a)pyrene	ug/l	0.183	0.236	0.216	0.019	8.08
Indeno(1,2,3-cd)pyrene	ug/l	0.185	0.096	0.099	-0.003	-3.16
Dibenzo(a,h)anthracene	ug/l	0.118	0.066	0.113	-0.016	-15.31
Benzo(g,h,i)perylene	ug/l	0.138	0.104	0.163	-0.069	-65.11
Na	mg/l	336.02	105.91	94.0	11.77	11.13
Hardness	mg/l	333.87	108.71	123.3	-14.53	-13.36
De-icing (Salt)	mg/l	528.24	178.66	159.48	17.18	9.72
BOD	mg/l	8.1	9.4	8.00	1.48	15.16
COD	mg/l	87.82	107.1	82.14	50.67	38.82
TSS	mg/l	88.8	308	138.31	178.73	56.31

	Units	Site 3 M4/River Ray Location 1 & 2: Road Run Off Average	Location 2 Oil Trap (Manhole) Average	Actual Reduction	% Reduction	Site 4 M40/Souldern Brook Location 1 & 2: Road Run Off Average	Location 2 Oil Trap (Full Retention Oil Separator) Average	Actual Reduction	% Reduction
Copper	ug/l	64.22	63.19	0.83	1.30	32.41	28.31	3.98	12.09
Filtered Copper	ug/l	34.37	35.18	-0.81	-2.36	11.82	11.68	0.29	2.23
Zinc	ug/l	213.05	202.44	10.89	4.47	97.86	87.57	10.41	10.62
Filtered Zinc	ug/l	55.46	58.58	-4.12	-7.41	29.01	21.58	8.82	28.71
Cadmium	ug/l	0.67	0.71	-0.20	-36.87	0.25	0.33	-0.07	-28.57
Aluminium	ug/l	1803.25	2207.56	-504.33	-15.56	792.75	610.08	130.77	16.72
Lead	ug/l	45.05	40.85	2.81	4.40	15.73	14.16	2.55	15.72
Platinum	ug/l	ND	0.13	ND	ND	ND	ND	ND	ND
Palladium	ug/l	0.09	0.10	-0.01	-10.00	0.42	0.00	0.42	100.00
Nickel	ug/l	8.15	8.44	-0.29	-4.08	4.04	4.18	-0.14	-2.47
Chromium	ug/l	8.60	8.62	-0.01	-0.12	7.73	4.83	2.98	37.32
Simazine	ug/l	ND	ND	ND	ND	0.01	0.22	0.21	2300.67
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	0.06	0.03	0.03	55.56	3.73	2.04	1.68	45.25
Diuron	ug/l	ND	ND	ND	ND	ND	ND	ND	ND
Bromacil	ug/l	0.04	0.03	0.03	41.13	0.01	0.01	0.00	-3.33
Atrazine	ug/l	ND	ND	NA	NA	0.01	0.01	-0.01	-85.00
Total Herbicides	ug/l								
Naphthalene	ug/l	0.02	0.01	0.00	0.00	0.06	0.02	0.04	67.97
Acenaphthylene	ug/l	0.00	0.00	0.00	0.00	0.01	ND	ND	ND
Acenaphthene	ug/l	0.00	0.00	0.00	0.00	0.04	ND	ND	ND
Fluorene	ug/l	0.01	0.00	0.00	25.00	0.04	0.00	0.04	87.5
Phenanthrene	ug/l	0.03	0.04	-0.01	-41.11	0.04	0.01	0.03	76.92
Anthracene	ug/l	0.02	0.02	0.00	9.46	0.05	0.02	0.04	66.3
Fluoranthene	ug/l	0.08	0.12	-0.04	-40.00	0.12	0.11	0.02	13.08
Pyrene	ug/l	0.08	0.12	-0.04	-44.77	0.15	0.12	0.03	20.1
Benzo(a)anthracene	ug/l	0.04	0.07	-0.02	-54.46	0.13	0.04	0.08	65.13
Chrysene	ug/l	0.09	0.12	-0.02	-24.26	0.11	0.09	0.02	22.14
Benzo(b)fluoranthene	ug/l	0.05	0.08	-0.03	-68.24	0.08	0.09	0.00	-0.18
Benzo(k)fluoranthene	ug/l	0.07	0.11	-0.04	-64.23	0.10	0.09	0.01	11.18
Benzo(a)pyrene	ug/l	0.08	0.16	-0.07	-86.26	0.12	0.12	-0.01	-4.87
Indeno(1,2,3-cd)pyrene	ug/l	0.06	0.08	-0.01	-13.42	0.07	0.11	-0.04	-60.03
Dibenzo(a,h)anthracene	ug/l	0.07	0.09	-0.01	-13.46	0.06	0.08	-0.03	-41.76
Benzo(g,h,i)perylene	ug/l	0.03	0.04	-0.02	-54.71	0.04	0.08	-0.03	-84.37
							0.08		
Na	mg/l	371.67	403.77	-41.90	-13.83	78.01	76.09	1.92	2.46
Hardness	mg/l	124.81	140.70	-16.69	-15.13	270.80	280.25	-10.25	-3.80
De-icing (Salt)	mg/l	817.14	874.46	-106.71	-26.27	123.90	123.96	-0.01	-0.01
BOD	mg/l	6	6	0.89	15.80	14.97	4.21	10.76	71.88
COD	mg/l	96	97	-1.42	-1.70	71	54	17.33	24.34
TSS	mg/l	101	132	-18.81	-18.81	79	84	-8.08	-8.08

	Units	Site 5 A34/Dalles Brook Filter Drain Location 1 & 2: Road Run Off Average	Discharge To Water Course (Filter Drain) Average	Actual Reduction	% Reduction	Site 6 A34/Newbury Pond D Location 1 & 2: Road Run Off Average	Location 2 Oil Trap (Bypass Oil Separator) Average	Actual Reduction	% Reduction
Copper	ug/l	42.83	34.40	8.14	19.11	23.08	20.05	3.16	13.17
Filtered Copper	ug/l	17.61	19.71	-2.10	-11.94	16.60	14.86	1.86	11.27
Zinc	ug/l	169.37	79.61	19.75	60.03	62.68	38.83	16.78	31.82
Filtered Zinc	ug/l	36.75	38.88	23.75	37.23	31.51	14.06	7.32	34.25
Cadmium	ug/l	0.43	0.33	0.13	23.06	0.21	1.32	-1.11	-520.78
Aluminium	ug/l	520.92	469.63	58.56	11.42	181.58	87.06	5.90	3.81
Lead	ug/l	15.50	11.54	3.92	24.05	4.30	3.58	0.50	17.54
Platinum	ug/l	ND	ND	ND	ND	ND	ND	ND	ND
Palladium	ug/l	0.42	3.82	-3.40	-114.02	0.34	0.13	0.25	61.75
Nickel	ug/l	4.47	3.02	1.42	31.94	4.06	4.05	-0.26	5.90
Chromium	ug/l	4.62	4.79	0.03	0.61	2.73	3.18	-0.44	-16.18
Simazine	ug/l	0.02	0.01	ND	ND	0.18	0.18	0.18	96.78
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	0.43	0.12	0.31	72.34	ND	ND	ND	ND
Diuron	ug/l	ND	0.01	ND	ND	ND	ND	ND	ND
Bromacil	ug/l	ND	ND	ND	ND	0.08	0.08	0.00	0.00
Atrazine	ug/l	0.01	ND	ND	ND	0.02	0.01	0.00	24.51
Total Herbicides	ug/l								
Naphthalene	ug/l	0.02	0.01	0.01	46.45	ND	ND	ND	ND
Acenaphthylene	ug/l	0.01	0.00	0.00	22.22	0.08	0.08	0.00	0.00
Acenaphthene	ug/l	0.01	0.00	0.00	38.61	ND	ND	ND	ND
Fluorene	ug/l	0.01	0.01	0.00	1.61	0.02	0.02	0.00	-28.19
Phenanthrene	ug/l	0.03	0.01	0.02	68.00	0.05	0.04	0.00	6.59
Anthracene	ug/l	0.01	0.00	0.01	70.00	0.05	0.04	0.01	15.75
Fluoranthene	ug/l	0.13	0.03	0.10	75.01	0.23	0.22	0.01	5.50
Pyrene	ug/l	0.13	0.04	0.09	69.01	0.21	0.20	0.01	5.24
Benzo(a)anthracene	ug/l	0.06	0.02	0.05	77.90	0.13	0.13	0.01	5.78
Chrysene	ug/l	0.10	0.03	0.07	69.44	0.13	0.13	0.00	1.83
Benzo(b)fluoranthene	ug/l	0.23	0.06	0.12	67.28	0.14	0.14	-0.01	-4.28
Benzo(k)fluoranthene	ug/l	0.07	0.02	0.05	73.08	0.06	0.08	-0.01	-11.33
Benzo(a)pyrene	ug/l	0.13	0.04	0.09	67.80	0.11	0.11	0.00	2.78
Indeno(1,2,3-cd)pyrene	ug/l	0.12	0.04	0.09	70.68	0.12	0.12	0.00	1.11
Dibenzo(a,h)anthracene	ug/l	0.03	0.01	0.01	42.70	0.03	0.03	0.00	-8.81
Benzo(g,h,i)perylene	ug/l	0.14	0.05	0.09	59.10	ND	ND	ND	ND
Na	mg/l	134.90	153.64	-18.74	-13.41	39.03	47.47	-8.44	-21.63
Hardness	mg/l	93.71	103.73	-11.82	-6.72	140.30	178.08	-35.38	-25.84
De-icing (Salt)	mg/l	197.94	244.36	-19.72	-45.71	59.48	71.16	-11.68	-19.60
BOD	mg/l	4.19	5.19	0.80	16.09	6	3.98	1.98	38.14
COD	mg/l	72.27	58.18	23.16	30.36	71	58	13.87	19.11
TSS	mg/l	72.64	52.87	19.90	27.36	68	41	23.48	36.52

NM= Not Measured
ND = Not Detected

Actual and Percentage Reduction – Location 1 (Road Runoff) and Location 2

		Comparison of Average Concentrations from Loc 1 to Loc 2				Comparison of Maximum & Minimum concentrations from Loc 1 to Loc 2							
		Overall Average RRO	Location 2	Overall Actual Difference	Overall % Difference	Overall Maximum RRO	Overall Maximum Loc2	Overall Maximum Actual Difference	Overall % Maximum Difference	Overall Minimum RRO	Overall Minimum Loc2	Overall Minimum Actual Difference	Overall % Minimum Difference
	Units												
Copper	ug/l	40.35	36.87	3.48	8.82	84.02	83.19	0.83	1.30	23.99	20.83	3.16	13.17
Filtered Copper	ug/l	17.49	17.17	0.32	1.82	24.57	25.18	-0.61	-2.50	11.82	11.58	0.24	2.03
Zinc	ug/l	140.63	113.67	26.96	19.17	221.50	202.44	19.06	8.60	52.60	35.81	16.79	31.92
Filtered Zinc	ug/l	43.98	39.53	4.44	10.11	81.71	68.45	13.26	16.23	8.60	14.05	-5.45	-63.37
Cadmium	ug/l	0.46	0.71	-0.25	-53.88	0.89	1.32	-0.43	-48.98	0.21	0.33	-0.12	-57.28
Aluminium	ug/l	1117.06	1186.03	-68.97	-6.17	2850.00	2545.00	305.00	10.70	101.98	97.98	3.90	3.91
Lead	ug/l	23.05	20.29	2.75	11.95	45.06	43.05	2.01	4.46	4.38	3.80	0.58	13.34
Platinum	ug/l	24.00	0.02	23.98	99.93	24.00	0.02	23.98	99.93	24.00	0.02	23.98	99.93
Palladium	ug/l	0.43	0.24	0.19	44.53	0.90	0.90	0.00	-0.45	0.09	0.00	0.09	100.00
Nickel	ug/l	5.59	5.06	0.53	9.49	9.74	6.68	3.06	31.42	4.04	4.18	-0.14	-3.47
Chromium	ug/l	6.26	6.01	0.25	3.97	8.98	9.02	-0.08	-0.83	2.72	3.16	-0.44	-16.19
										0.00	0.00		
Simazine	ug/l	0.06	0.10	-0.04	-69.88	0.30	0.22	0.07	24.94	0.00	0.01	-0.01	-233.33
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	0.81	0.58	0.23	28.48	3.73	2.04	1.69	45.25	0.02	0.02	0.00	-1.01
Diuron	ug/l	0.33	0.15	0.17	53.34	0.33	0.30	0.03	8.59	0.33	0.30	0.03	8.59
Bromacil	ug/l	0.04	0.03	0.01	14.47	0.07	0.07	0.00	-3.01	0.00	0.00	0.00	0.00
Atrazine	ug/l	0.01	0.01	0.00	14.72	0.04	0.01	0.02	57.71	0.00	0.01	-0.01	-170.27
Total Herbicides	ug/l												
Naphthalene	ug/l	0.12	0.07	0.05	43.16	0.51	0.22	0.29	57.00	0.02	0.01	0.01	38.41
Acenaphthylene	ug/l	0.02	0.01	0.01	63.86	0.06	0.02	0.04	70.69	0.00	0.00	0.00	0.00
Acenaphthene	ug/l	0.03	0.01	0.02	78.59	0.08	0.01	0.08	90.36	0.00	0.00	0.00	0.00
Fluorene	ug/l	0.02	0.01	0.01	61.82	0.07	0.02	0.05	69.99	0.01	0.00	0.00	80.20
Phenanthrene	ug/l	0.07	0.04	0.03	45.83	0.19	0.06	0.13	68.45	0.03	0.03	0.00	-17.69
Anthracene	ug/l	0.04	0.03	0.01	33.19	0.13	0.07	0.06	44.98	0.01	0.02	-0.01	-166.92
Fluoranthene	ug/l	0.14	0.13	0.02	11.67	0.23	0.22	0.01	6.09	0.09	0.10	-0.02	-20.73
Pyrene	ug/l	0.15	0.12	0.02	16.71	0.21	0.20	0.01	5.34	0.09	0.12	-0.03	-37.03
Benzo(a)anthracene	ug/l	0.11	0.07	0.04	34.82	0.18	0.13	0.03	20.25	0.04	0.04	0.00	2.44
Chrysene	ug/l	0.11	0.09	0.02	17.52	0.18	0.13	0.03	19.03	0.09	0.09	0.01	5.79
Benzo(b)fluoranthene	ug/l	0.15	0.10	0.05	31.98	0.21	0.14	0.07	32.16	0.05	0.08	-0.03	-58.78
Benzo(k)fluoranthene	ug/l	0.08	0.08	0.00	2.95	0.10	0.11	-0.01	-6.96	0.08	0.06	-0.01	-11.35
Benzo(a)pyrene	ug/l	0.14	0.13	0.01	-5.98	0.24	0.22	0.02	8.09	0.08	0.12	-0.04	-51.65
Indeno(1,2,3-cd)pyrene	ug/l	0.10	0.09	0.01	10.21	0.12	0.12	0.01	4.99	0.07	0.09	-0.02	-27.84
Dibenzo(a,h)anthracene	ug/l	0.06	0.06	-0.01	-9.89	0.12	0.11	0.01	4.34	0.01	0.03	-0.02	-148.43
Benzo(g,h,i)perylene	ug/l	0.10	0.08	0.02	18.18	0.14	0.16	-0.02	-16.55	0.03	0.04	-0.02	-54.27
Na	mg/l	169.56	154.60	14.99	8.84	357.87	403.77	-45.90	-12.83	39.03	47.47	-8.44	-21.62
Hardness	mg/l	136.97	171.52	-35.56	-26.15	210.00	260.20	-50.20	-23.90	82.11	123.30	-41.19	-50.16
De-IcingSalts	mg/l	249.87	254.63	-4.76	-1.90	536.24	674.46	-138.22	-25.77	59.49	71.15	-11.66	-19.60
BOD	mg/l	7.98	5.24	2.75	34.43	14.97	6.80	8.18	54.62	5.52	3.86	1.66	30.14
COD	mg/l	87.62	69.42	18.20	20.77	137.78	97.02	40.68	29.54	70.82	53.58	17.24	24.35
TSS	mg/l	107.92	83.57	24.35	22.56	318.00	139.27	178.73	56.21	52.64	41.08	11.54	21.93
NM= Not Measured													
ND = Not Detected													

All Sites Average - Actual and Percentage Reduction – Location 1 (Road Runoff) and Location 2

Determinand	Unit	Site 1 Brinkworth Brook / M4 Location 1 Road Run Off / Discharge To Watercourse	Site 2 A417/River Frome			Location 2 & 3	Site 3 M4/River Ray			Location 2 & 3
		Road Run Off & Discharge To Water Course	Location 2 Oil Trap (Bypass Oil Separator)	Discharge To Water Course (Dry Pond)			Location 2 Oil Trap (Manhole)	Discharge To Water Course (Sedimentation Tank)		
		Average	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction
	Units									
Copper	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Filtered Copper	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zinc	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Filtered Zinc	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cadmium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aluminium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lead	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Platinum	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Palladium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nickel	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chromium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Simazine	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Atrazine	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Glyphosate	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diuron	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Herbicides	ug/l									
Naphthalene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acenaphthylene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acenaphthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fluorene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Phenanthrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(a)anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chrysene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(b)fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(k)fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(a)pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Indeno(1,2,3-cd)pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dibenzo(a,h)anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(g,h,i)perylene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Na	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hardness	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BOD	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COD	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TSS	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Determinand	Unit	Site 4 M40/Souldern Brook			Location 2 & 3	Site 5 A34/[illegible] Brook			Location 1 & 3
		Location 2 Oil Trap (Full Retention Oil Separator)	Discharge To Water Course (Wet Pond)			Road Run Off	Discharge To Water Course (Filter Drain)		
		Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction
Copper	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Filtered Copper	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zinc	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Filtered Zinc	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cadmium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aluminium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lead	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Platinum	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Palladium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nickel	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chromium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Simazine	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Atrazine	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Glyphosate	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diuron	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Herbicides	ug/l								
Naphthalene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acenaphthylene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acenaphthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fluorene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Phenanthrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(a)anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chrysene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(b)fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(k)fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(a)pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Indeno(1,2,3-cd)pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dibenzo(a,h)anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(g,h,i)perylene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Na	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hardness	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BOD	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COD	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TSS	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Determinand	Unit	Site 6 Newbury Pond D / A34 Location 2 & 3			
		Location 2 Oil Trap (Bypass Oil Separator)	Discharge To Water Course (Pond Bed)		
		Average	Average	Actual Reduction	% Reduction
Copper	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Filtered Copper	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Zinc	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Filtered Zinc	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Cadmium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Aluminium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Lead	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Platinum	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Palladium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Nickel	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Chromium	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Simazine	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Atrazine	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Glyphosate	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Diuron	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Total Herbicides	ug/l				
Naphthalene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Acenaphthylene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Acenaphthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Fluorene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Phenanthrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(a)anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Chrysene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(b)fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(k)fluoranthene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(a)pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Indeno(1,2,3-cd)pyrene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Dibenzo(a,h)anthracene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(g,h,i)perylene	ug/l	[illegible]	[illegible]	[illegible]	[illegible]
Na	mg/l	[illegible]	[illegible]	[illegible]	[illegible]
Hardness	mg/l	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	mg/l	[illegible]	[illegible]	[illegible]	[illegible]
BOD	mg/l	[illegible]	[illegible]	[illegible]	[illegible]
COD	mg/l	[illegible]	[illegible]	[illegible]	[illegible]
TSS	mg/l	[illegible]	[illegible]	[illegible]	[illegible]

Actual and Percentage Reduction – Location 2 and Location 3 (Discharge to Watercourse)

		Comparison of Average Concentrations from Loc 2 to Loc 3				Comparison of Maximum & Minimum concentrations from Loc 2 to Loc 3							
		Overall Average Loc 2	Overall Average DWC	Overall Actual Difference	Overall % Difference	Overall Maximum Loc2	Overall Maximum DWC	Overall Maximum Actual Difference	Overall % Maximum Difference	Overall Minimum Loc2	Overall Minimum DWC	Overall Minimum Actual Difference	Overall % Minimum Difference
	Units												
Copper	ug/l	37.47	25.54	11.93	31.84	63.19	38.39	24.80	39.25	20.83	12.79	8.04	38.60
Filtered Copper	ug/l	16.54	11.97	4.56	27.60	25.18	19.71	5.47	21.71	11.58	6.64	4.94	42.66
Zinc	ug/l	123.44	79.88	43.55	35.28	202.44	137.62	64.82	32.02	35.81	38.52	-2.71	-7.57
Filtered Zinc	ug/l	40.67	29.08	11.58	28.50	68.45	38.02	30.43	44.45	14.85	14.89	-0.04	-5.98
Cadmium	ug/l	0.81	0.38	0.43	52.98	1.32	0.67	0.65	49.33	0.32	0.22	0.11	33.64
Aluminium	ug/l	1367.38	529.43	837.95	61.28	2545.00	1146.00	1399.00	54.97	97.99	50.20	47.79	48.77
Lead	ug/l	22.48	13.72	8.76	38.98	43.05	27.20	15.85	36.81	3.80	3.58	0.21	5.64
Platinum	ug/l	0.02	ND	ND	ND	0.02	0.00	0.02	100.00	0.02	ND	ND	ND
Palladium	ug/l	0.07	0.33	-0.25	-341.76	0.13	0.90	-0.77	-582.31	0.00	0.02	-0.02	#DIV/0!
Nickel	ug/l	5.56	4.89	0.67	12.11	6.68	7.15	-0.47	-7.04	4.18	3.05	1.13	27.03
Chromium	ug/l	6.32	5.12	1.20	19.01	9.02	7.31	1.71	18.92	3.16	3.32	-0.16	-5.06
Simazine	ug/l	0.13	0.05	0.13	100.00	0.22	0.11	0.11	49.28	0.01	0.01	0.00	-12.00
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	2.30	1.47	0.82	35.78	2.04	0.65	1.40	68.39	0.02	0.04	-0.02	-88.00
Diuron	ug/l	0.30	0.16	0.14	46.94	0.30	0.31	-0.01	-4.03	0.30	0.01	0.29	97.90
Bromacil	ug/l	0.03	0.03	0.00	-2.65	0.07	0.07	0.00	5.46	0.00	0.00	0.00	100.00
Atrazine	ug/l	0.01	ND	ND	ND	0.01	0.01	0.01	38.86	0.01	0.01	0.00	40.00
Total Herbicides	ug/l												
Naphthalene	ug/l	0.08	0.08	0.00	3.28	0.22	0.34	-0.12	-52.94	0.01	0.00	0.01	86.44
Acenaphthylene	ug/l	0.01	0.01	0.00	-10.35	0.02	0.02	0.00	1.46	0.00	0.00	0.00	100.00
Acenaphthene	ug/l	0.00	0.01	0.00	-102.15	0.01	0.02	-0.01	-163.66	0.00	0.00	0.00	-87.50
Fluorene	ug/l	0.01	0.01	0.00	6.88	0.02	0.02	0.00	14.72	0.00	0.00	0.00	-227.27
Phenanthrene	ug/l	0.04	0.03	0.01	24.14	0.06	0.05	0.01	13.67	0.03	0.01	0.02	61.01
Anthracene	ug/l	0.04	0.02	0.01	34.85	0.07	0.03	0.04	54.29	0.02	0.00	0.01	82.02
Fluoranthene	ug/l	0.15	0.07	0.08	52.13	0.22	0.14	0.07	34.22	0.10	0.01	0.09	85.94
Pyrene	ug/l	0.14	0.07	0.07	51.88	0.20	0.12	0.07	37.50	0.12	0.02	0.10	84.56
Benzo[a]anthracene	ug/l	0.08	0.05	0.03	39.18	0.13	0.12	0.00	3.00	0.04	0.01	0.04	85.47
Chrysene	ug/l	0.11	0.06	0.05	44.05	0.13	0.13	0.00	-2.46	0.09	0.01	0.09	94.18
Benzo[b]fluoranthene	ug/l	0.11	0.05	0.06	53.16	0.14	0.11	0.03	21.33	0.08	0.01	0.07	86.68
Benzo[k]fluoranthene	ug/l	0.09	0.06	0.03	38.13	0.11	0.10	0.01	7.67	0.06	0.02	0.04	70.23
Benzo[a]pyrene	ug/l	0.16	0.06	0.08	59.61	0.22	0.16	0.06	26.85	0.12	0.01	0.12	88.33
Indeno[1,2,3-cd]pyrene	ug/l	0.10	0.05	0.06	52.70	0.12	0.13	-0.01	-12.02	0.09	0.01	0.09	92.35
Dibenzo[a,h]anthracene	ug/l	0.08	0.04	0.04	45.05	0.11	0.09	0.02	17.39	0.03	0.01	0.03	78.42
Benzo[g,h,i]perylene	ug/l	0.09	0.04	0.05	59.39	0.16	0.09	0.07	43.83	0.04	0.00	0.04	93.51
Na	mg/l	155.34	144.51	10.83	6.97	403.77	374.84	28.92	7.16	47.47	50.87	-3.40	-7.16
Hardness	mg/l	175.97	238.34	-62.36	-35.44	260.20	357.10	-96.90	-37.24	123.30	132.70	-9.40	-7.62
De-IcingSalts	mg/l	257.19	213.43	43.76	17.01	674.46	486.90	187.56	27.81	71.15	86.64	-15.49	-21.77
BOD	mg/l	5.25	4.74	0.51	9.62	6.80	6.00	0.80	11.71	3.86	2.75	1.11	28.72
COD	mg/l	74.22	64.30	9.87	13.29	97.02	107.40	-10.38	-10.69	53.58	38.52	15.06	28.10
TSS	mg/l	96.22	66.78	29.44	30.59	139.27	189.90	-50.63	-36.36	41.09	11.01	30.08	73.21

All Sites Average - Actual and Percentage Reduction – Location 2 and Location 3 (Discharge to Watercourse)

		Site 1 Brixworth Brook / A43 Location 1 Road Run Off / Discharge To Watercourse	Site 2 A417/River Frome			Location 1 & 3	Site 3 M6/River Rea			Location 1 & 3	Site 4 M40/Souldern Brook			Location 1 & 3	Site 5 A34/Gallos Brook			Location 1 & FD	Site 6 A34/Newbury Pond D			Location 1 & 3
		Road Run Off & Discharge To Water Course	Road Run Off	Discharge To Water Course (Dry Pond)			Road Run Off	Discharge To Water Course (Sedimentation Tank)			Road Run Off	Discharge To Water Course (Wet Pond)			Road Run Off	Discharge To Water Course (Filter Drain)			Road Run Off	Discharge To Water Course (Reed Bed)		
	Units	Average	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction	Average	Average	Actual Reduction	% Reduction
Copper	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Filtered Copper	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Zinc	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Filtered Zinc	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cadmium	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Aluminium	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lead	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Platinum	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Palladium	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Nickel	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chromium	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Simazine	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Atrazine	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Glyphosate	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Diuron	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bromacil	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Herbicides	µg/l																					
Naphthalene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acenaphthylene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acenaphthene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fluorene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Phenanthrene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Anthracene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fluoranthene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pyrene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(a)anthracene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Chrysene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(b)fluoranthene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(k)fluoranthene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(a)pyrene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Indeno(1,2,3-cd)pyrene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dibenzo(a,h)anthracene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Benzo(ghi)perylene	µg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Oil	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Hardness	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Conductivity	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BOD	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COD	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TSS	mg/l	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

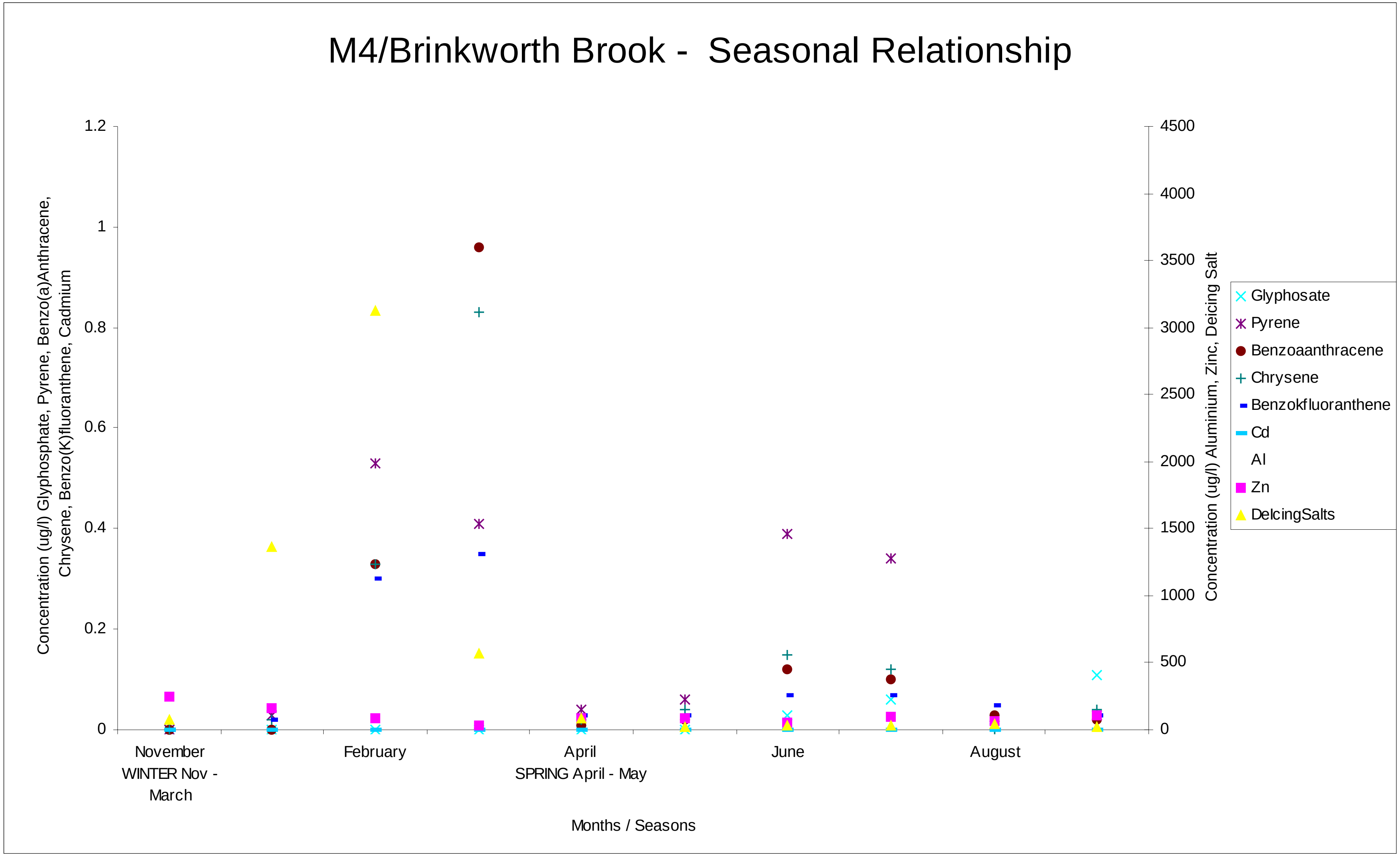
NM = Not Measured
ND = Not Detected

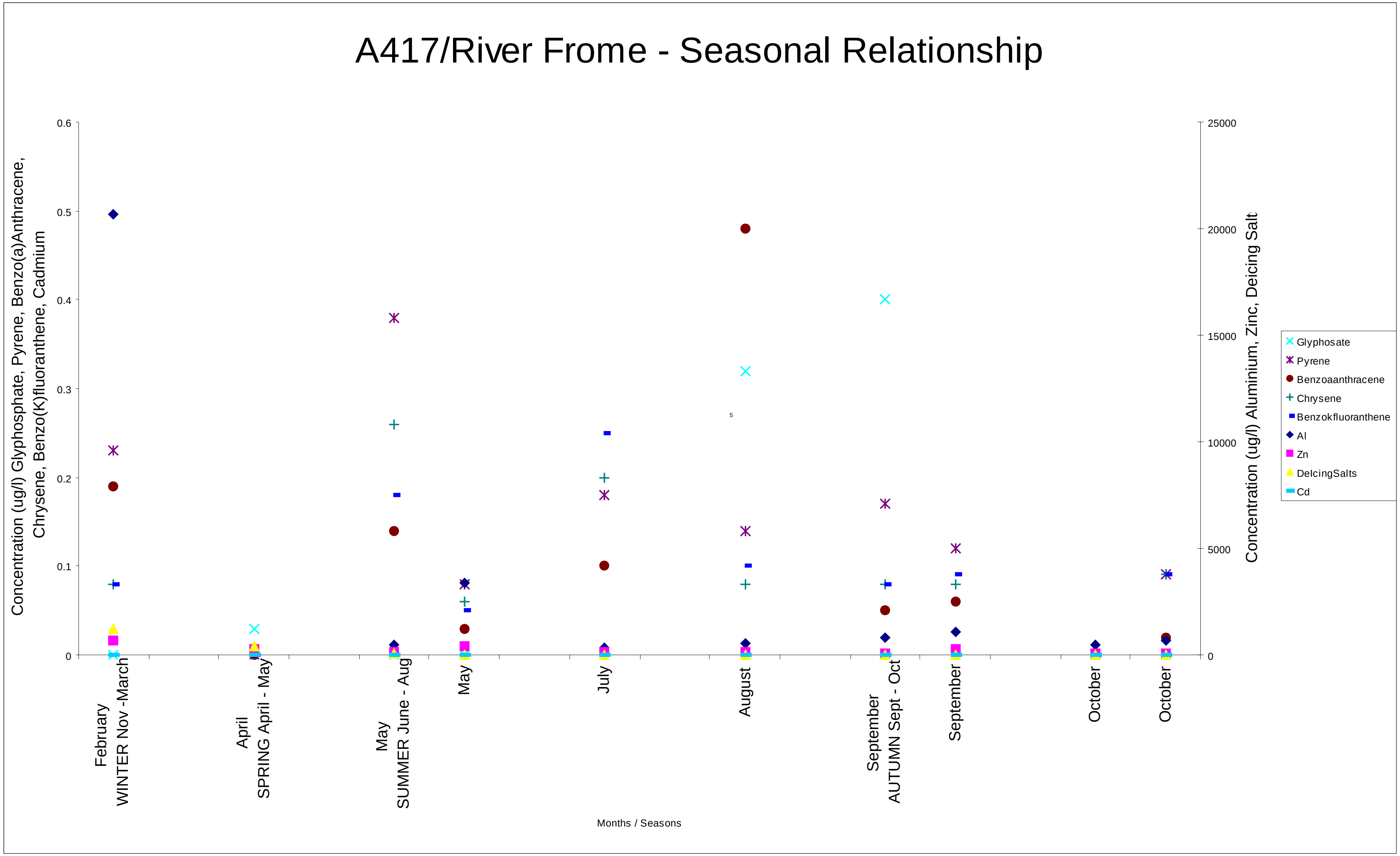
Actual and Percentage Reduction – Location 1 (Road Runoff) and Location 3 (Discharge to Watercourse)

		Comparison of Average Concentrations over all sites				Comparison of Maximum & Minimum concentrations over all sites							
		Overall Average RRO	Overall Average DWC	Overall Actual Difference	Overall % Difference	Overall Maximum RRO	Overall Maximum DWC	Overall Maximum Actual Difference	Overall % Maximum Difference	Overall Minimum RRO	Overall Minimum DWC	Overall Minimum Actual Difference	Overall % Minimum Difference
	Units												
Copper	ug/l	43.76	27.17	16.58	37.90	64.02	42.65	21.37	33.38	23.99	12.78	11.20	46.69
Filtered Copper	ug/l	17.43	11.55	5.88	33.72	24.57	17.61	6.96	28.32	11.82	6.64	5.18	43.82
Zinc	ug/l	146.28	94.82	51.46	35.18	221.58	149.31	72.19	32.58	52.60	38.52	14.08	26.77
Filtered Zinc	ug/l	46.94	33.23	13.71	29.21	81.11	55.74	25.37	31.78	21.37	14.88	6.48	30.32
Cadmium	ug/l	0.48	0.40	0.08	16.12	0.89	0.67	0.22	24.56	0.21	0.22	-0.01	-4.37
Aluminium	ug/l	1388.81	541.30	857.31	61.30	2850.08	1146.00	1704.60	59.79	101.95	50.28	51.76	50.77
Lead	ug/l	26.89	14.48	12.41	46.15	45.08	27.20	17.89	39.63	4.38	3.58	0.80	18.22
Platinum	ug/l	ND	ND	ND	ND	0.08	0.00	ND	ND	ND	ND	ND	ND
Palladium	ug/l	0.44	0.17	0.27	62.85	0.88	0.40	0.48	53.13	0.09	0.02	0.01	17.90
Nickel	ug/l	6.15	5.17	0.98	15.84	9.14	7.15	2.59	26.58	4.04	3.86	0.18	4.46
Chromium	ug/l	6.96	5.12	1.86	26.80	8.98	7.31	1.65	18.48	2.72	3.32	-0.60	-22.86
Simazine	ug/l	0.10	0.05	0.10	108.30	0.38	0.11	0.18	61.93	0.00	0.01	-0.01	-323.33
Amitrole	ug/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Glyphosate	ug/l	2.30	1.47	0.82	35.76	3.13	0.65	3.89	82.68	0.05	0.04	0.01	28.83
Diuron	ug/l	0.33	0.31	0.02	4.91	0.33	0.31	0.02	4.91	0.33	0.31	0.02	4.81
Bromacil	ug/l	0.04	0.05	-0.01	-31.50	0.07	0.07	0.00	2.61	0.00	0.03	-0.03	-1208.99
Atrazine	ug/l	0.01	ND	ND	ND	0.02	0.01	0.01	95.58	0.01	0.00	0.00	53.75
Naphthalene	ug/l	0.20	0.08	0.11	58.89	0.51	0.34	0.18	34.24	0.02	0.08	0.02	87.99
Acenaphthylene	ug/l	0.02	0.01	0.01	48.60	0.03	0.02	0.01	41.08	0.00	0.09	0.00	106.80
Acenaphthene	ug/l	0.02	0.01	0.01	43.31	0.04	0.02	0.02	48.59	0.00	0.08	0.00	-35.80
Fluorene	ug/l	0.02	0.01	0.01	56.81	0.04	0.02	0.02	50.91	0.01	0.09	0.00	35.20
Phenanthrene	ug/l	0.05	0.04	0.01	27.80	0.18	0.05	0.05	46.95	0.03	0.02	0.00	8.39
Anthracene	ug/l	0.04	0.02	0.02	41.94	0.05	0.03	0.02	37.13	0.02	0.01	0.02	74.10
Fluoranthene	ug/l	0.15	0.08	0.08	48.13	0.23	0.14	0.09	38.23	0.09	0.01	0.01	83.83
Pyrene	ug/l	0.15	0.09	0.06	48.39	0.21	0.13	0.08	37.38	0.09	0.02	0.01	78.84
Benzo[a]anthracene	ug/l	0.10	0.06	0.04	48.10	0.13	0.12	0.01	8.62	0.04	0.01	0.04	85.82
Chrysene	ug/l	0.11	0.07	0.03	21.34	0.13	0.13	0.00	-1.41	0.09	0.01	0.09	94.52
Benzo[b]fluoranthene	ug/l	0.10	0.08	0.03	28.34	0.15	0.20	-0.04	-29.01	0.05	0.01	0.04	85.20
Benzo[k]fluoranthene	ug/l	0.08	0.07	0.01	13.79	0.18	0.10	0.00	1.34	0.05	0.02	0.03	58.53
Benzo[a]pyrene	ug/l	0.14	0.08	0.06	42.51	0.24	0.16	0.08	32.77	0.09	0.01	0.01	92.82
Indeno(1,2,3-cd)pyrene	ug/l	0.09	0.07	0.02	25.85	0.12	0.13	-0.01	-11.42	0.07	0.01	0.06	98.22
Dibenzo[a,h]anthracene	ug/l	0.07	0.04	0.02	30.83	0.18	0.08	0.00	4.75	0.03	0.01	0.02	68.34
Benzo[g,h,i]perylene	ug/l	0.06	0.05	0.00	5.87	0.18	0.14	-0.03	-32.02	0.03	0.08	0.02	68.88
Na	mg/l	145.19	141.18	-4.02	2.77	357.97	374.94	-16.98	-4.74	39.33	50.67	-11.94	-38.33
Hardness	mg/l	145.97	224.01	-79.04	-53.46	210.08	357.10	-147.10	-70.05	108.71	82.11	26.66	24.51
De-IcingSalts	mg/l	219.39	198.09	21.31	9.71	517.14	488.90	38.84	5.56	59.49	86.64	-27.15	-45.64
BOD	mg/l	8.81	4.94	3.67	42.60	14.97	6.18	8.79	58.73	5.52	2.75	2.77	50.21
COD	mg/l	85.26	66.80	20.47	27.76	137.16	107.40	36.30	27.06	78.82	38.52	32.30	45.81
TSS	mg/l	140.39	70.71	69.66	49.83	318.08	188.90	128.10	40.26	84.75	11.01	83.75	83.80
NM= Not Measured													
ND = Not Detected													

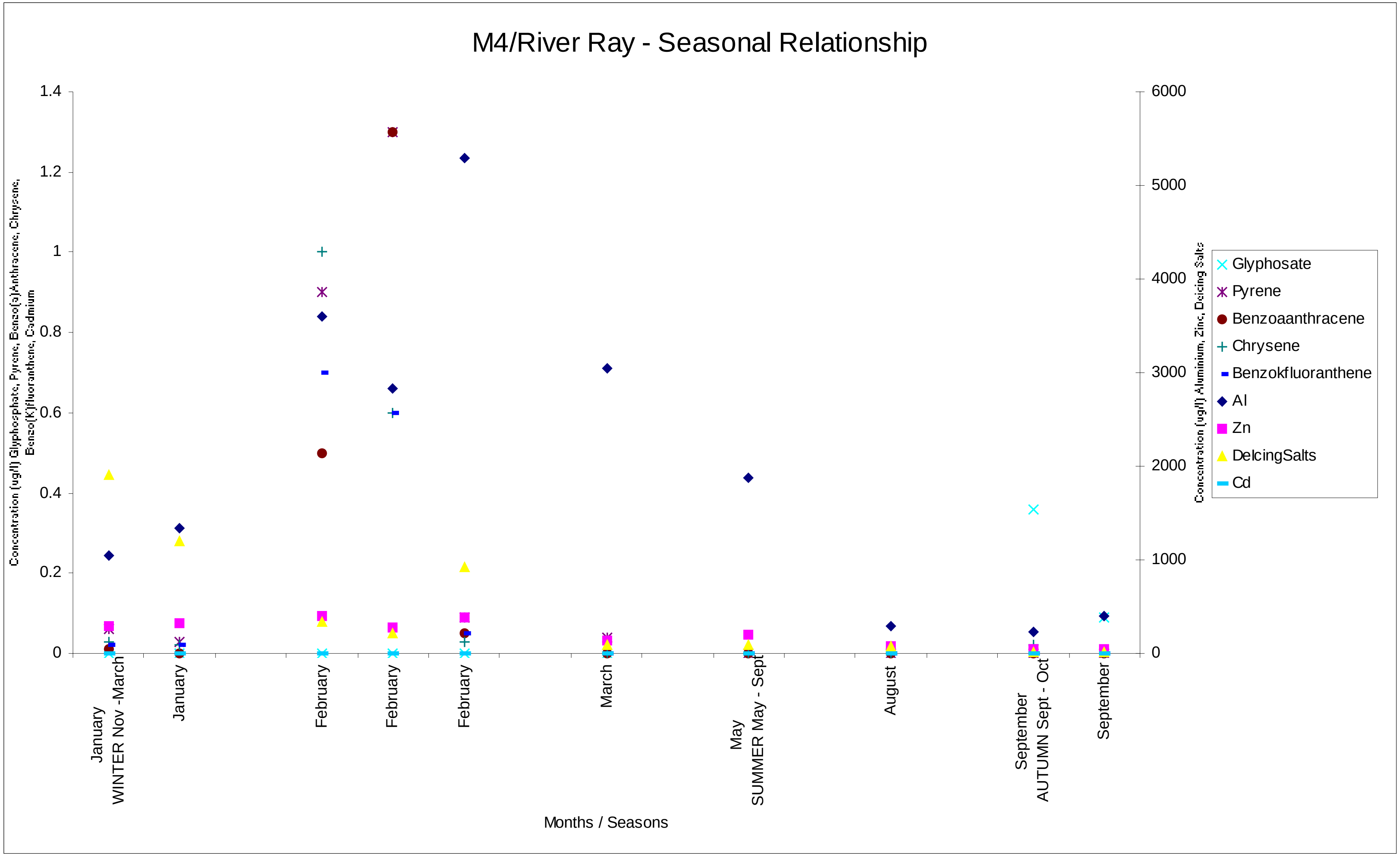
All Sites Average - Actual and Percentage Reduction – Location 1 (Road Runoff) and Location 3 (Discharge to Watercourse)

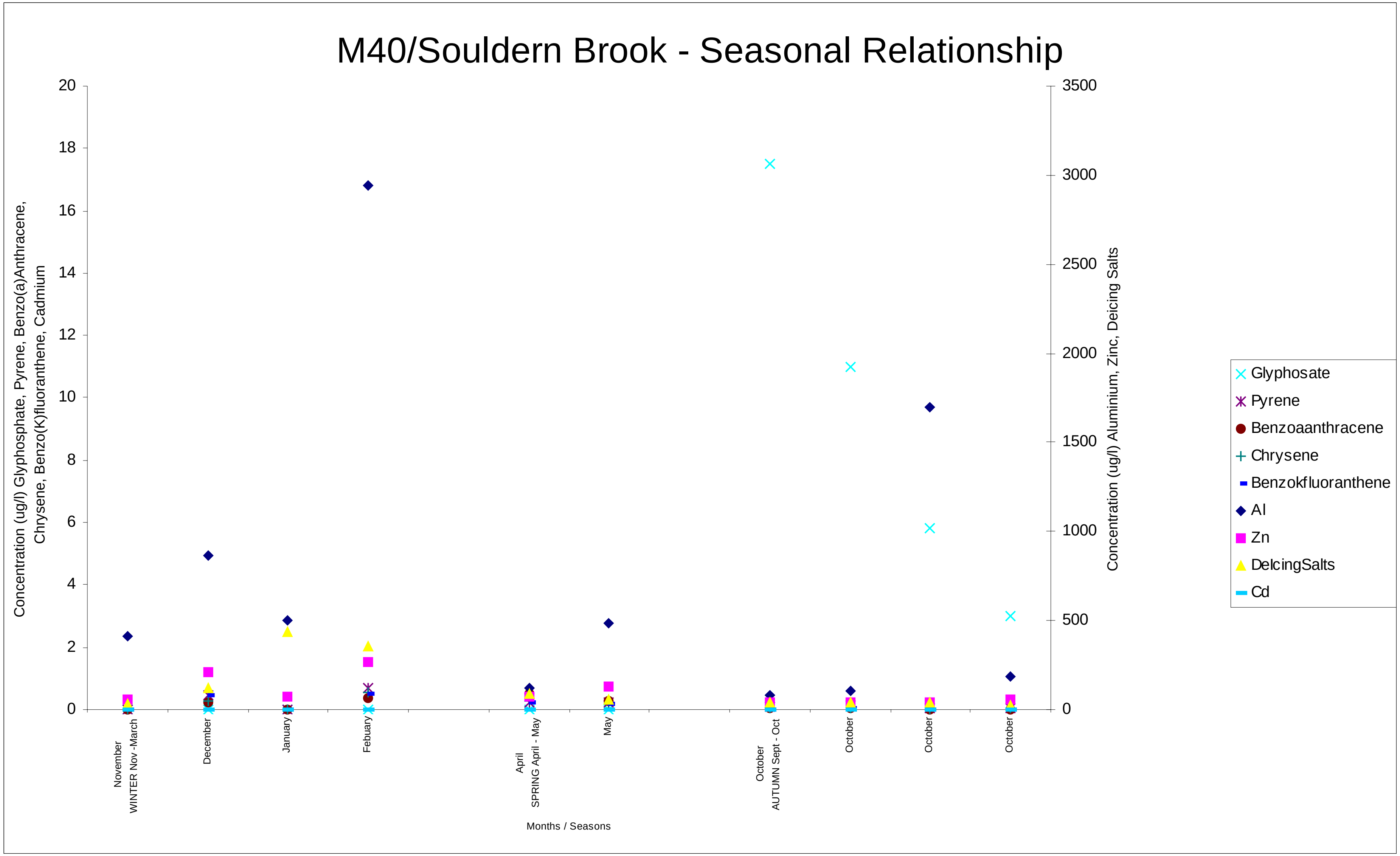
APPENDIX F GRAPHICAL PLOTS OF SEASONAL RELATIONSHIPS

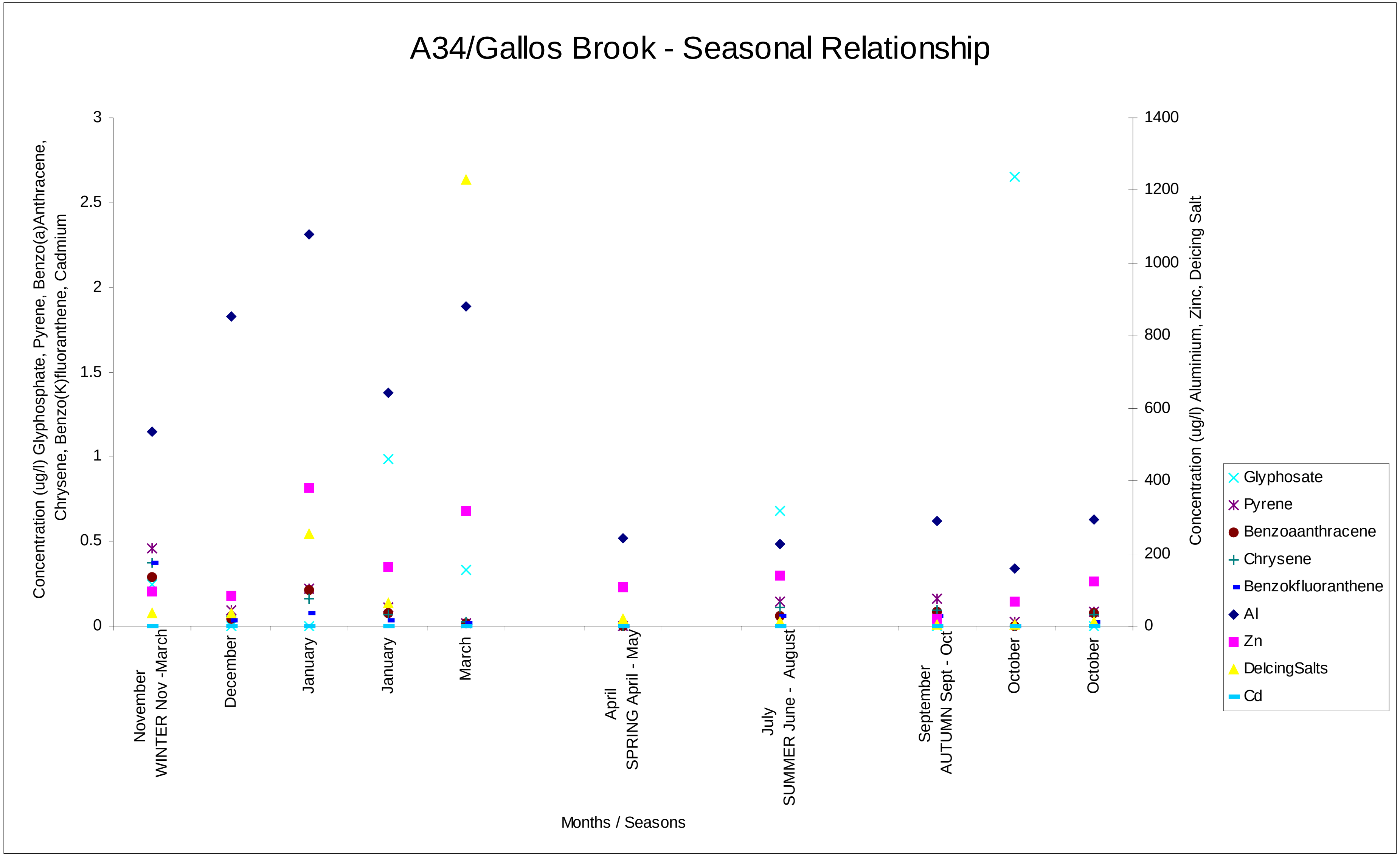

M4/Brinkworth Brook - Seasonal Relationship
Concentration (ug/l) Glyphosphate, Pyrene, Benzo(a)Anthracene, Chrysene, Benzo(K)fluoranthene, Cadmium
1.2
1
0.8
0.6
0.4
0.2
0
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Concentration (ug/l) Aluminium, Zinc, Deicing Salt
Glyphosate
Pyrene
Benzoaanthracene
Chrysene
Benzokfluoranthene
Cd
Al
Zn
DeIcingSalts
November
WINTER Nov - March
February
April
SPRING April - May
June
August
Months / Seasons

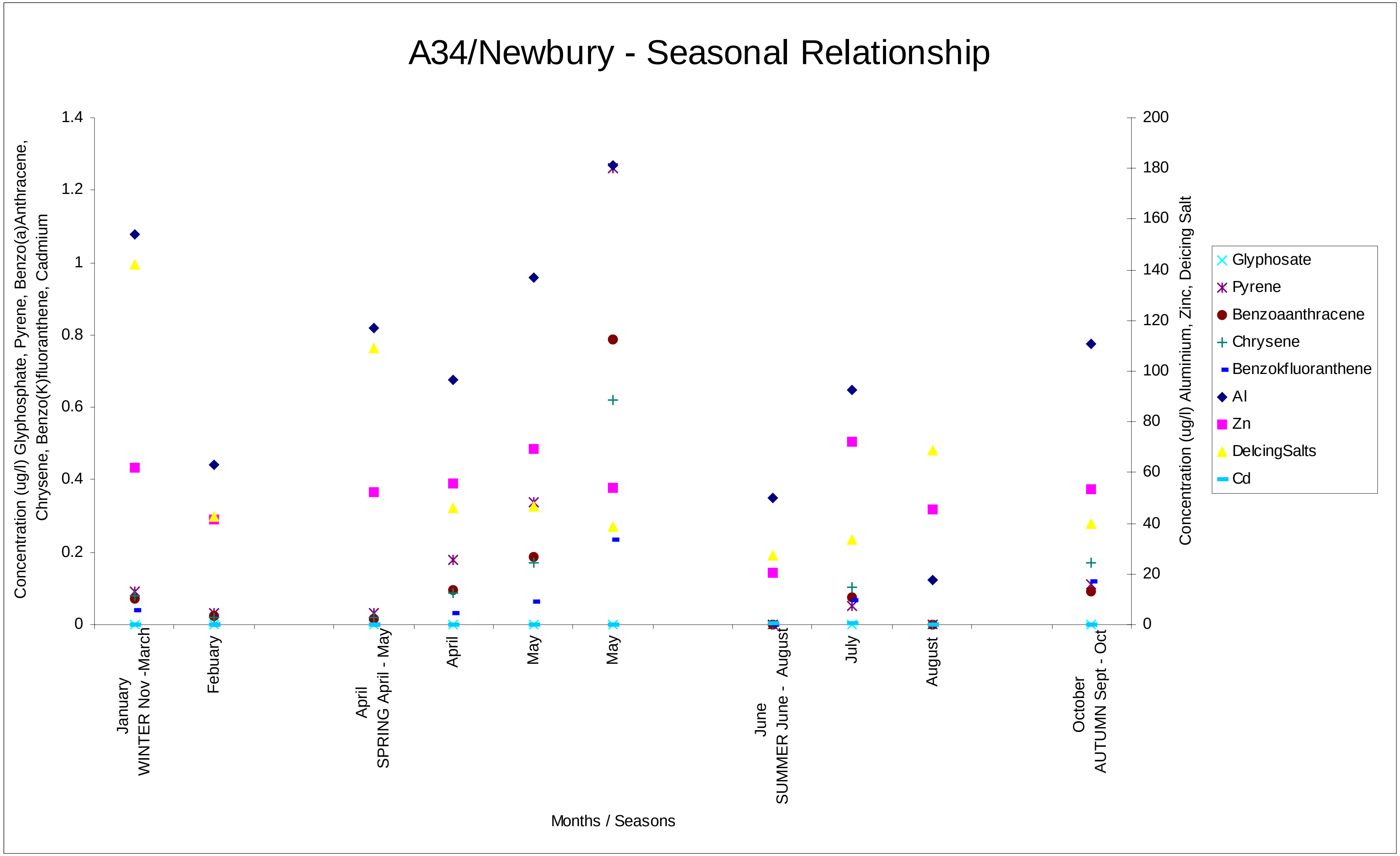


A417/River Frome - Seasonal Relationship
Concentration (ug/l) Glyphosphate, Pyrene, Benzo(a)Anthracene, Chrysene, Benzo(K)fluoranthene, Cadmium
Concentration (ug/l) Aluminium, Zinc, Deicing Salt
0.6
0.5
0.4
0.3
0.2
0.1
0
25000
20000
15000
10000
5000
0
February
WINTER Nov -March
April
SPRING April - May
May
SUMMER June - Aug
May
July
August
September
AUTUMN Sept - Oct
September
October
October
Months / Seasons
Glyphosate
Pyrene
Benzoaanthracene
Chrysene
Benzokfluoranthene
Al
Zn
DeIcingSalts
Cd

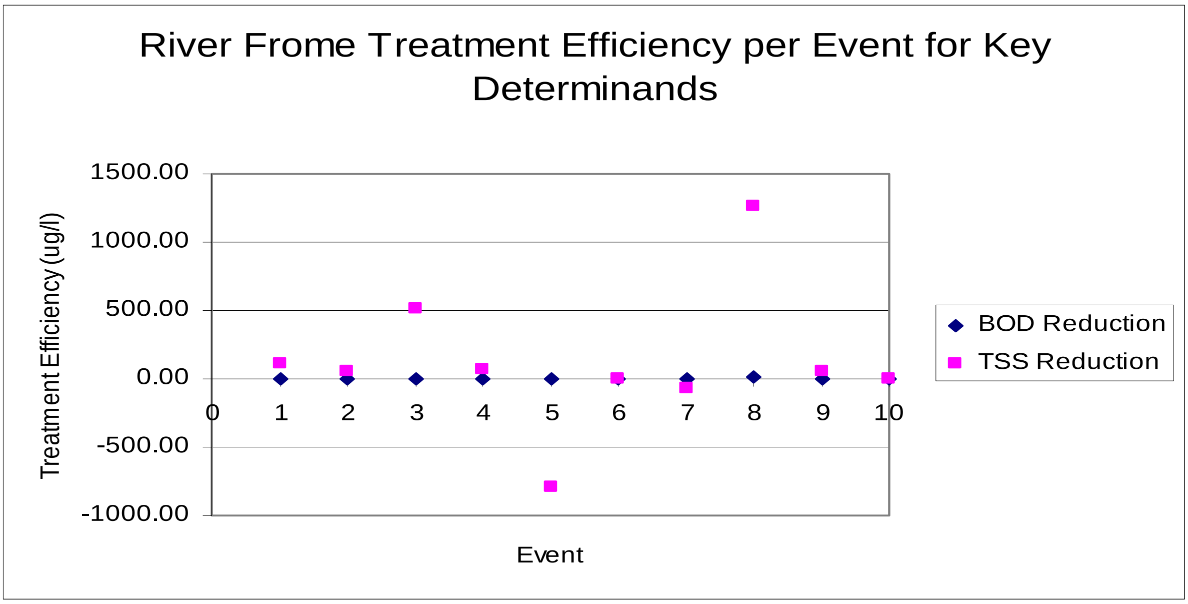

M4/River Ray - Seasonal Relationship
Concentration (ug/l) Glyphosphate, Pyrene, Benzo(a)Anthracene, Chrysene, Benzo(K)fluoranthene, Cadmium
Concentration (ug/l) Aluminium, Zinc, Deicing Salts
1.4
1.2
1
0.8
0.6
0.4
0.2
0
6000
5000
4000
3000
2000
1000
0
Glyphosate
Pyrene
Benzoaanthracene
Chrysene
Benzokfluoranthene
Al
Zn
DelcingSalts
Cd
January
WINTER Nov -March
January
February
February
February
March
May
SUMMER May - Sept
August
September
AUTUMN Sept - Oct
September
Months / Seasons

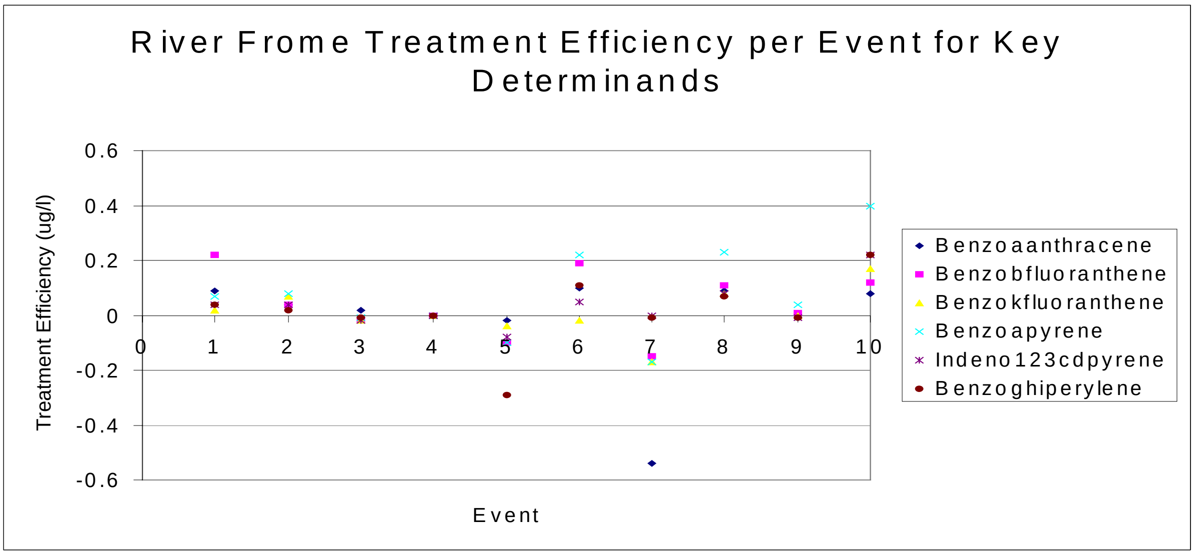

M40/Souldern Brook - Seasonal Relationship
Concentration (ug/l) Glyphosphate, Pyrene, Benzo(a)Anthracene, Chrysene, Benzo(K)fluoranthene, Cadmium
Concentration (ug/l) Aluminium, Zinc, Deicing Salts
20
18
16
14
12
10
8
6
4
2
0
3500
3000
2500
2000
1500
1000
500
0
November WINTER Nov -March
December
January
Febuary
April SPRING April - May
May
October AUTUMN Sept - Oct
October
October
October
Months / Seasons
Glyphosate
Pyrene
Benzoaanthracene
Chrysene
Benzokfluoranthene
Al
Zn
DeIcingSalts
Cd

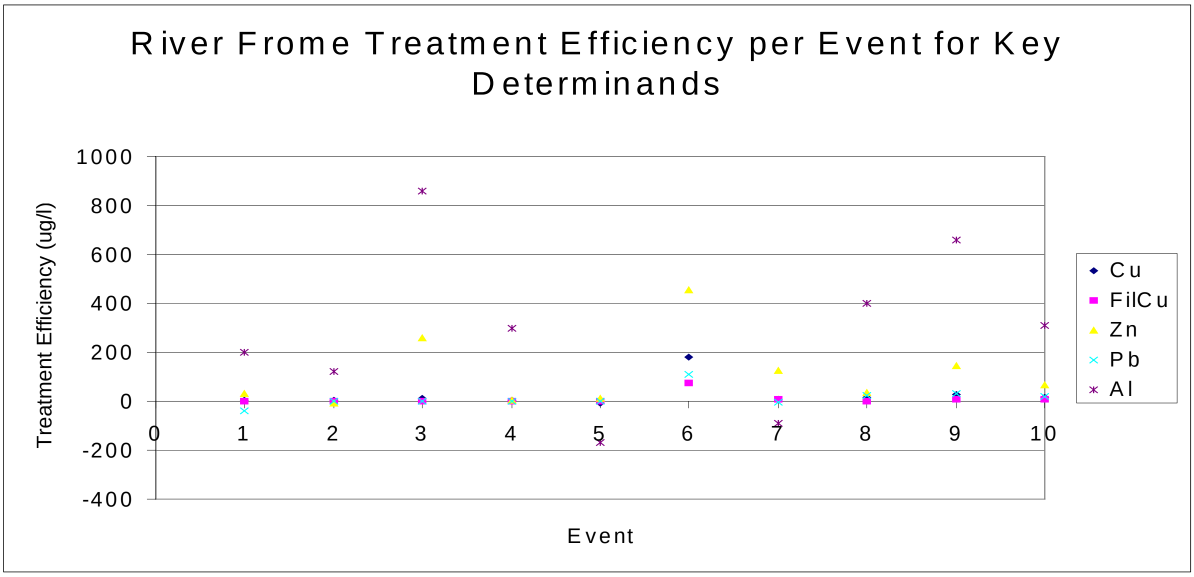

A34/Gallos Brook - Seasonal Relationship
Concentration (ug/l) Glyphosphate, Pyrene, Benzo(a)Anthracene, Chrysene, Benzo(K)fluoranthene, Cadmium
Concentration (ug/l) Aluminium, Zinc, Deicing Salt
3
2.5
2
1.5
1
0.5
0
1400
1200
1000
800
600
400
200
0
November
WINTER Nov -March
December
January
January
March
April
SPRING April - May
July
SUMMER June - August
September
AUTUMN Sept - Oct
October
October
Months / Seasons
Glyphosate
Pyrene
Benzoaanthracene
Chrysene
Benzokfluoranthene
Al
Zn
DeIcingSalts
Cd

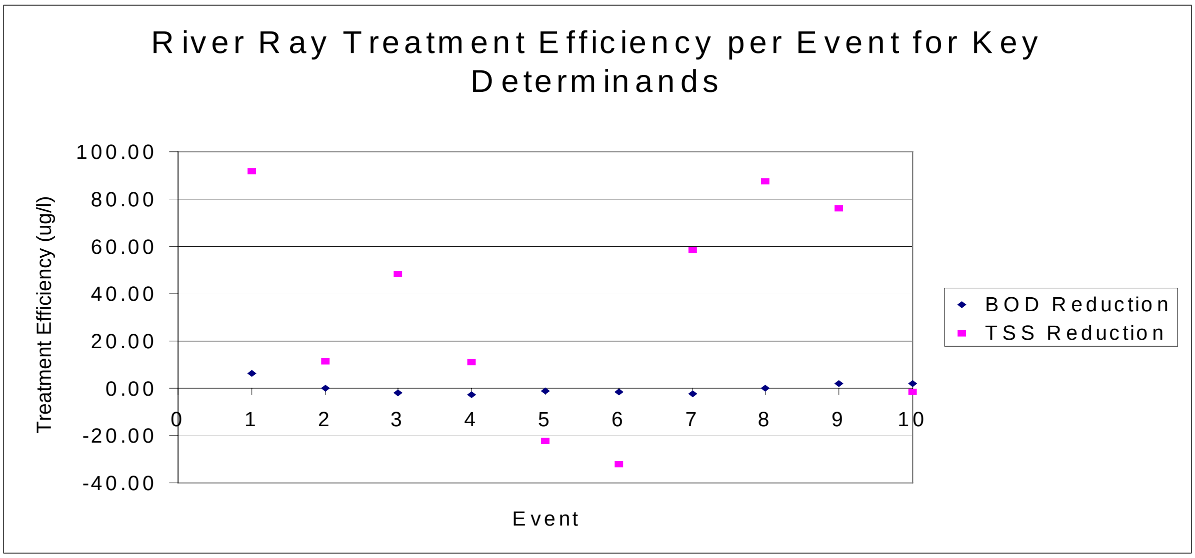

A34/Newbury - Seasonal Relationship
Concentration (ug/l) Glyphosphate, Pyrene, Benzo(a)Anthracene, Chrysene, Benzo(K)fluoranthene, Cadmium
Concentration (ug/l) Aluminium, Zinc, Deicing Salt
1.4
1.2
1
0.8
0.6
0.4
0.2
0
200
180
160
140
120
100
80
60
40
20
0
January
WINTER Nov -March
Febuary
April
SPRING April - May
April
May
May
June
SUMMER June - August
July
August
October
AUTUMN Sept - Oct
Months / Seasons
Glyphosate
Pyrene
Benzoaanthracene
Chrysene
Benzokfluoranthene
Al
Zn
DeIcingSalts
Cd

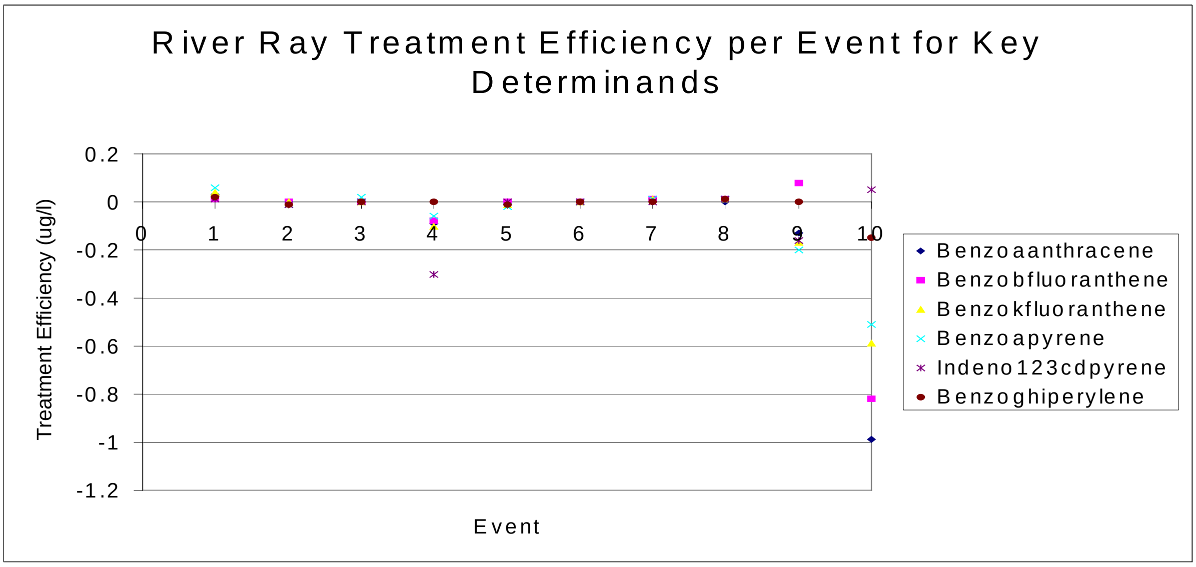
APPENDIX G GRAPHICAL PLOTS OF EVENT TREATMENT EFFICIENCY

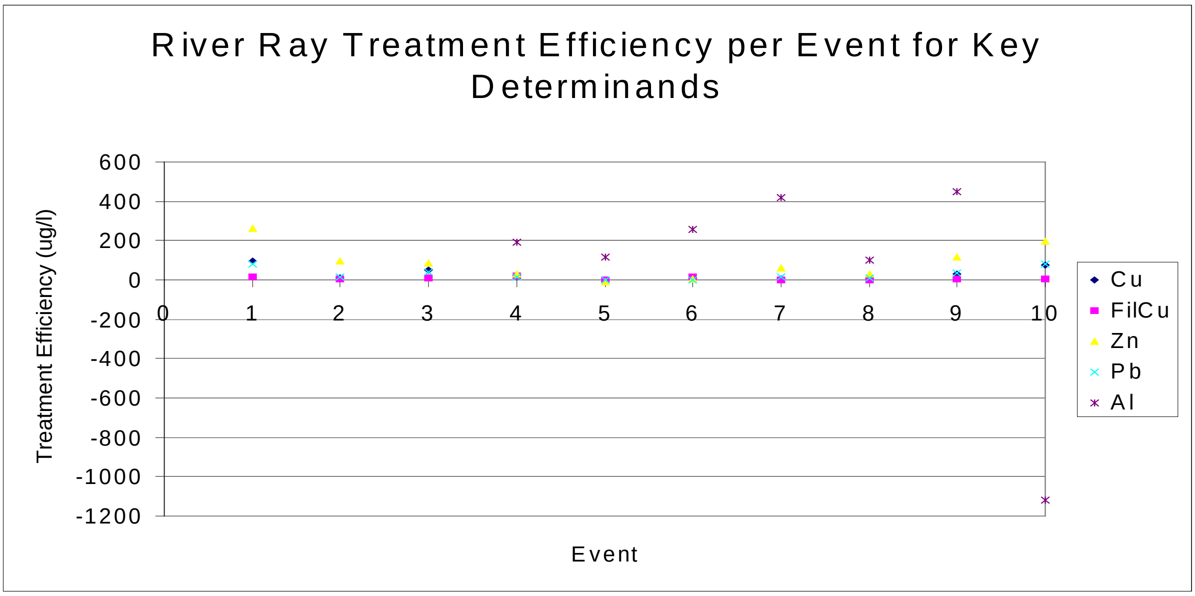

River Frome Treatment Efficiency per Event for Key Determinands
1500.00
1000.00
500.00
0.00
-500.00
-1000.00
Treatment Efficiency (ug/l)
0
1
2
3
4
5
6
7
8
9
10
Event
BOD Reduction
TSS Reduction

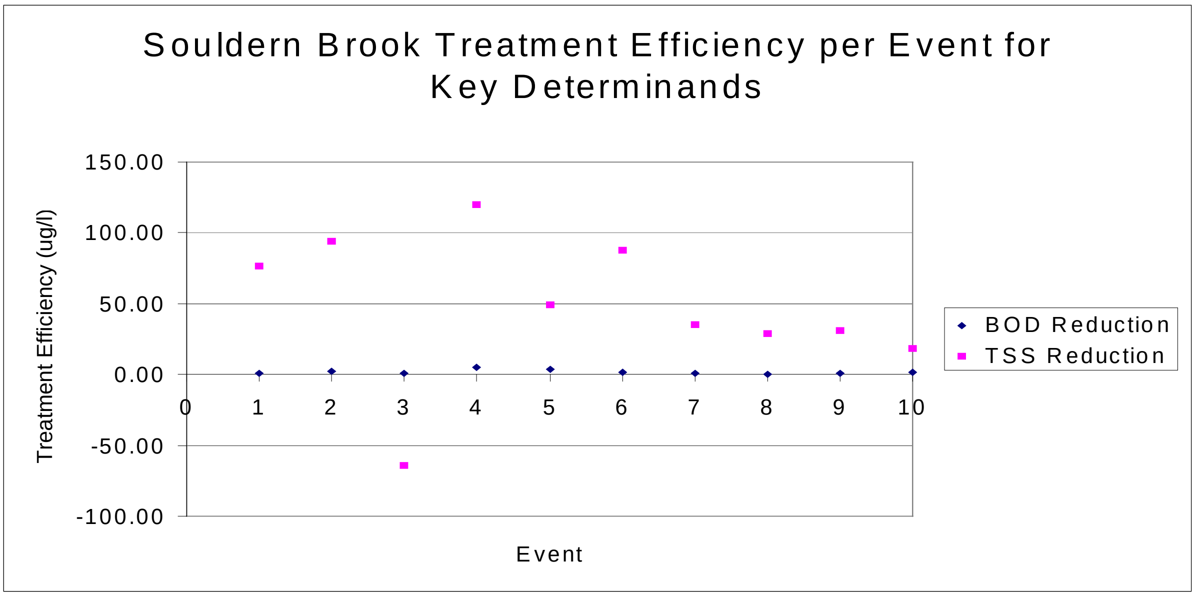

River Frome Treatment Efficiency per Event for Key Determinands
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
Treatment Efficiency (ug/l)
0
1
2
3
4
5
6
7
8
9
10
Event
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

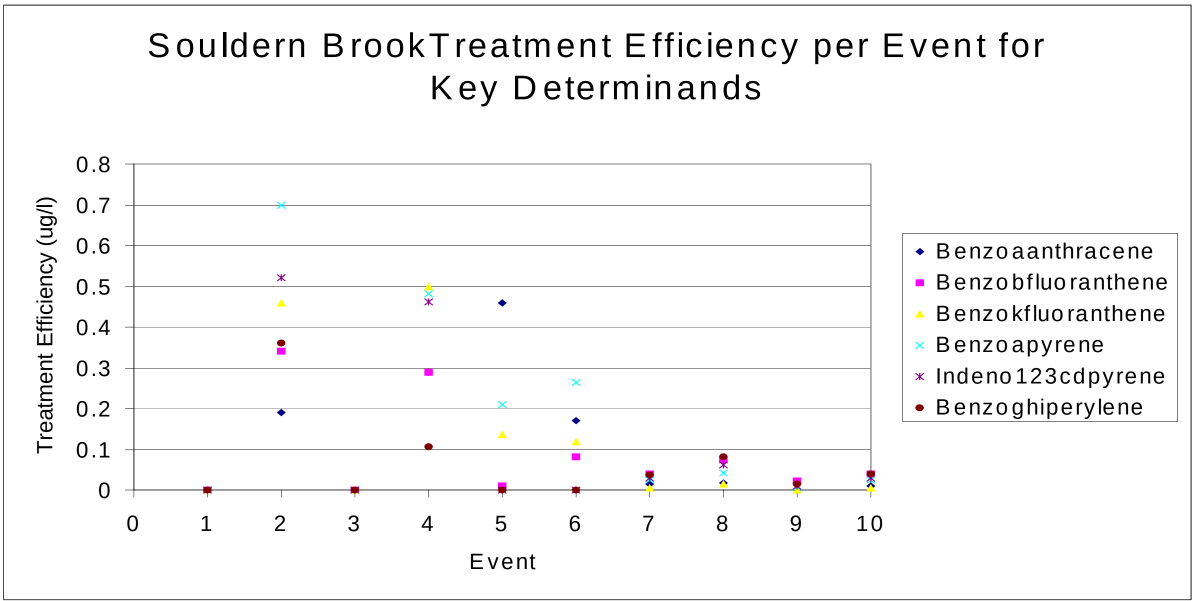

River Frome Treatment Efficiency per Event for Key Determinands
1000
800
600
400
200
0
-200
-400
Treatment Efficiency (ug/l)
0
1
2
3
4
5
6
7
8
9
10
Event
Cu
FilCu
Zn
Pb
Al

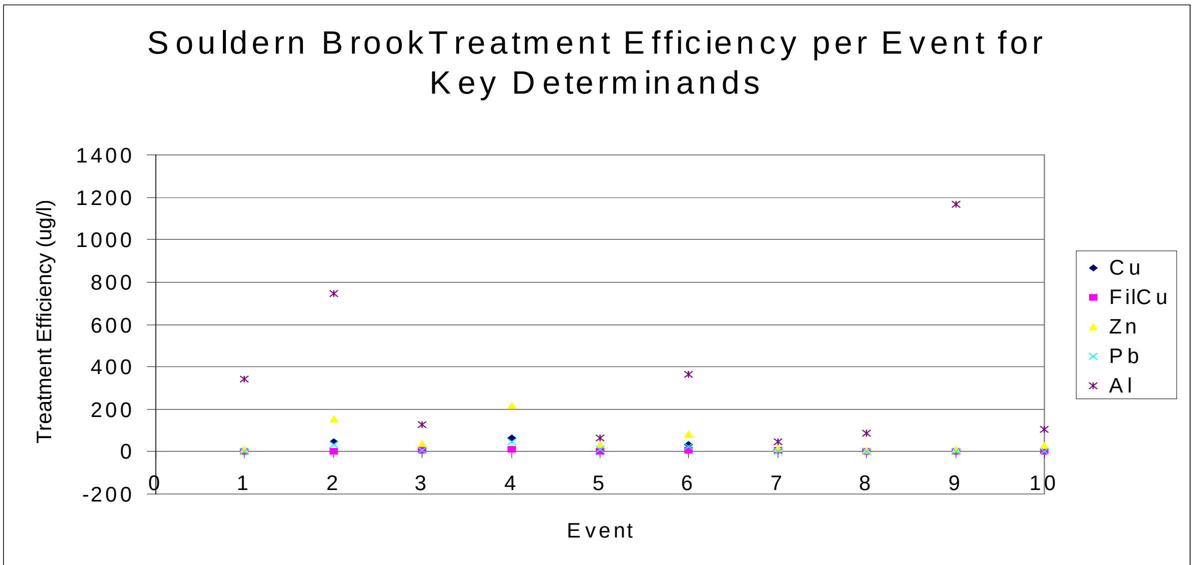

River Ray Treatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
0
1
2
3
4
5
6
7
8
9
10
Event
BOD Reduction
TSS Reduction

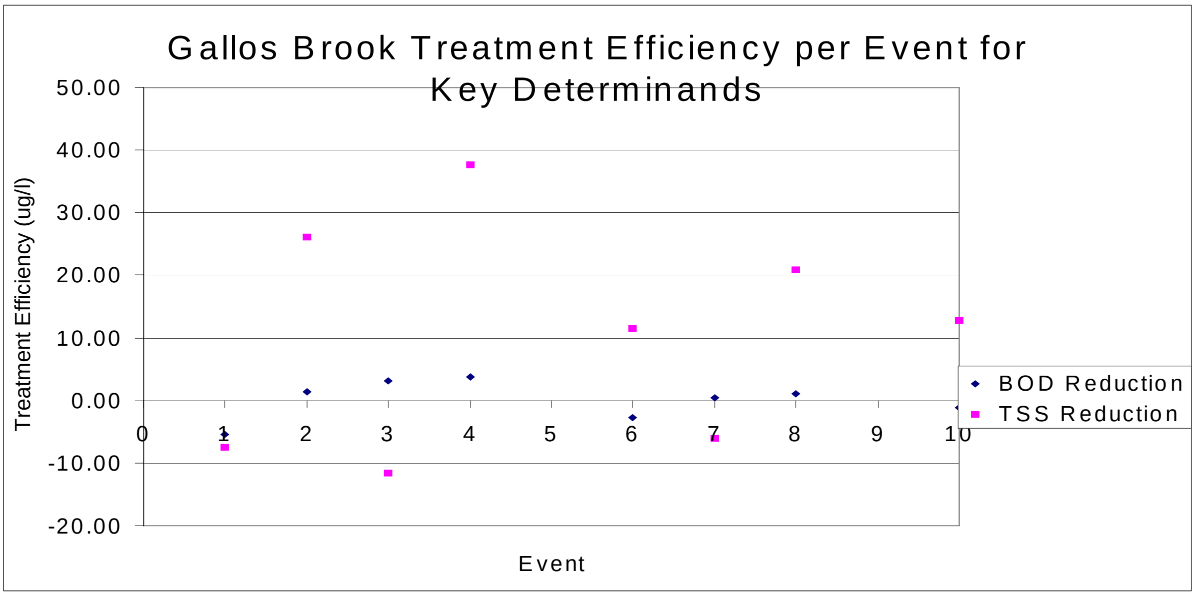

River Ray Treatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0
1
2
3
4
5
6
7
8
9
10
Event
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

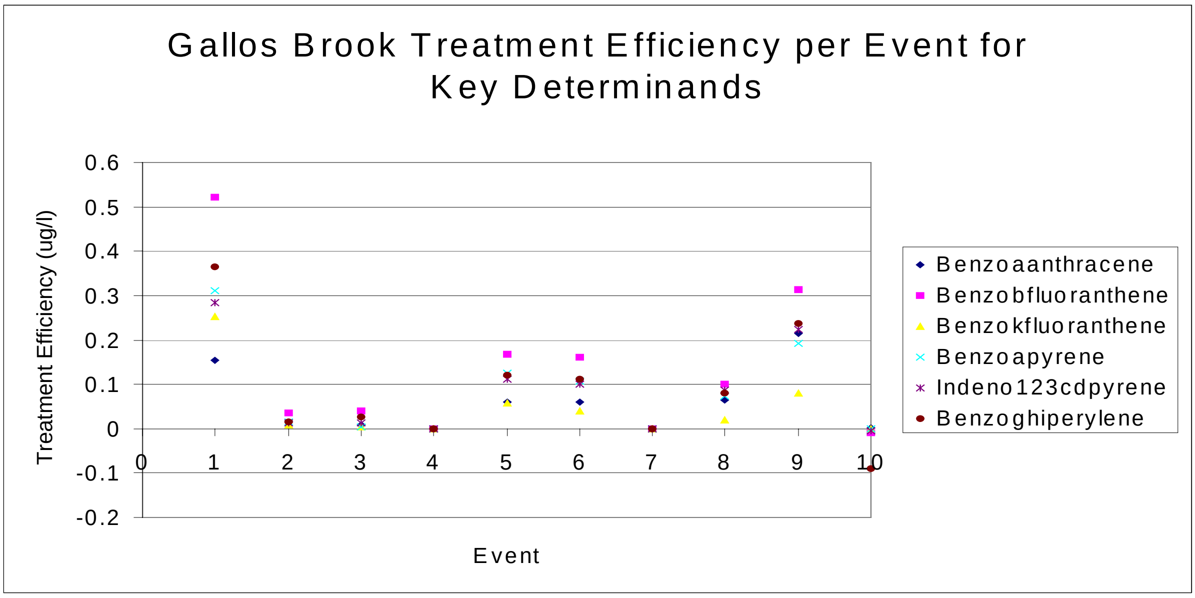

River Ray Treatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
600
400
200
0
-200
-400
-600
-800
-1000
-1200
0
1
2
3
4
5
6
7
8
9
10
Event
Cu
FilCu
Zn
Pb
Al

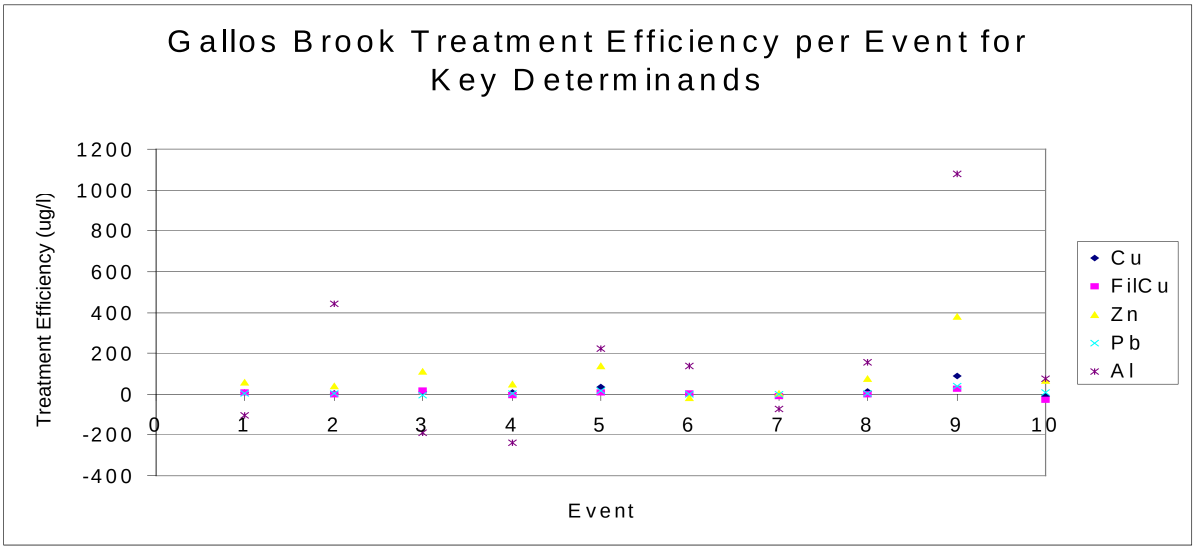

Souldern Brook Treatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
150.00
100.00
50.00
0.00
-50.00
-100.00
0
1
2
3
4
5
6
7
8
9
10
Event
BOD Reduction
TSS Reduction

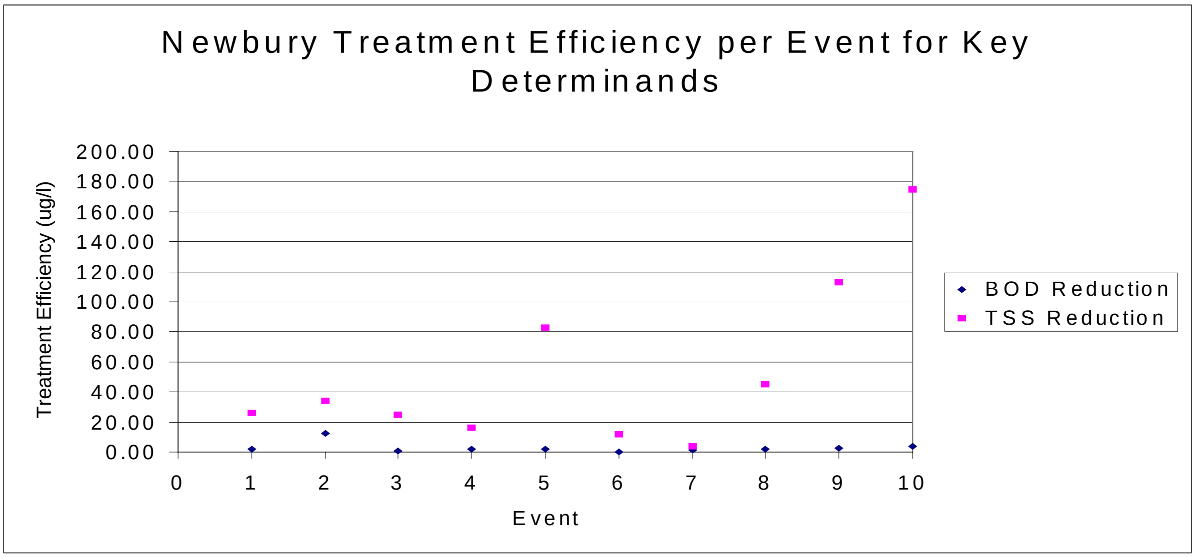

Souldern BrookTreatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
5
6
7
8
9
10
Event
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

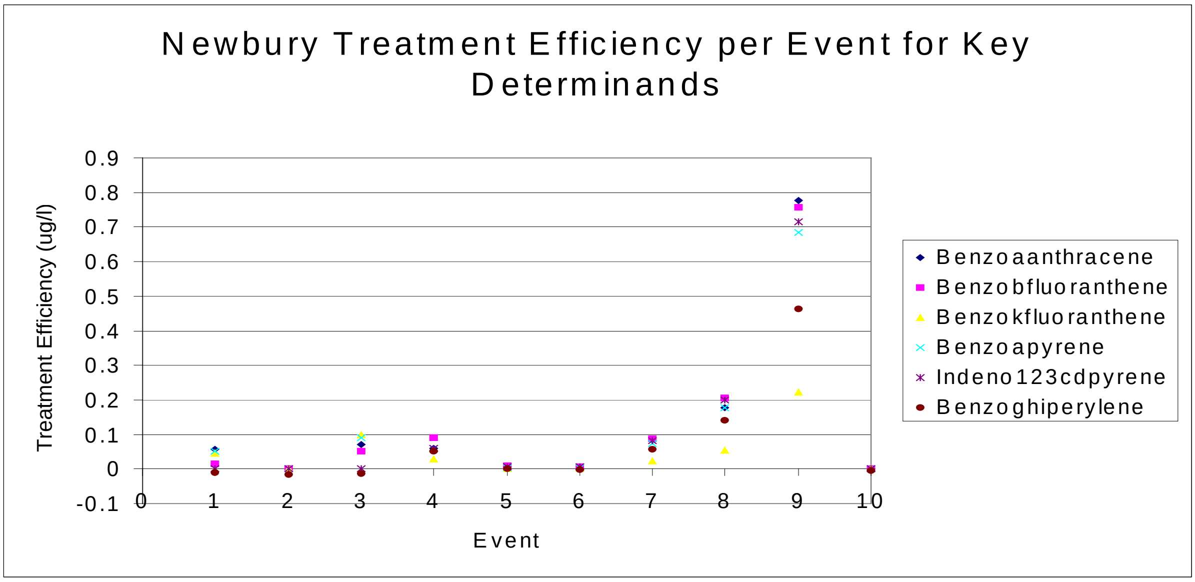

Souldern BrookTreatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
1400
1200
1000
800
600
400
200
0
-200
0
1
2
3
4
5
6
7
8
9
10
Event
Cu
FilCu
Zn
Pb
Al

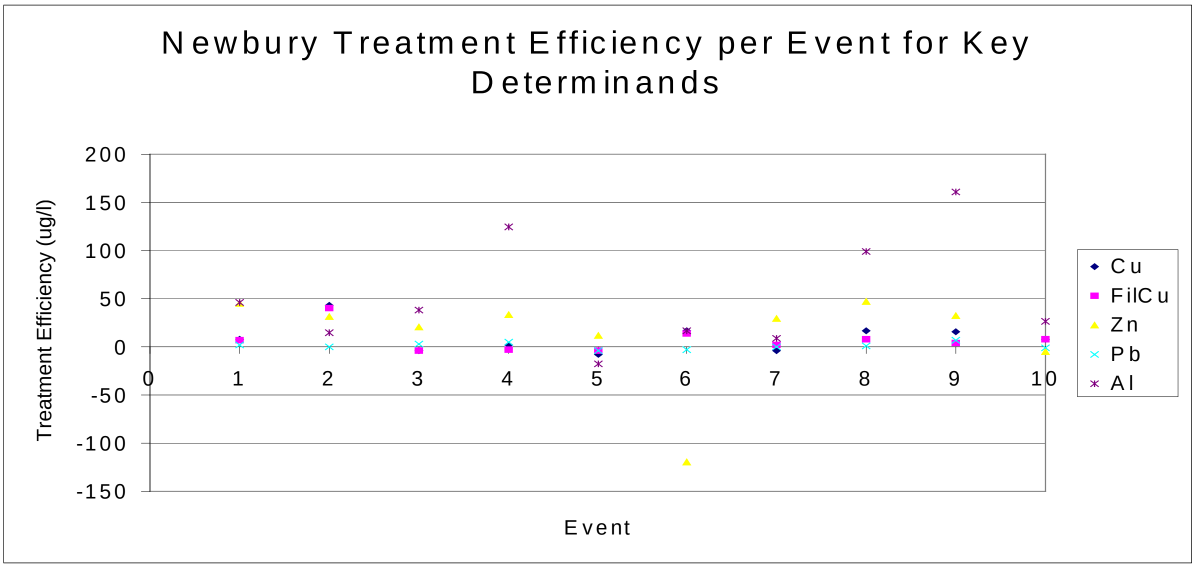

Gallos Brook Treatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
0 1 2 3 4 5 6 7 8 9 10
Event
BOD Reduction
TSS Reduction

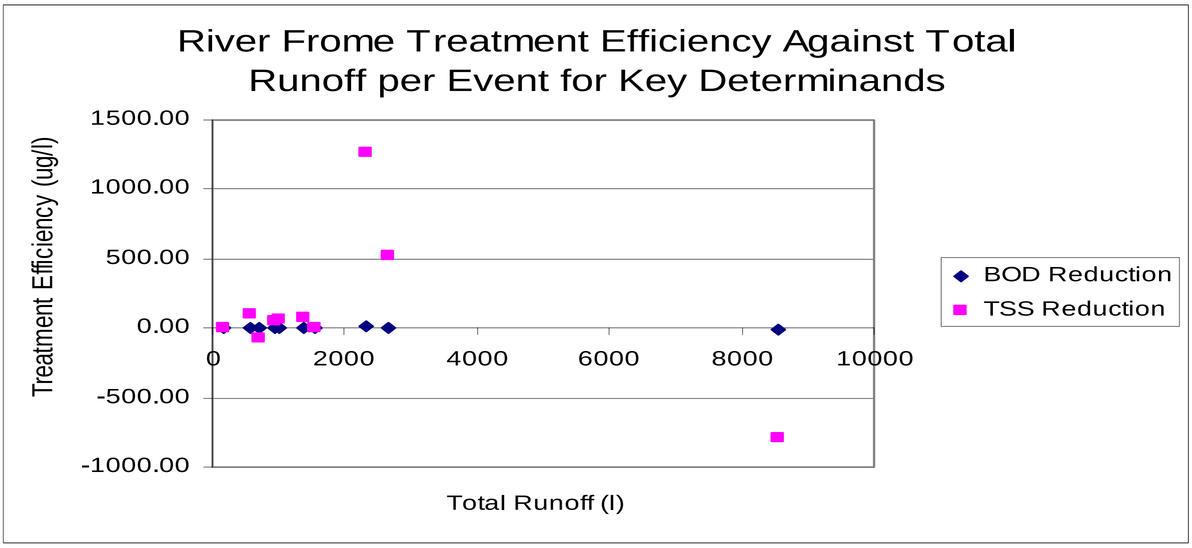

Gallos Brook Treatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0 1 2 3 4 5 6 7 8 9 10
Event
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

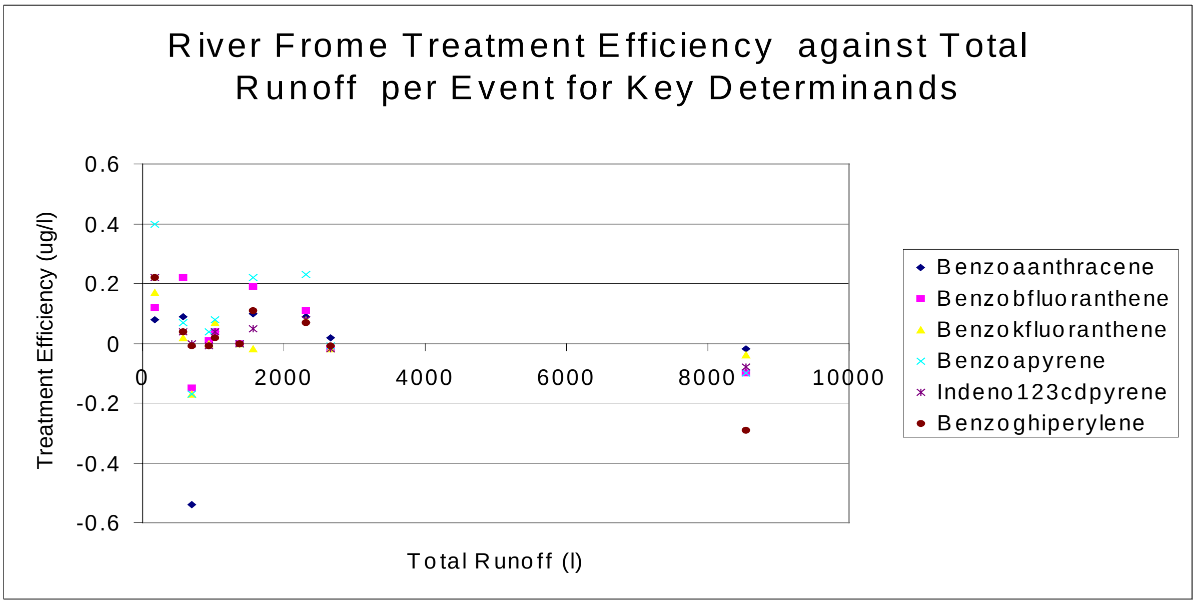

Gallos Brook Treatment Efficiency per Event for Key Determinands
Treatment Efficiency (ug/l)
1200
1000
800
600
400
200
0
-200
-400
0 1 2 3 4 5 6 7 8 9 10
Event
Cu
FilCu
Zn
Pb
Al

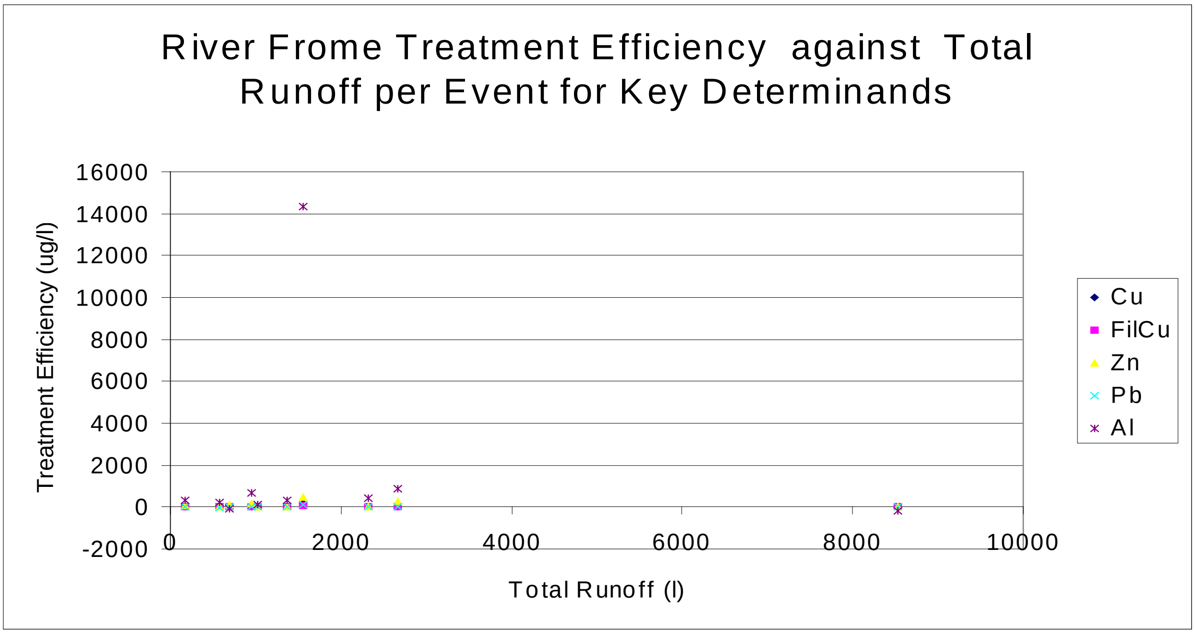

Newbury Treatment Efficiency per Event for Key Determinands
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
Treatment Efficiency (ug/l)
0 1 2 3 4 5 6 7 8 9 10
Event
BOD Reduction
TSS Reduction

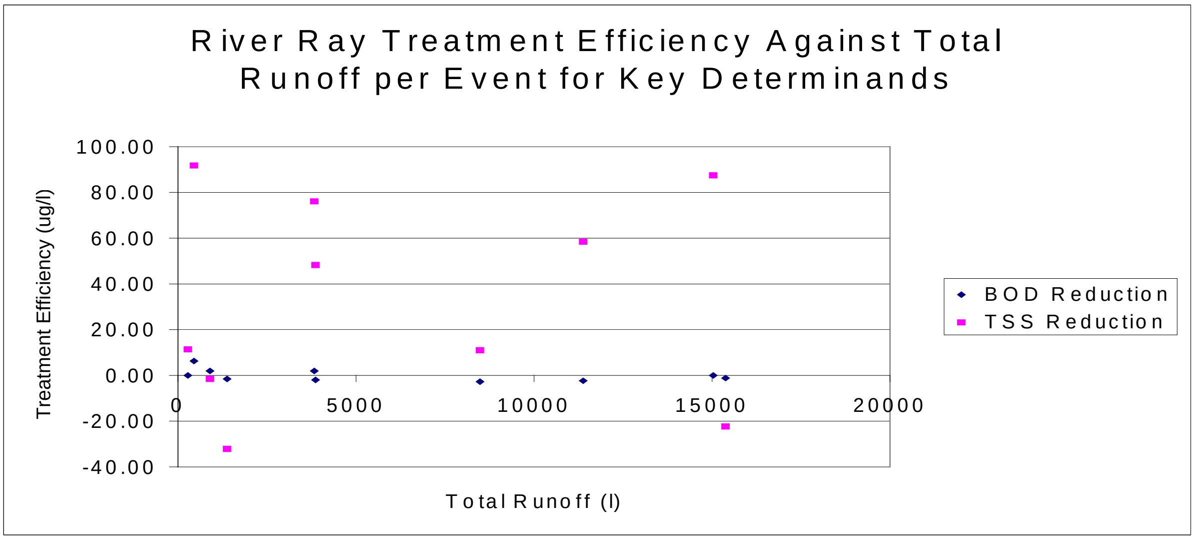

Newbury Treatment Efficiency per Event for Key Determinands
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
Treatment Efficiency (ug/l)
0 1 2 3 4 5 6 7 8 9 10
Event
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

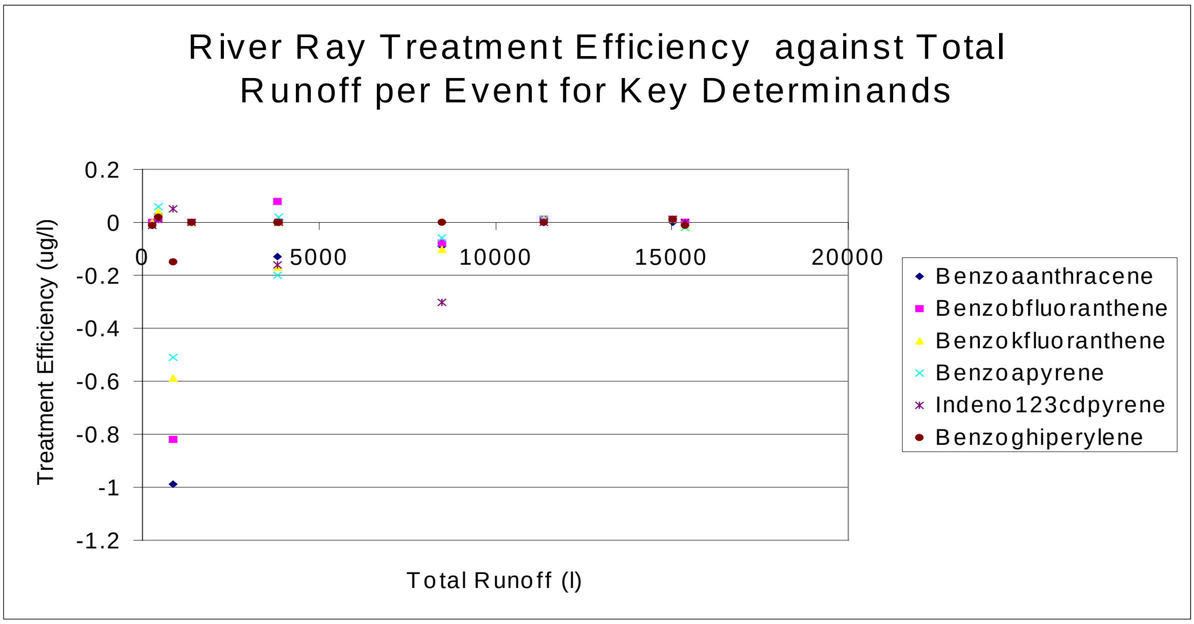

Newbury Treatment Efficiency per Event for Key Determinands
200
150
100
50
0
-50
-100
-150
Treatment Efficiency (ug/l)
0 1 2 3 4 5 6 7 8 9 10
Event
Cu
FilCu
Zn
Pb
Al

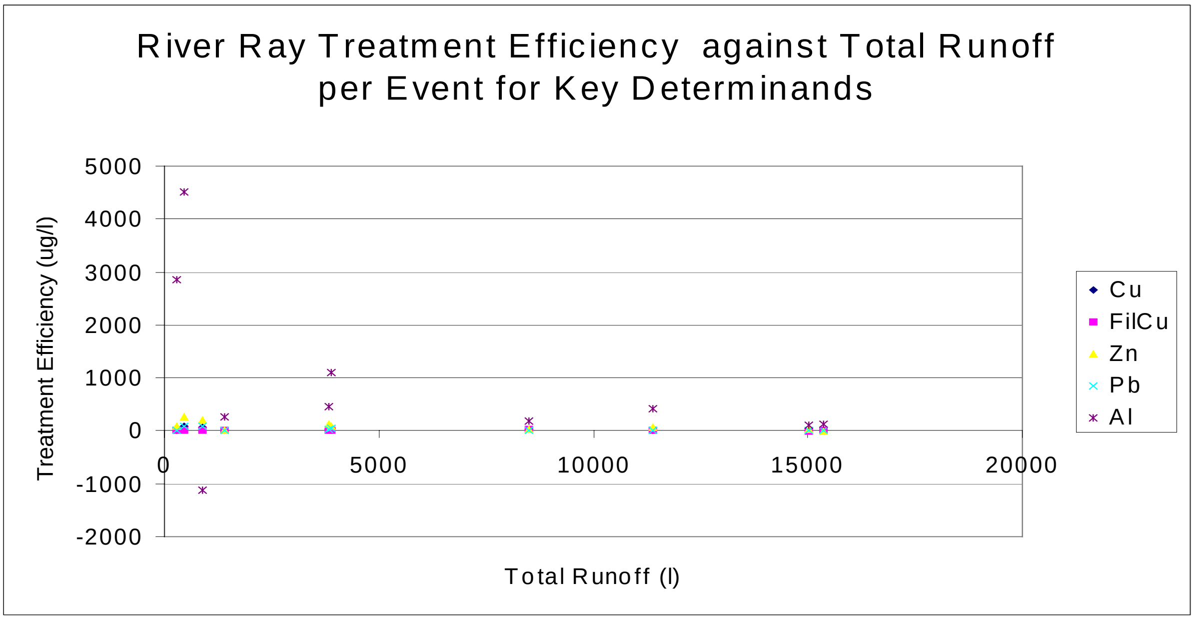

River Frome Treatment Efficiency Against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
1500.00
1000.00
500.00
0.00
-500.00
-1000.00
0
2000
4000
6000
8000
10000
Total Runoff (l)
BOD Reduction
TSS Reduction

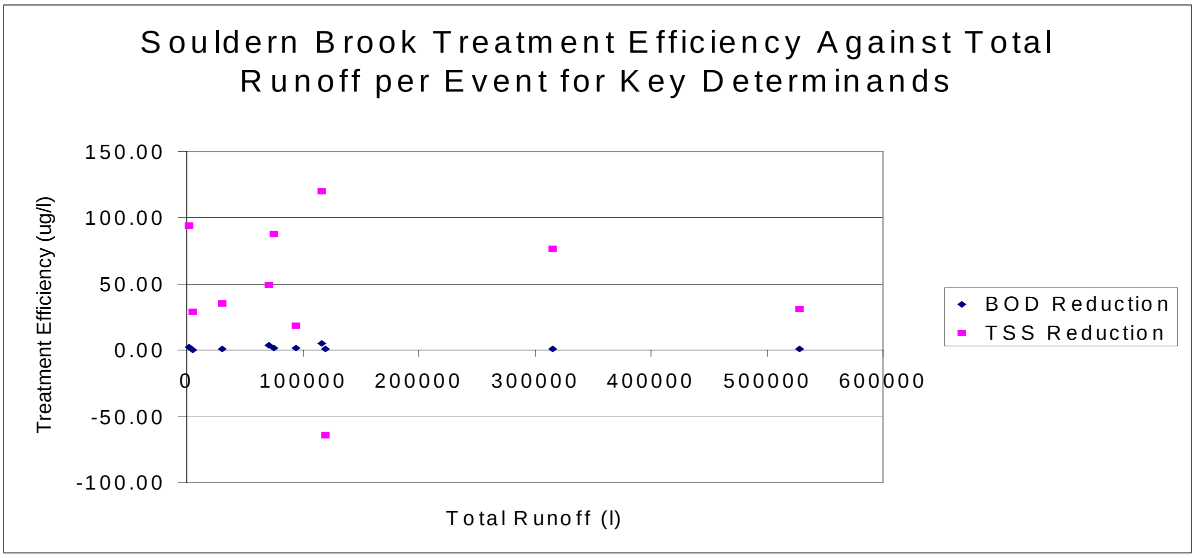

River Frome Treatment Efficiency against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
2000
4000
6000
8000
10000
Total Runoff (l)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene


River Frome Treatment Efficiency against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
0
2000
4000
6000
8000
10000
Total Runoff (l)
Cu
FilCu
Zn
Pb
Al

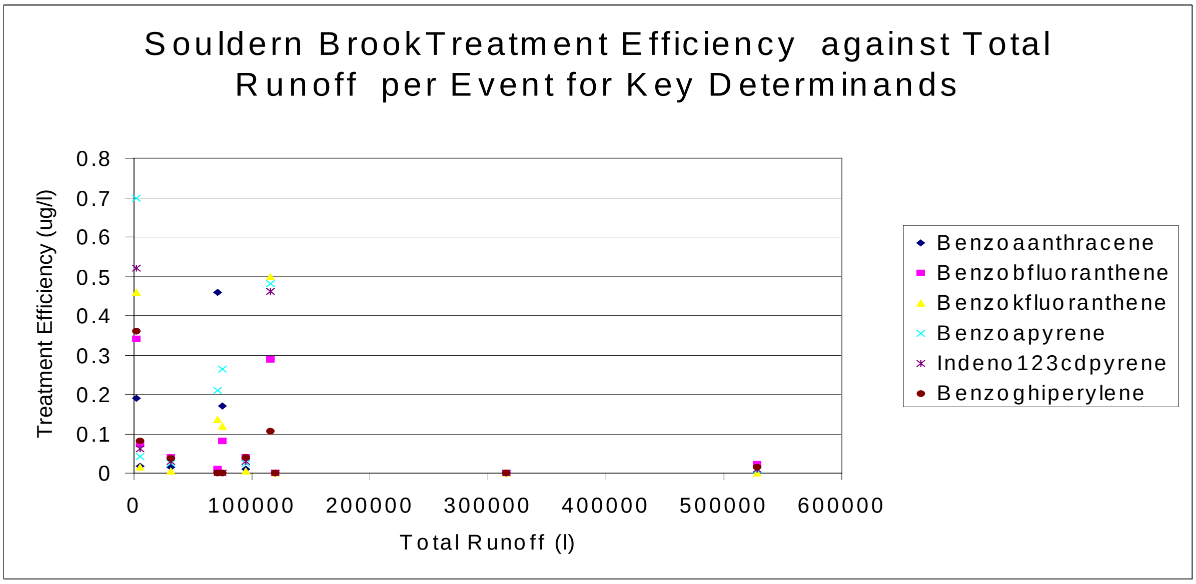

River Ray Treatment Efficiency Against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
0
5000
10000
15000
20000
Total Runoff (l)
BOD Reduction
TSS Reduction


River Ray Treatment Efficiency against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0
5000
10000
15000
20000
Total Runoff (l)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

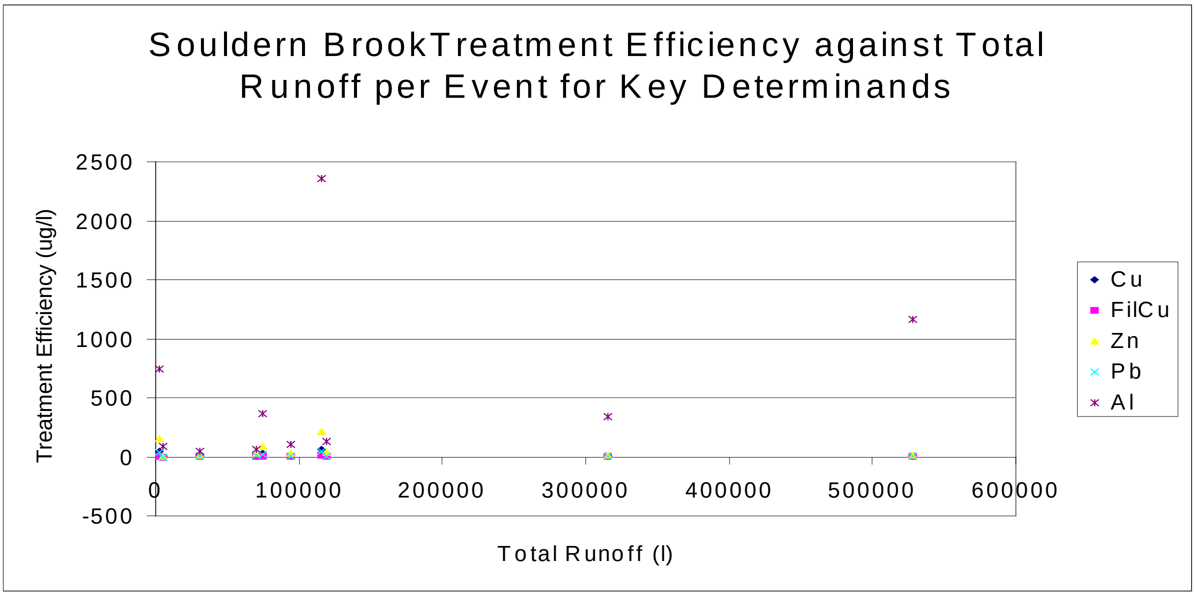

River Ray Treatment Efficiency against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
5000
4000
3000
2000
1000
0
-1000
-2000
0
5000
10000
15000
20000
Total Runoff (l)
Cu
FilCu
Zn
Pb
Al



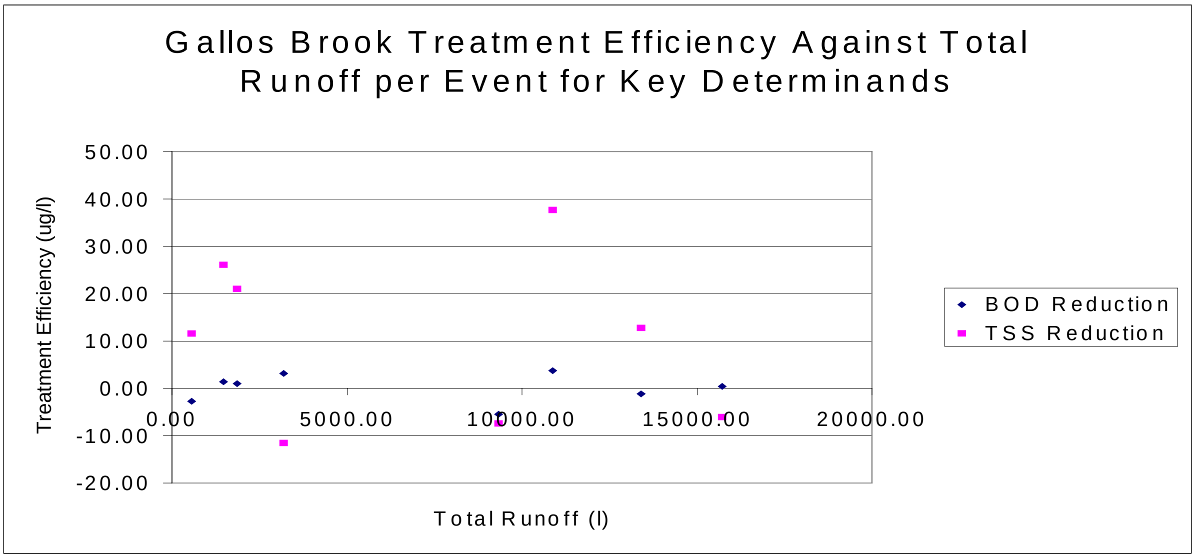
Souldern Brook Treatment Efficiency Against Total Runoff per Event for Key Determinands
150.00
100.00
50.00
0.00
-50.00
-100.00
0
100000
200000
300000
400000
500000
600000
Treatment Efficiency (ug/l)
Total Runoff (l)
BOD Reduction
TSS Reduction

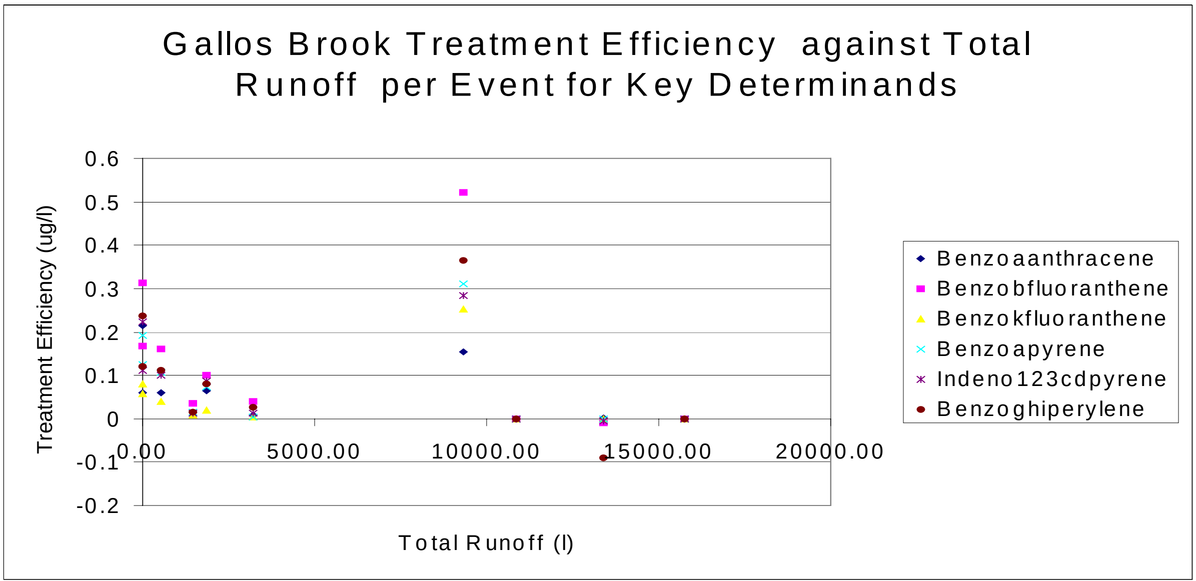


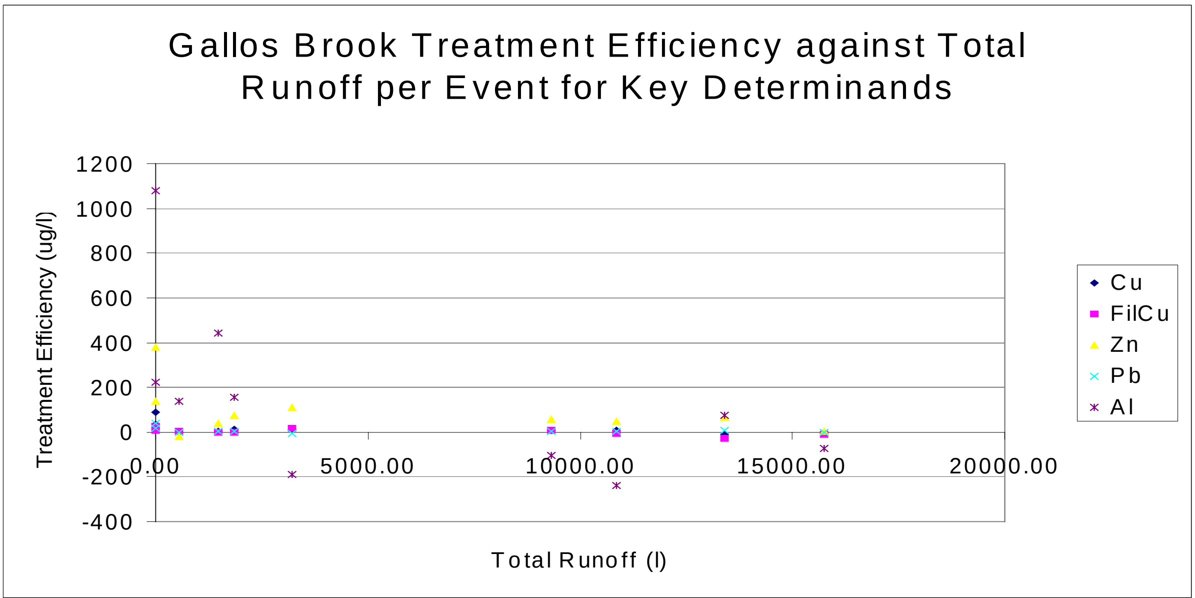
Souldern BrookTreatment Efficiency against Total Runoff per Event for Key Determinands
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100000
200000
300000
400000
500000
600000
Treatment Efficiency (ug/l)
Total Runoff (l)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

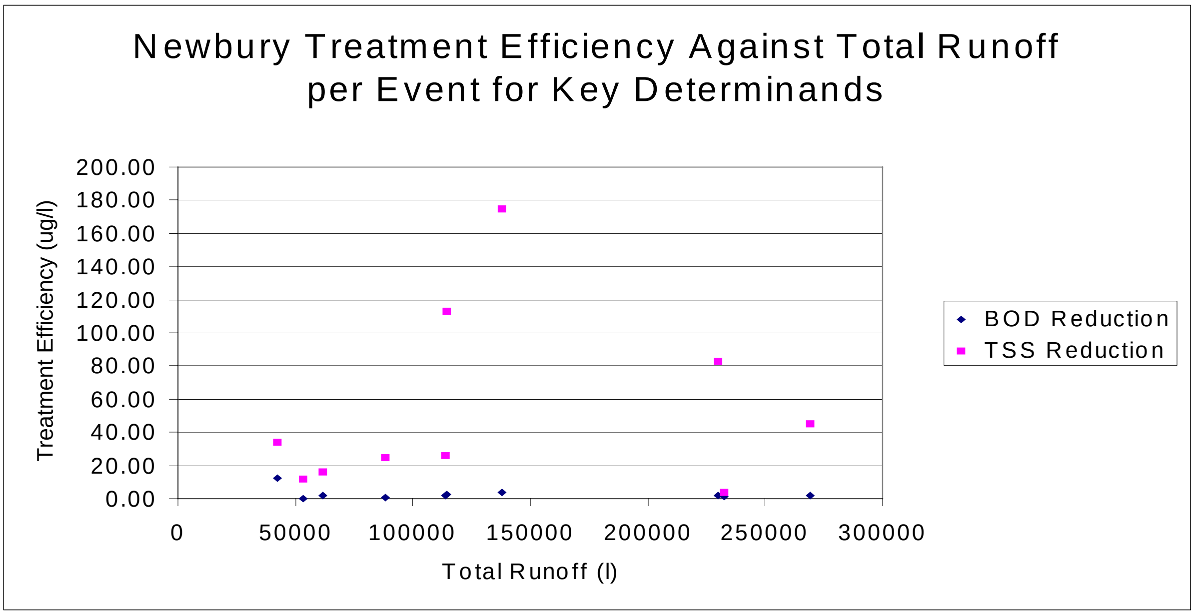


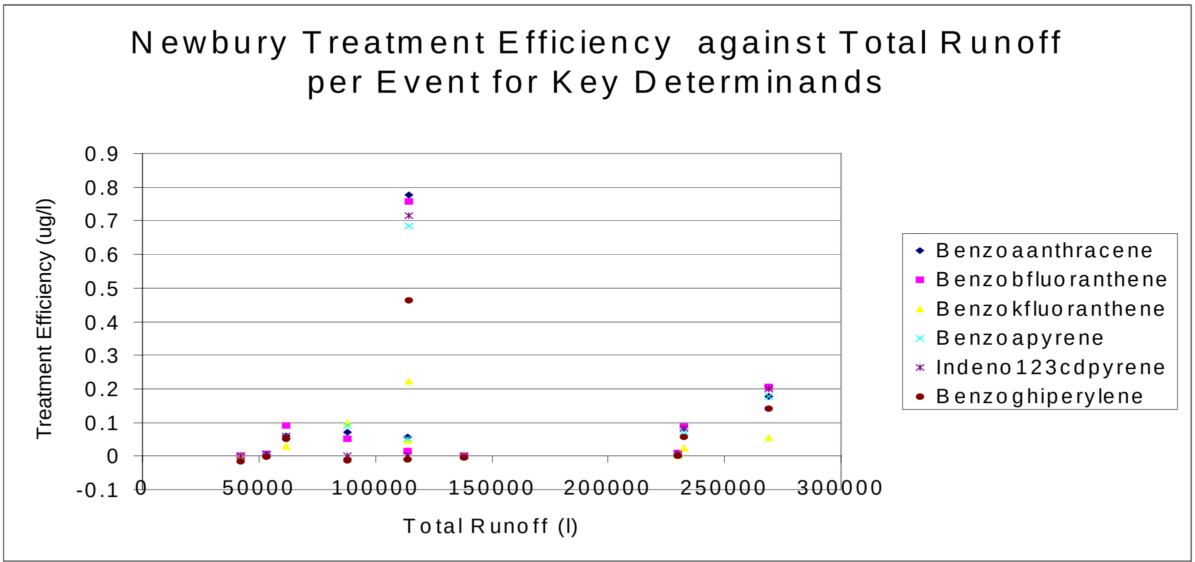
Souldern BrookTreatment Efficiency against Total Runoff per Event for Key Determinands
2500
2000
1500
1000
500
0
-500
0
100000
200000
300000
400000
500000
600000
Treatment Efficiency (ug/l)
Total Runoff (l)
Cu
FilCu
Zn
Pb
Al

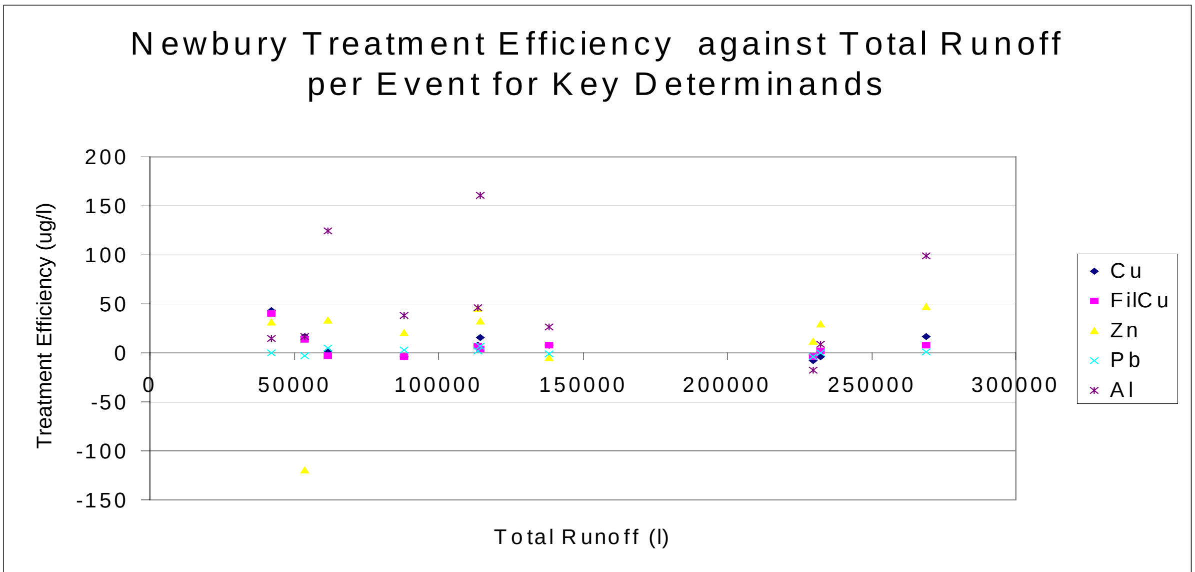

Gallos Brook Treatment Efficiency Against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
0.00
5000.00
10000.00
15000.00
20000.00
Total Runoff (l)
BOD Reduction
TSS Reduction

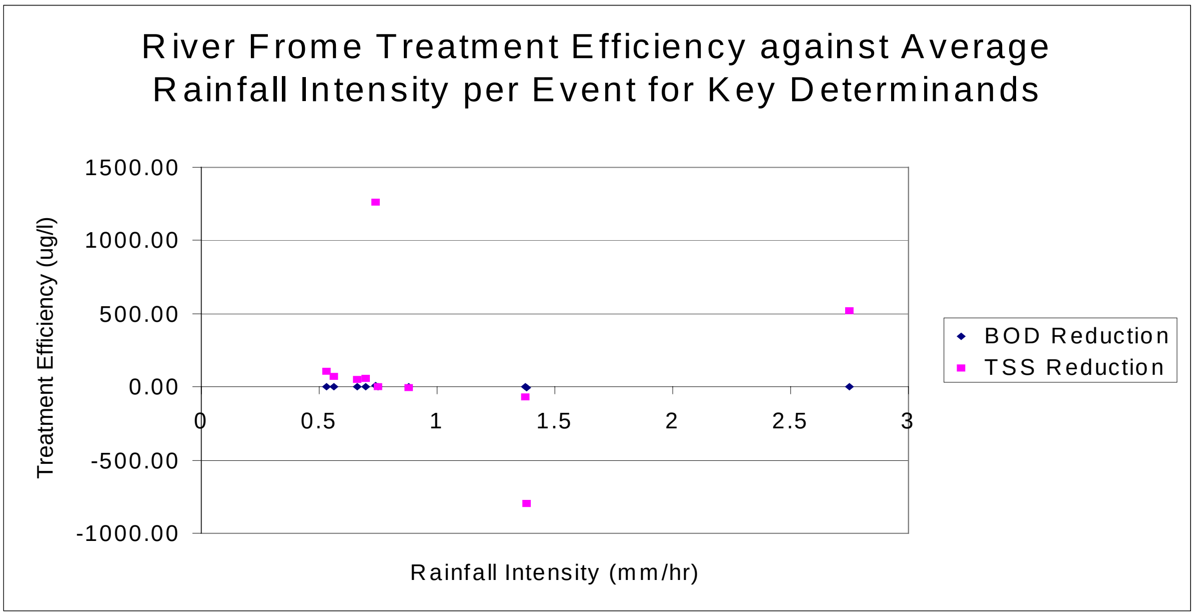

Gallos Brook Treatment Efficiency against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0.00
5000.00
10000.00
15000.00
20000.00
Total Runoff (l)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

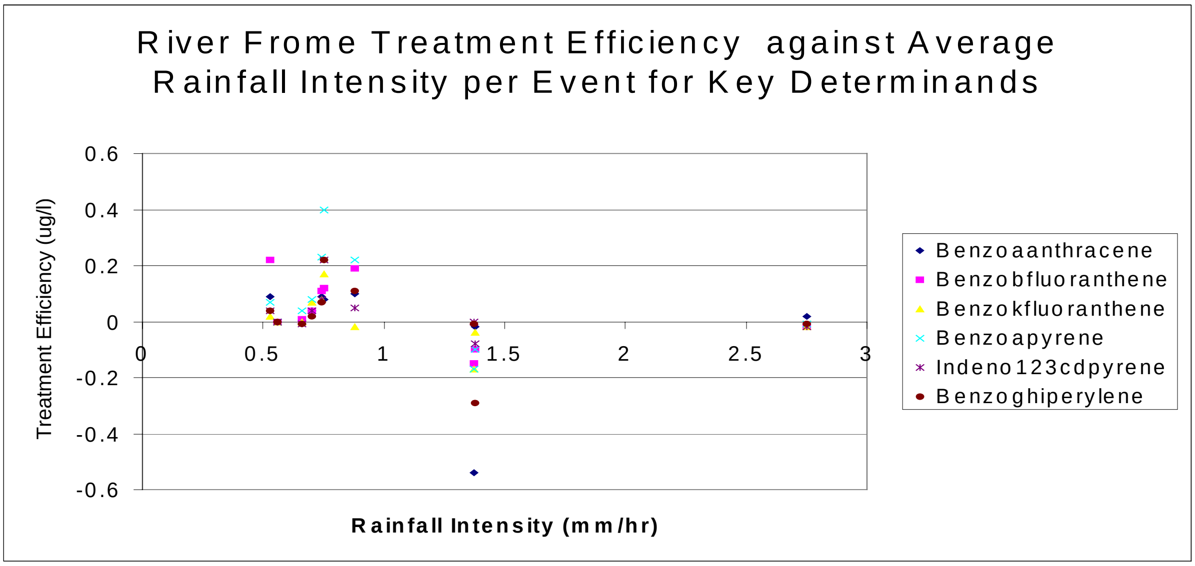

Gallos Brook Treatment Efficiency against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
1200
1000
800
600
400
200
0
-200
-400
0.00
5000.00
10000.00
15000.00
20000.00
Total Runoff (l)
Cu
FilCu
Zn
Pb
Al

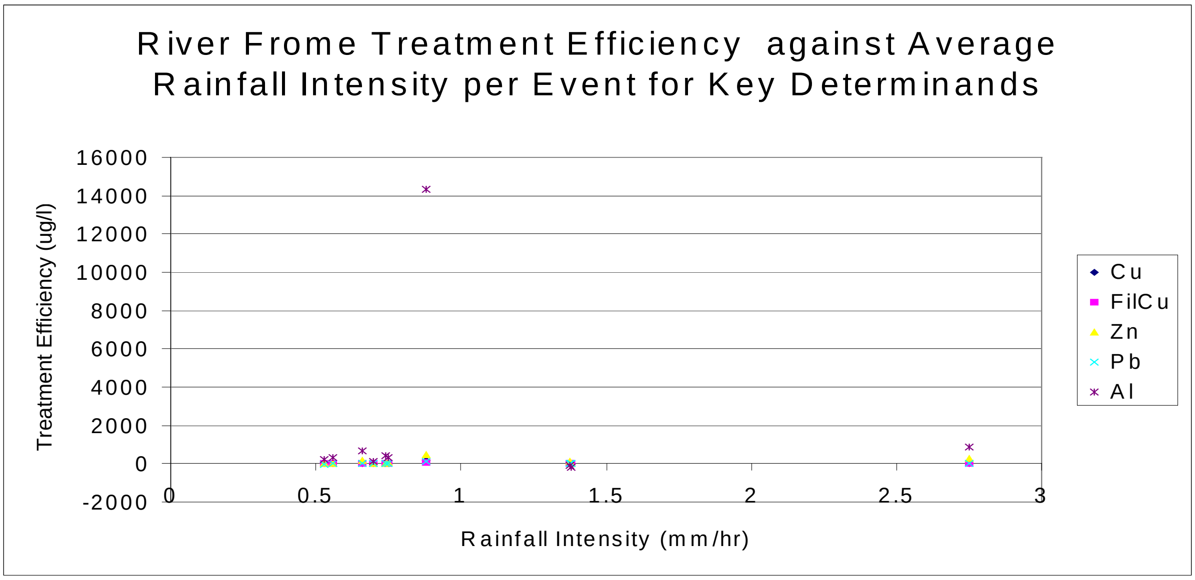

Newbury Treatment Efficiency Against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
50000
100000
150000
200000
250000
300000
Total Runoff (l)
BOD Reduction
TSS Reduction

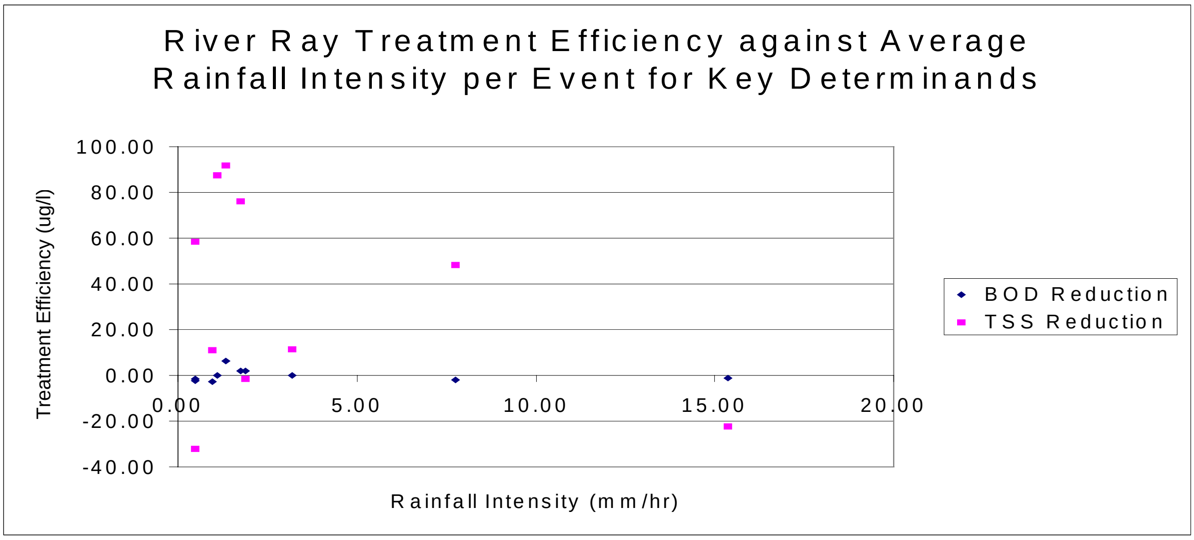

Newbury Treatment Efficiency against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
50000
100000
150000
200000
250000
300000
Total Runoff (l)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

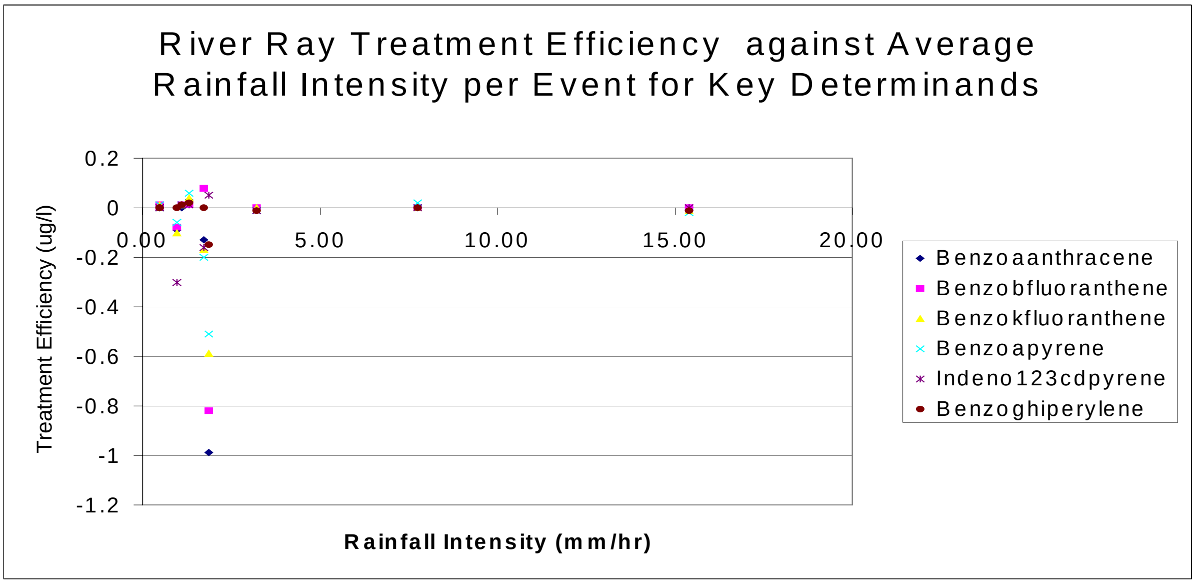

Newbury Treatment Efficiency against Total Runoff per Event for Key Determinands
Treatment Efficiency (ug/l)
200
150
100
50
0
-50
-100
-150
0
50000
100000
150000
200000
250000
300000
Total Runoff (l)
Cu
FilCu
Zn
Pb
Al

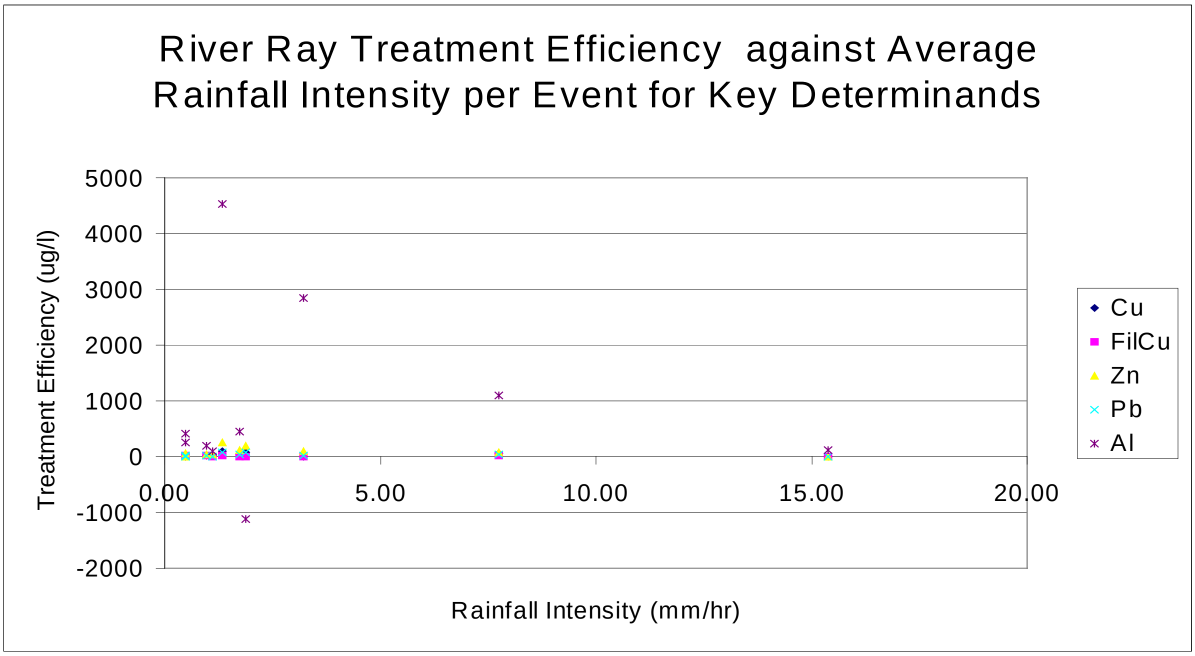

River Frome Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
1500.00
1000.00
500.00
0.00
-500.00
-1000.00
0
0.5
1
1.5
2
2.5
3
Rainfall Intensity (mm/hr)
BOD Reduction
TSS Reduction

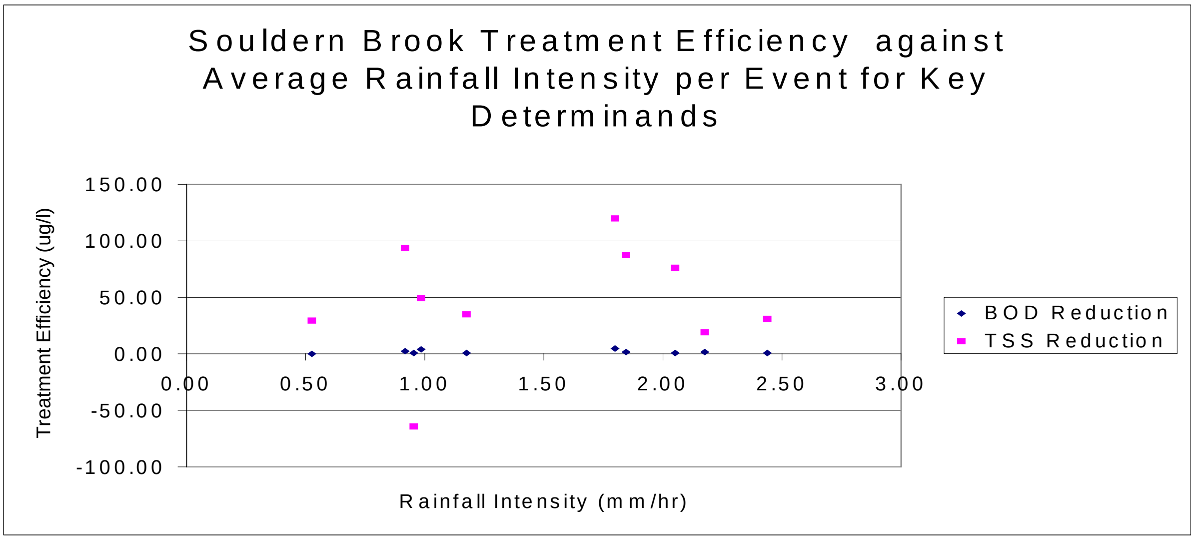

River Frome Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.5
1
1.5
2
2.5
3
Rainfall Intensity (mm/hr)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

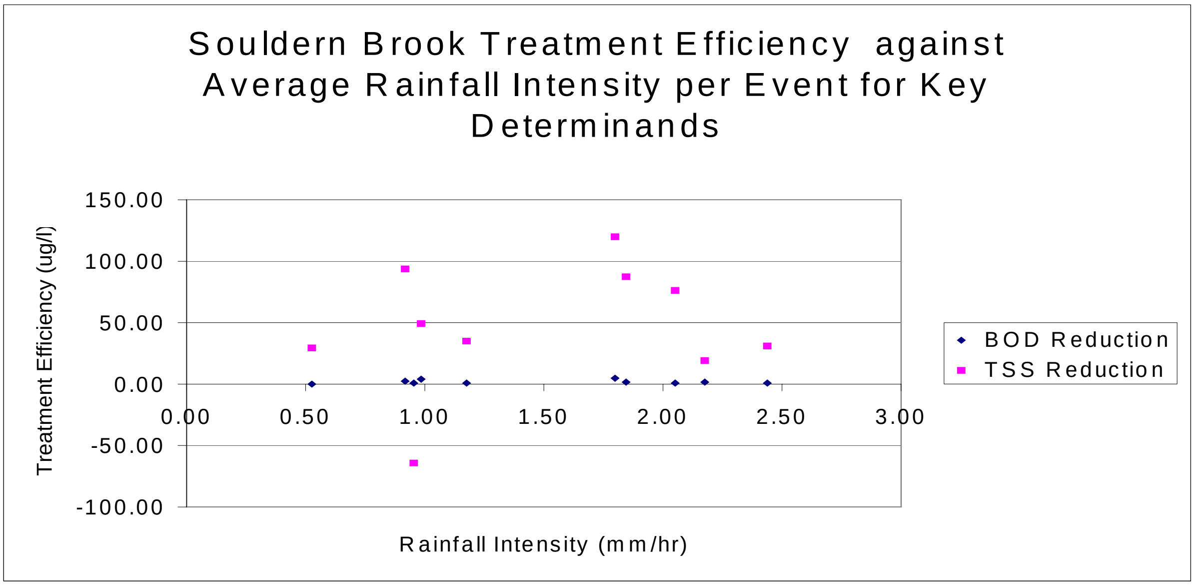

River Frome Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
0
0.5
1
1.5
2
2.5
3
Rainfall Intensity (mm/hr)
Cu
FilCu
Zn
Pb
Al

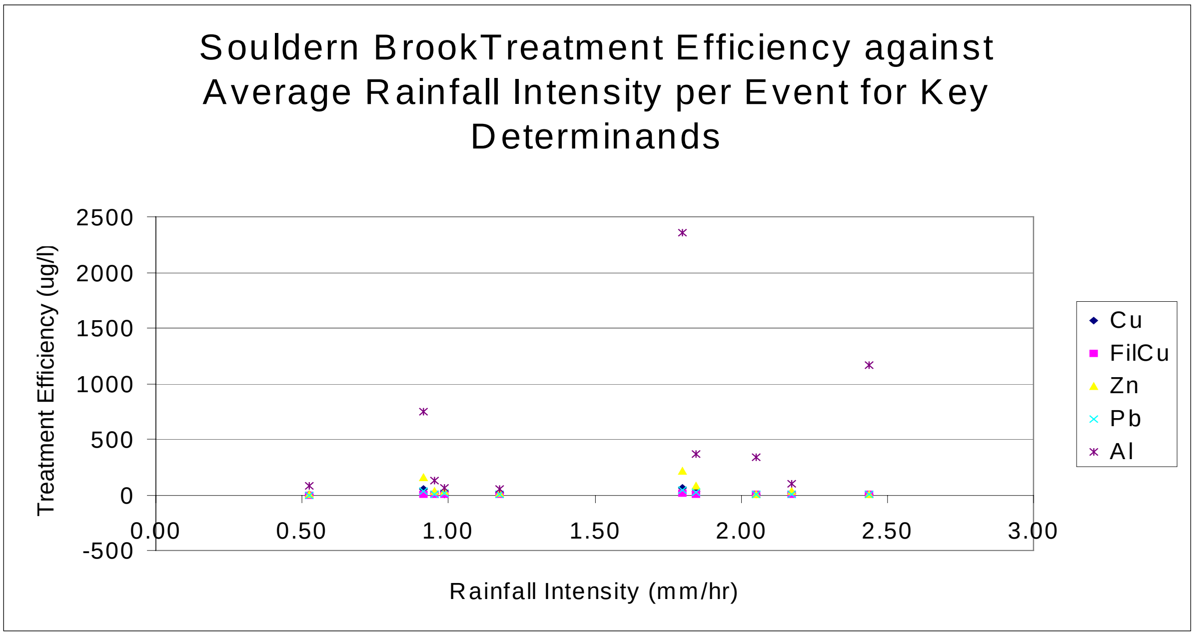

River Ray Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
100.00
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
0.00
5.00
10.00
15.00
20.00
Rainfall Intensity (mm/hr)
BOD Reduction
TSS Reduction

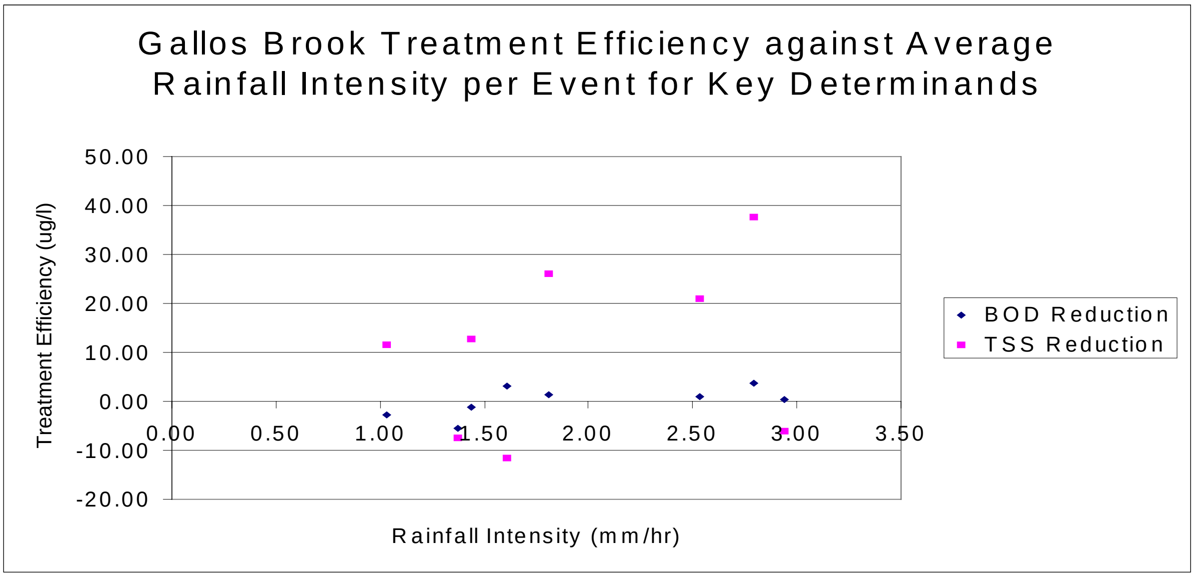

River Ray Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
0.00
5.00
10.00
15.00
20.00
Rainfall Intensity (mm/hr)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene

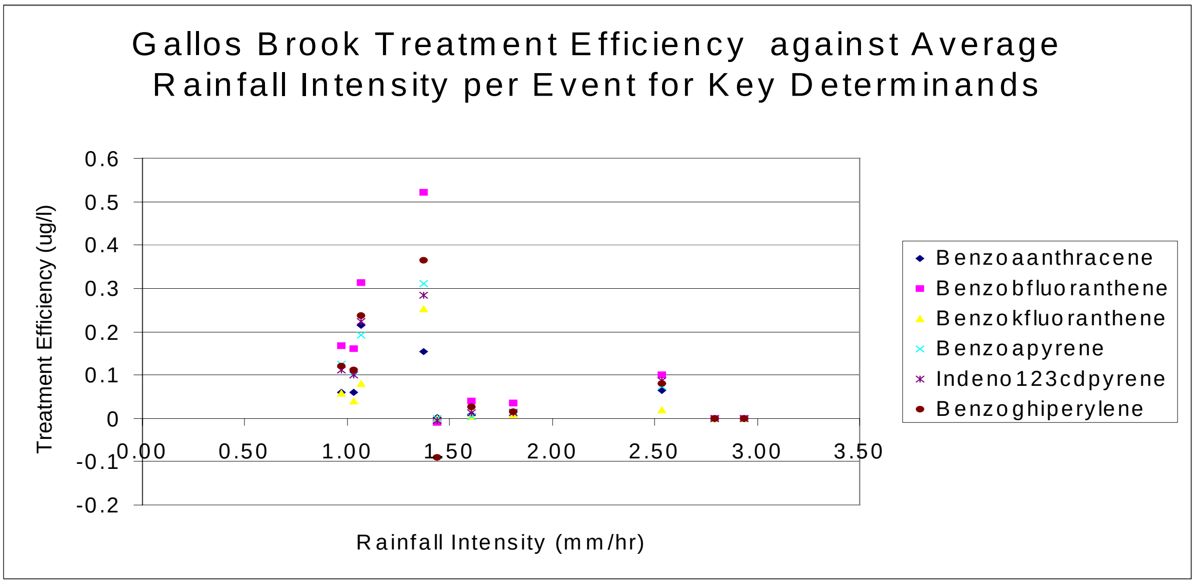

River Ray Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
5000
4000
3000
2000
1000
0
-1000
-2000
0.00
5.00
10.00
15.00
20.00
Rainfall Intensity (mm/hr)
Cu
FilCu
Zn
Pb
Al

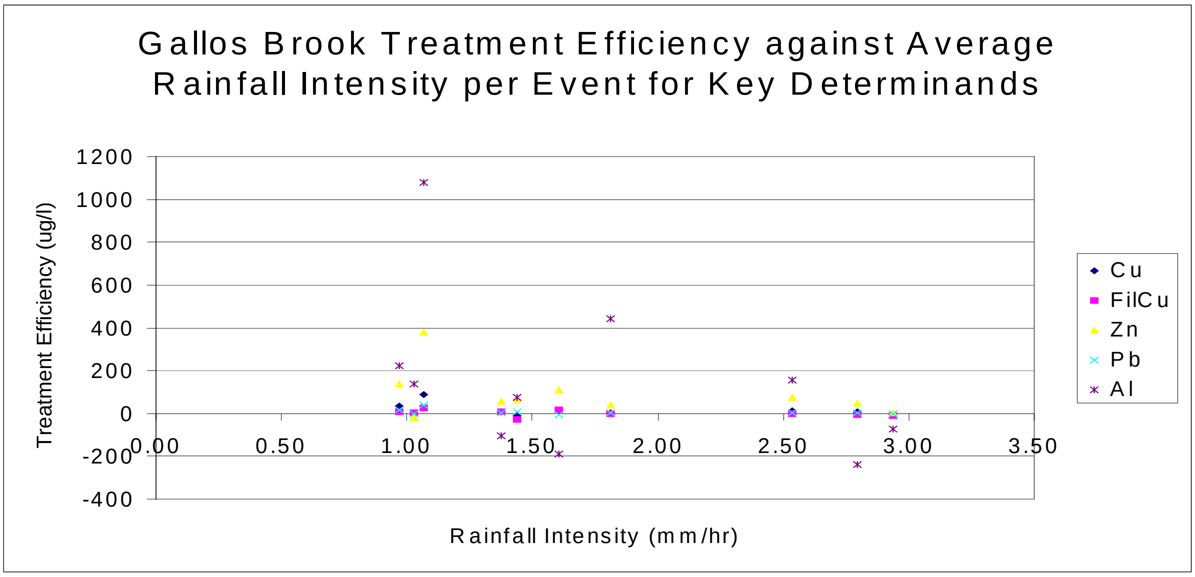

Souldern Brook Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
150.00
100.00
50.00
0.00
-50.00
-100.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Rainfall Intensity (mm/hr)
BOD Reduction
TSS Reduction

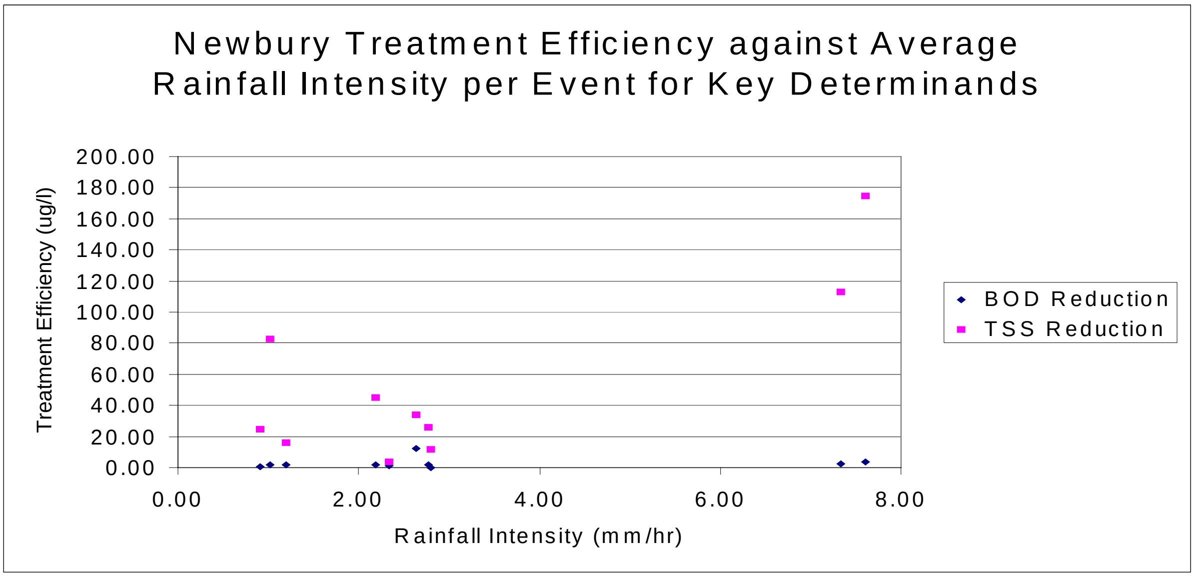

Souldern Brook Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
150.00
100.00
50.00
0.00
-50.00
-100.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Rainfall Intensity (mm/hr)
BOD Reduction
TSS Reduction

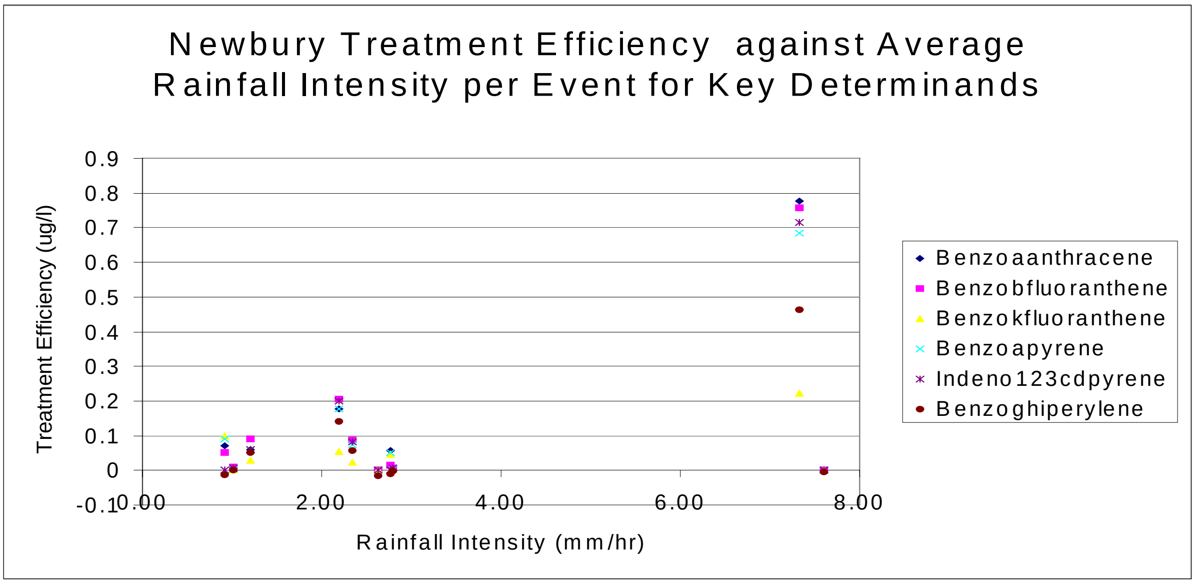

Souldern BrookTreatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
2500
2000
1500
1000
500
0
-500
0.00
0.50
1.00
1.50
2.00
2.50
3.00
Rainfall Intensity (mm/hr)
Cu
FilCu
Zn
Pb
Al

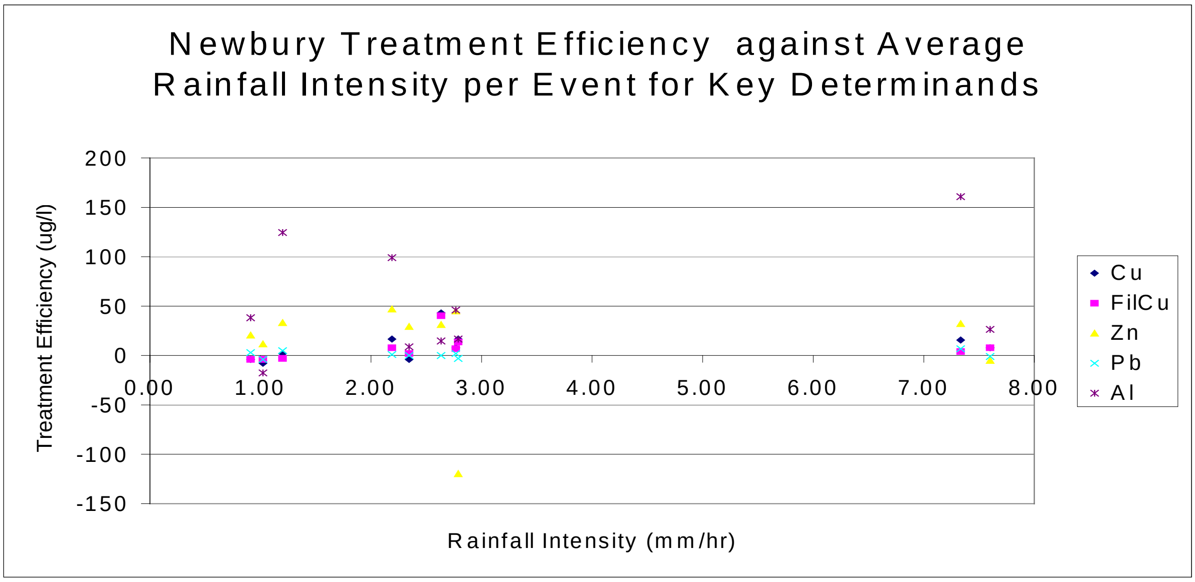

Gallos Brook Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
50.00
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Rainfall Intensity (mm/hr)
BOD Reduction
TSS Reduction


Gallos Brook Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Rainfall Intensity (mm/hr)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene


Gallos Brook Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
1200
1000
800
600
400
200
0
-200
-400
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
Rainfall Intensity (mm/hr)
Cu
FilCu
Zn
Pb
Al


Newbury Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00
2.00
4.00
6.00
8.00
Rainfall Intensity (mm/hr)
BOD Reduction
TSS Reduction


Newbury Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0.00
2.00
4.00
6.00
8.00
Rainfall Intensity (mm/hr)
Benzoaanthracene
Benzobfluoranthene
Benzokfluoranthene
Benzoapyrene
Indeno123cdpyrene
Benzoghiperylene


Newbury Treatment Efficiency against Average Rainfall Intensity per Event for Key Determinands
Treatment Efficiency (ug/l)
200
150
100
50
0
-50
-100
-150
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
Rainfall Intensity (mm/hr)
Cu
FilCu
Zn
Pb
Al

APPENDIX H TREATMENT DEVICE REDUCTION EFFICIENCY – SEDIMENT SAMPLES

		Brinkworth Brook Sediment sample analysis result		River Frome Sediment sample analysis results							
Parameter	Units	Highway Runoff		Highway Runoff		Pond		Actual Reduction	% Reduction	Actual Reduction	% Reduction
		17/12/97	03/02/99	21/09/98	29/07/99	19/06/98	29/07/99	Initial	Initial	Final	Final
Copper	g/Kg	0.151	0.096	0.070	0.158	0.057	0.019	0.013	19.143	0.139	87.975
Zinc	g/Kg	0.401	0.487	0.268	0.932	0.337	0.096	-0.069	-25.746	0.836	89.678
Cadmium	g/Kg	0.001	0.001	0.001	0.002	0.001	0.001	0.000	30.000	0.001	67.284
Aluminium	g/Kg	8.240	10.250	11.700	13.600	18.100	16.900	-6.400	-54.701	-3.300	-24.265
Lead	g/Kg	0.170	0.128	0.060	0.204	0.250	0.085	-0.190	-316.667	0.119	58.431
Platinum	g/Kg	0.003	0.000	0.003	0.000	0.003	0.000	0.000	0.000	0.000	0.000
Palladium	g/Kg	0.004	0.000	0.004	0.001	0.004	0.001	0.000	0.000	0.000	0.000
Nickel	g/Kg	0.019	0.022	0.016	0.044	0.020	0.033	-0.004	-21.875	0.010	23.853
Chromium	g/Kg	0.029	0.059	0.026	0.047	0.067	0.037	-0.041	-153.788	0.010	21.489
Napthalene	mg/Kg	1.114	0.313	0.233	0.868	0.595	1.119	-0.362	-155.365	-0.251	-28.917
Acenapthylene	mg/Kg	0.168	0.103	0.165	0.496	0.119	0.362	0.046	27.879	0.134	27.016
Acenapthene	mg/Kg	0.551	0.296	0.358	0.640	0.168	0.246	0.190	53.073	0.394	61.563
Fluorene	mg/Kg	0.698	0.332	0.459	0.984	0.152	0.412	0.307	66.885	0.572	58.130
Phenanthrene	mg/Kg	4.594	2.171	3.271	6.625	1.188	4.011	2.083	63.681	2.614	39.457
Anthracene	mg/Kg	1.405	0.715	0.895	2.332	0.353	1.725	0.542	60.559	0.607	26.029
Fluoranthene	mg/Kg	6.889	3.455	6.378	13.602	2.973	8.321	3.405	53.387	5.281	38.825
Pyrene	mg/Kg	5.064	2.871	5.294	11.287	2.766	6.499	2.528	47.752	4.788	42.420
Benzo(a) anthracene	mg/Kg	2.797	1.218	2.720	6.066	1.335	4.004	1.385	50.919	2.702	40.518
Chrysene	mg/Kg	3.023	2.004	3.250	7.248	1.918	3.584	1.332	40.985	3.664	50.552
Benzo(b) fluoranthene	mg/Kg	2.637	1.567	3.319	8.368	1.959	3.388	1.360	40.976	4.980	59.512
Benzo(k) fluoranthene	mg/Kg	2.167	1.410	2.357	6.400	1.592	3.037	0.765	32.457	3.443	53.133
Benzo(a)pyrene	mg/Kg	2.657	1.415	3.038	8.683	1.763	4.577	1.275	41.968	4.106	47.288
Indeno (1,2,3-cd) pyrene	mg/Kg	1.800	1.485	2.703	7.530	1.791	2.849	0.912	33.740	4.681	62.165
Dibenzo(a,h) anthracene	mg/Kg	0.675	0.428	0.781	2.568	0.445	1.134	0.336	43.022	1.434	55.841
Benzo(g,h,i) perylene	mg/Kg	1.667	1.036	2.360	6.807	1.273	2.867	1.087	46.059	3.940	57.882
Diesel Range	mg/Kg	0.909	1.511	2.295	1.912	1.248	0.524	1.047	45.621	1.388	72.594
Organic content (VM)	%	5.000	4.600	12.200	10.400	10.500	3.970	1.700	13.934	6.430	61.827

		River Ray Sediment sample analysis results							
Parameter	Units	Highway Runoff		Sedimentation Tank		Actual Reduction	% Reduction	Actual Reduction	% Reduction
		17/12/98	09/03/00	17/12/98	09/03/00	Initial	Initial	Final	Final
Copper	g/Kg	0.033	0.041	0.077	0.105	-0.044	-131.024	-0.064	-154.854
Zinc	g/Kg	0.204	0.248	0.258	0.394	-0.054	-26.471	-0.146	-58.871
Cadmium	g/Kg	0.001	0.001	0.002	0.001	-0.001	-94.872	0.000	-30.000
Aluminium	g/Kg	7.100	6.900	21.900	18.300	-14.800	-208.451	-11.400	-165.217
Lead	g/Kg	0.129	0.128	0.209	0.137	-0.080	-62.016	-0.009	-7.031
Platinum	g/Kg	0.003	0.000	0.003	0.000	0.000	0.000	0.000	0.000
Palladium	g/Kg	0.004	0.001	0.004	0.001	0.000	0.000	0.000	0.000
Nickel	g/Kg	0.013	0.015	0.024	0.048	-0.011	-86.154	-0.033	-219.205
Chromium	g/Kg	0.019	0.022	0.052	0.094	-0.033	-168.557	-0.072	-325.455
Napthalene	mg/Kg	0.157	0.942	0.339	2.340	-0.182	-115.924	-1.398	-148.408
Acenapthylene	mg/Kg	0.092	0.094	0.098	0.094	-0.006	-6.522	0.000	0.000
Acenapthene	mg/Kg	0.036	0.014	0.108	0.033	-0.072	-200.000	-0.019	-135.714
Fluorene	mg/Kg	0.069	0.001	0.197	0.001	-0.128	-185.507	0.000	0.000
Phenanthrene	mg/Kg	0.580	0.284	1.638	0.638	-1.058	-182.414	-0.354	-124.648
Anthracene	mg/Kg	0.163	0.123	0.370	0.168	-0.207	-126.994	-0.045	-36.585
Fluoranthene	mg/Kg	1.149	0.702	2.680	1.555	-1.531	-133.246	-0.853	-121.510
Pyrene	mg/Kg	1.081	0.440	2.268	1.401	-1.187	-109.806	-0.961	-218.409
Benzo(a) anthracene	mg/Kg	0.512	0.663	1.046	1.801	-0.534	-104.297	-1.138	-171.644
Chrysene	mg/Kg	0.945	0.646	1.663	1.443	-0.718	-75.979	-0.797	-123.375
Benzo(b) fluoranthene	mg/Kg	0.774	0.800	1.261	1.922	-0.487	-62.920	-1.122	-140.250
Benzo(k) fluoranthene	mg/Kg	0.770	0.777	1.123	1.443	-0.353	-45.844	-0.666	-85.714
Benzo(a)pyrene	mg/Kg	0.782	0.897	1.044	1.865	-0.262	-33.504	-0.968	-107.915
Indeno (1,2,3-cd) pyrene	mg/Kg	0.605	1.789	0.802	2.689	-0.197	-32.562	-0.900	-50.307
Dibenzo(a,h) anthracene	mg/Kg	0.260	0.465	0.325	0.815	-0.065	-25.000	-0.350	-75.269
Benzo(g,h,i) perylene	mg/Kg	0.873	1.632	1.099	2.244	-0.226	-25.888	-0.612	-37.500
Diesel Range	mg/Kg	0.453	0.992	0.965	26.300	-0.512	-113.024	-25.308	-2551.210
Organic content (VM)	%	1.400	5.800	11.800	17.000	-10.400	-742.857	-11.200	-193.103

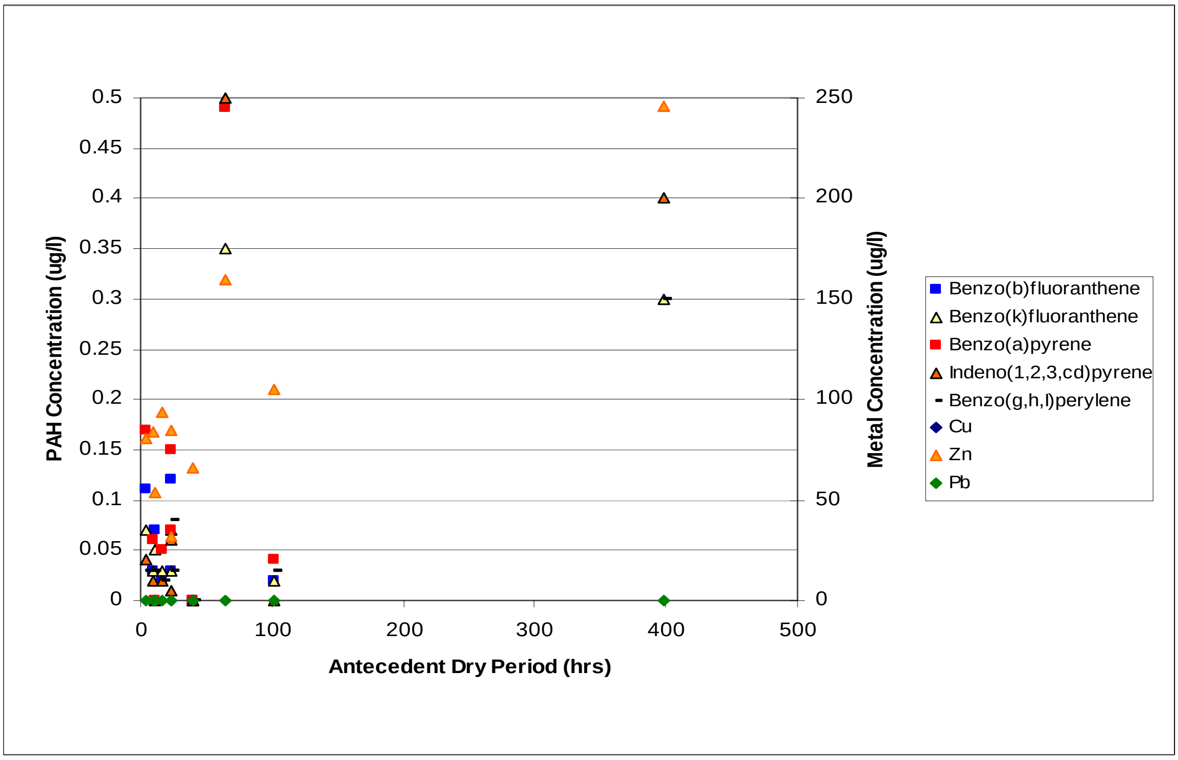
		Souldern Brook Sediment sample analysis results							
Parameter	Units	Highway Runoff		Pond		Actual Reduction	% Reduction	Actual Reduction	% Reduction
		04/08/99	23/11/00	04/08/99	23/11/00	Initial	Initial	Final	Final
Copper	g/Kg	0.051	0.050	0.064	0.067	-0.013	-26.535	-0.017	-34.068
Zinc	g/Kg	0.254	0.429	0.428	0.807	-0.174	-68.504	-0.378	-88.112
Cadmium	g/Kg	0.000	0.001	0.001	0.001	0.000	-58.974	0.000	-16.923
Aluminium	g/Kg	8.050	13.400	11.700	12.800	-3.650	-45.342	0.600	4.478
Lead	g/Kg	0.091	0.095	0.075	0.081	0.016	17.952	0.014	14.675
Platinum	g/Kg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Palladium	g/Kg	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Nickel	g/Kg	0.049	0.057	0.026	0.022	0.023	47.561	0.035	61.376
Chromium	g/Kg	0.056	0.120	0.031	0.036	0.025	44.207	0.085	70.417
Napthalene	mg/Kg	1.113	0.005	0.641	0.011	0.472	42.408	-0.006	-120.000
Acenapthylene	mg/Kg	0.077	0.004	0.081	0.011	-0.004	-5.195	-0.007	-175.000
Acenapthene	mg/Kg	0.146	0.001	0.097	0.013	0.049	33.562	-0.012	-1200.000
Fluorene	mg/Kg	0.211	0.003	0.177	0.009	0.034	16.114	-0.006	-200.000
Phenanthrene	mg/Kg	0.778	0.033	1.066	0.032	-0.288	-37.018	0.001	3.030
Anthracene	mg/Kg	0.175	0.012	0.382	0.016	-0.207	-118.286	-0.004	-33.333
Fluoranthene	mg/Kg	0.614	0.133	1.209	0.104	-0.595	-96.906	0.029	21.805
Pyrene	mg/Kg	0.696	0.149	1.007	0.145	-0.311	-44.684	0.004	2.685
Benzo(a) anthracene	mg/Kg	0.319	0.069	0.565	0.080	-0.246	-77.116	-0.011	-15.942
Chrysene	mg/Kg	0.604	0.091	0.760	0.175	-0.156	-25.828	-0.084	-92.308
Benzo(b) fluoranthene	mg/Kg	0.588	0.065	0.631	0.247	-0.043	-7.313	-0.182	-280.000
Benzo(k) fluoranthene	mg/Kg	0.587	0.080	0.869	0.175	-0.282	-48.041	-0.095	-118.750
Benzo(a)pyrene	mg/Kg	0.627	0.088	0.883	0.144	-0.256	-40.829	-0.056	-63.636
Indeno (1,2,3-cd) pyrene	mg/Kg	1.081	0.039	0.901	0.144	0.180	16.651	-0.105	-269.231
Dibenzo(a,h) anthracene	mg/Kg	0.242	0.008	0.348	0.025	-0.106	-43.802	-0.017	-212.500
Benzo(g,h,i) perylene	mg/Kg	0.656	0.048	0.751	0.229	-0.095	-14.482	-0.181	-377.083
Diesel Range	mg/Kg	1.370	0.115	0.026	1.023	1.344	98.102	-0.908	-789.565
Organic content (VM)	%	3.460	2.910	13.400	15.400	-9.940	-287.283	-12.490	-429.210

		Gallos Brook Sediment sample analysis results							
Parameter	Units	Control		Filter		Actual Reduction	% Reduction	Actual Reduction	% Reduction
		08/05/00	18/03/02	08/05/00	18/03/02	Initial	Initial	Final	Final
Copper	g/Kg	0.259	0.179	0.092	0.067	0.167	64.363	0.113	62.849
Zinc	g/Kg	0.931	0.565	0.565	0.737	0.366	39.313	-0.172	-30.442
Cadmium	g/Kg	0.001	0.001	0.001	0.001	0.000	-5.102	0.000	-17.333
Aluminium	g/Kg	6.580	8.070	23.800	13.100	-17.220	-261.702	-5.030	-62.330
Lead	g/Kg	0.750	0.138	0.163	0.068	0.587	78.267	0.070	50.580
Platinum	g/Kg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Palladium	g/Kg	0.078	0.001	0.001	0.001	0.078	99.359	0.000	0.000
Nickel	g/Kg	0.028	0.027	0.043	0.034	-0.014	-50.177	-0.007	-25.468
Chromium	g/Kg	0.072	0.037	0.025	0.052	0.048	65.698	-0.015	-42.077
Napthalene	mg/Kg	3.439	0.106	0.007	0.156	3.432	99.796	-0.050	-47.170
Acenapthylene	mg/Kg	0.172	0.047	0.009	0.019	0.163	94.767	0.028	59.574
Acenapthene	mg/Kg	0.312	0.072	0.016	0.047	0.296	94.872	0.025	34.722
Fluorene	mg/Kg	0.289	0.087	0.001	0.044	0.288	99.654	0.043	49.425
Phenanthrene	mg/Kg	3.509	0.913	0.003	0.293	3.506	99.915	0.620	67.908
Anthracene	mg/Kg	0.935	0.225	0.008	0.069	0.927	99.144	0.156	69.333
Fluoranthene	mg/Kg	5.093	2.045	0.030	0.542	5.063	99.411	1.503	73.496
Pyrene	mg/Kg	4.061	1.631	0.032	0.478	4.029	99.212	1.153	70.693
Benzo(a) anthracene	mg/Kg	2.038	1.010	0.099	0.315	1.939	95.142	0.695	68.812
Chrysene	mg/Kg	2.796	0.854	0.114	0.235	2.682	95.923	0.619	72.482
Benzo(b) fluoranthene	mg/Kg	2.305	1.149	0.166	0.410	2.139	92.798	0.739	64.317
Benzo(k) fluoranthene	mg/Kg	2.113	0.660	0.142	0.219	1.971	93.280	0.441	66.818
Benzo(a)pyrene	mg/Kg	2.111	0.786	0.149	0.205	1.962	92.942	0.581	73.919
Indeno (1,2,3-cd) pyrene	mg/Kg	2.203	0.937	0.119	0.270	2.084	94.598	0.667	71.185
Dibenzo(a,h) anthracene	mg/Kg	0.515	0.363	0.023	0.092	0.492	95.534	0.271	74.656
Benzo(g,h,i) perylene	mg/Kg	1.215	1.035	0.164	0.347	1.051	86.502	0.688	66.473
Diesel Range	mg/Kg	1.075	0.808	0.284	0.482	0.791	73.581	0.326	40.347
Organic content (VM)	%	7.720	12.300	9.910	6.700	-2.190	-28.368	5.600	45.528

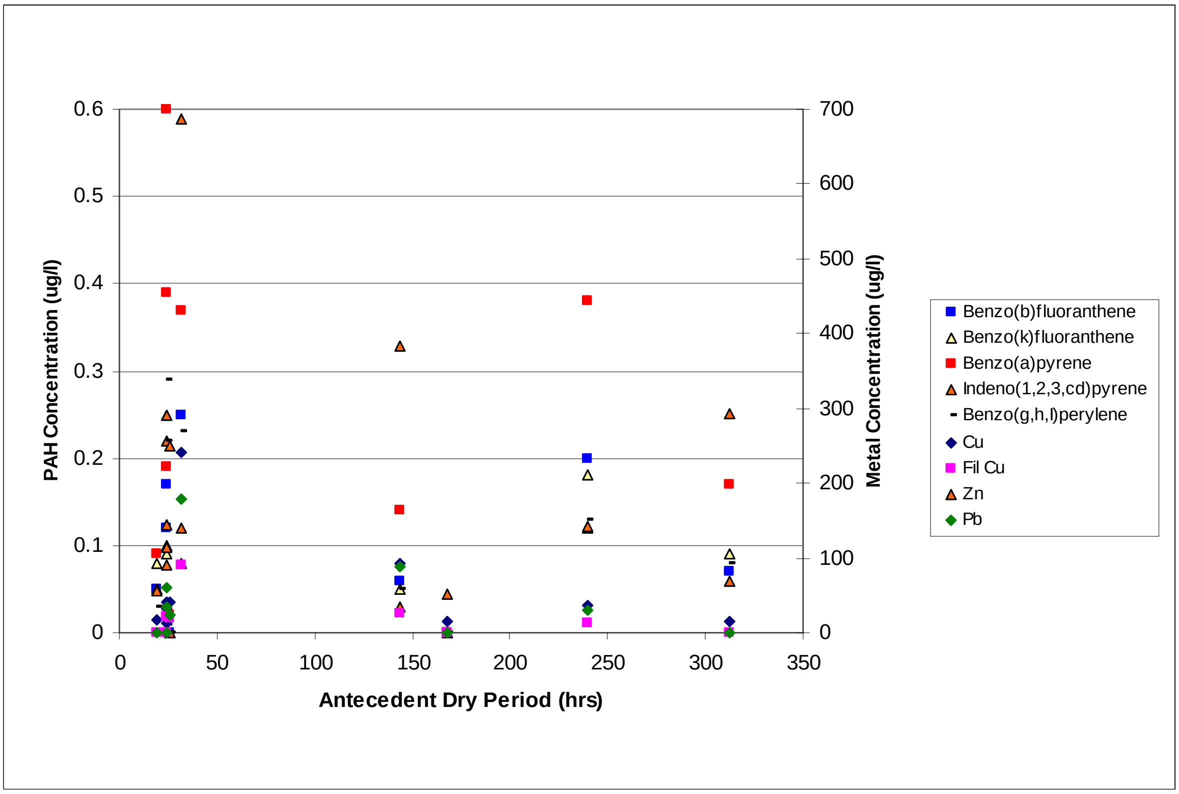
Newbury Sediment sample analysis results

Parameter	Units	Upstream oil		Downstream Oil		Downstream Pond		Actual Reduction	% Reduction	Actual Reduction	% Reduction	Actual Reduction	% Reduction	Actual Reduction	% Reduction
								U/S Oil - D/S Oil Initial	U/S Oil - D/S Oil Initial	U/S Oil - D/S Oil Final	U/S Oil - D/S Oil Final	D/S Oil- D/S Pond Initial	D/S Oil- D/S Pond Initial	D/S Oil- D/S Pond Final	D/S Oil- D/S Pond Final
		00/05/00	10/03/02	00/05/00	10/03/02	00/05/00	10/03/02								
Copper	g/Kg	0.073	0.008	0.056	0.052	0.021	0.014	-0.037	-140.260	0.044	590.667	0.034	61.441	0.038	72.394
Zinc	g/Kg	0.125	0.059	0.307	0.300	0.160	0.151	0.182	145.600	0.249	425.597	0.139	45.277	0.157	50.974
Cadmium	g/Kg	0.000	0.000	0.001	0.001	0.000	0.000	0.000	86.127	0.000	116.129	0.000	48.790	0.000	70.149
Aluminium	g/Kg	4.160	4.050	9.130	8.010	17.700	14.600	4.970	119.471	4.760	117.531	8.570	93.866	5.790	65.721
Lead	g/Kg	0.029	0.019	0.042	0.039	0.029	0.021	0.013	43.686	0.020	104.167	0.013	31.591	0.018	46.604
Platinum	g/Kg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Palladium	g/Kg	0.002	0.001	0.001	0.001	0.001	0.001	0.002	75.000	0.000	0.000	0.000	16.667	0.000	0.000
Nickel	g/Kg	0.017	0.014	0.026	0.027	0.023	0.018	0.008	47.701	0.013	99.259	0.003	11.673	0.009	33.457
Chromium	g/Kg	0.017	0.019	0.030	0.020	0.040	0.030	0.012	69.540	0.009	47.594	0.010	35.254	0.002	7.236
Napthalene	mg/Kg	0.145	0.042	0.564	0.066	0.211	0.016	0.419	288.966	0.024	57.143	0.353	62.589	0.050	75.758
Acenaphtylene	mg/Kg	0.028	0.026	0.140	0.037	0.017	0.007	0.112	400.000	0.011	30.556	0.123	87.857	0.030	85.106
Acenaphtene	mg/Kg	0.109	0.060	0.783	0.116	0.044	0.011	0.674	618.349	0.056	96.667	0.739	94.381	0.105	90.983
Fluorene	mg/Kg	0.067	0.072	0.685	0.088	0.043	0.012	0.618	922.388	0.016	22.222	0.642	93.723	0.076	86.364
Phenanthrene	mg/Kg	0.776	0.442	6.542	0.849	0.237	0.110	5.766	743.041	0.407	92.081	6.305	96.377	0.739	87.044
Anthracene	mg/Kg	0.271	0.202	1.020	0.240	0.005	0.040	1.557	574.539	0.042	14.894	1.023	99.726	0.200	83.333
Fluoranthene	mg/Kg	1.738	1.786	10.740	2.163	0.472	0.331	9.002	517.952	0.377	21.103	10.268	95.605	1.832	85.627
Pyrene	mg/Kg	1.492	0.873	9.296	1.871	0.425	0.238	7.804	523.056	0.998	114.318	8.871	95.428	1.633	87.280
Benzo(a) anthracene	mg/Kg	1.368	0.538	5.397	1.464	0.390	0.137	4.029	294.518	0.926	172.119	5.007	92.774	1.327	90.642
Chrysene	mg/Kg	0.747	0.568	3.756	1.080	0.214	0.176	3.009	402.811	0.520	91.549	3.542	94.302	0.912	83.824
Benzo(b) fluoranthene	mg/Kg	0.620	0.817	5.660	1.954	0.357	0.209	5.040	812.903	1.137	139.168	5.303	93.693	1.745	89.304
Benzo(k) fluoranthene	mg/Kg	0.514	0.221	1.767	0.557	0.152	0.097	1.253	243.774	0.336	152.036	1.615	91.398	0.460	82.585
Benzo(a)pyrene	mg/Kg	0.775	0.472	3.387	1.074	0.204	0.160	2.617	360.966	0.602	127.542	3.138	93.896	0.914	85.102
Indeno (1,2,3-cd) pyrene	mg/Kg	0.568	0.406	3.514	0.893	0.250	0.141	2.946	518.662	0.487	119.951	3.264	92.886	0.752	84.211
Dibenzo(a,h) anthracene	mg/Kg	0.180	0.151	0.984	0.299	0.072	0.044	0.804	446.667	0.148	98.156	0.912	92.683	0.255	85.284
Benzo(g,h,i) perylene	mg/Kg	0.651	0.482	3.829	1.053	0.251	0.152	3.178	488.172	0.571	118.465	3.578	93.445	0.901	85.565
Diesel Range	mg/Kg	2.590	0.750	1.802	0.870	0.442	0.297	1.796	69.347	0.520	150.057	1.360	75.472	0.581	66.173
Organic content (VM)	%	6.900	2.700	11.600	10.600	7.800	4.900	4.700	68.116	7.900	292.593	3.800	32.759	6.100	57.547

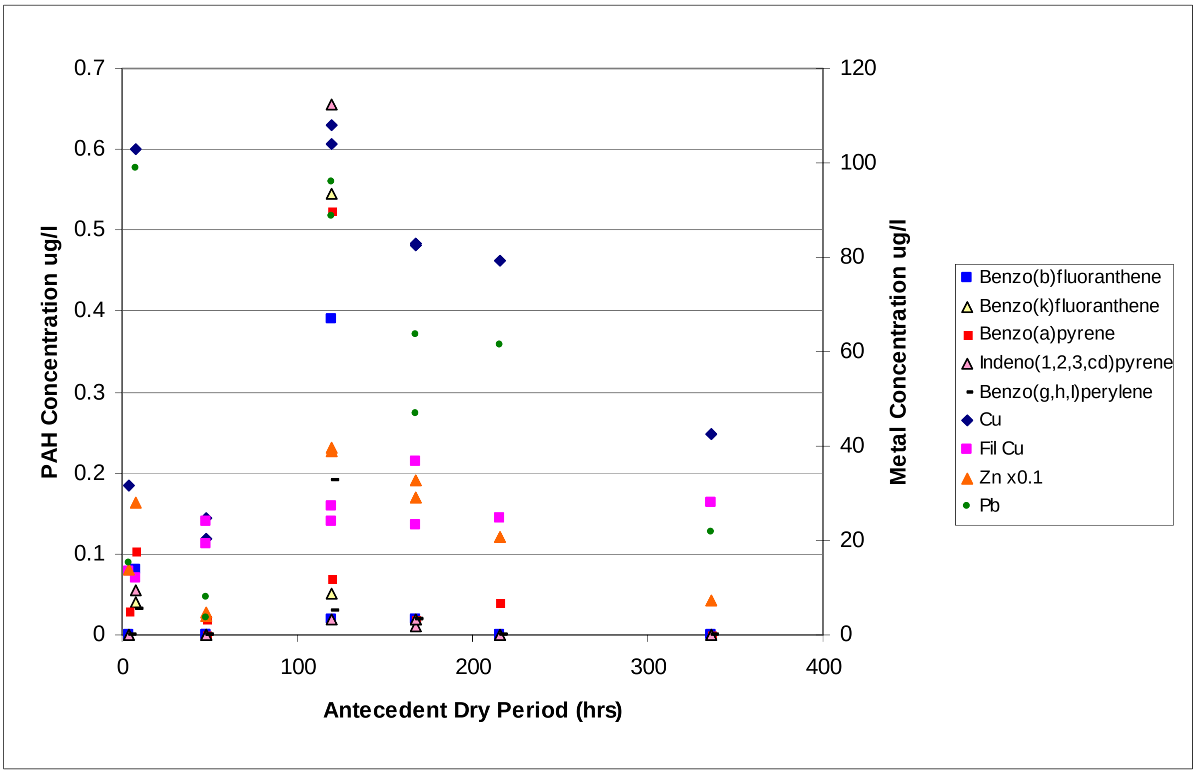
APPENDIX I INDIVIDUAL SITES EVENT COMPOSITE PLOTS KEY DETERMINANDS V ANTECEDENT DRY PERIOD



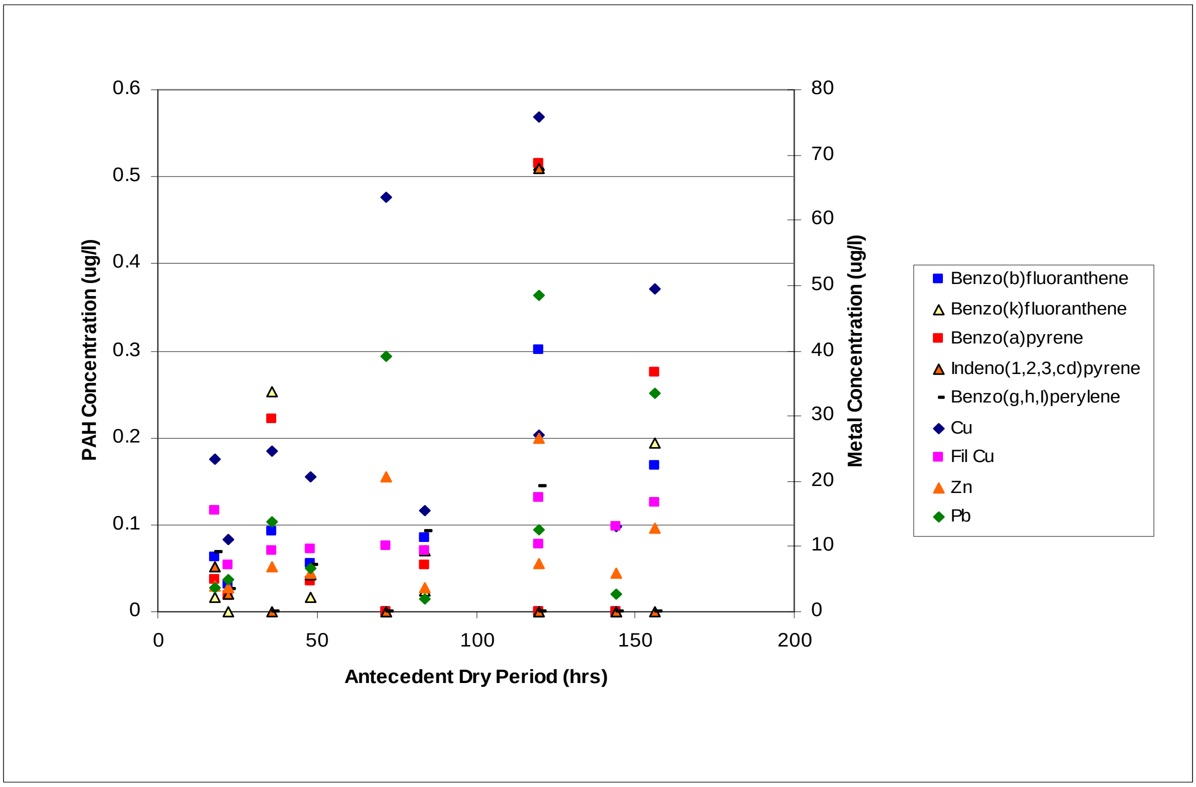
M4/Brinkworth Brook – Key determinands V ADP



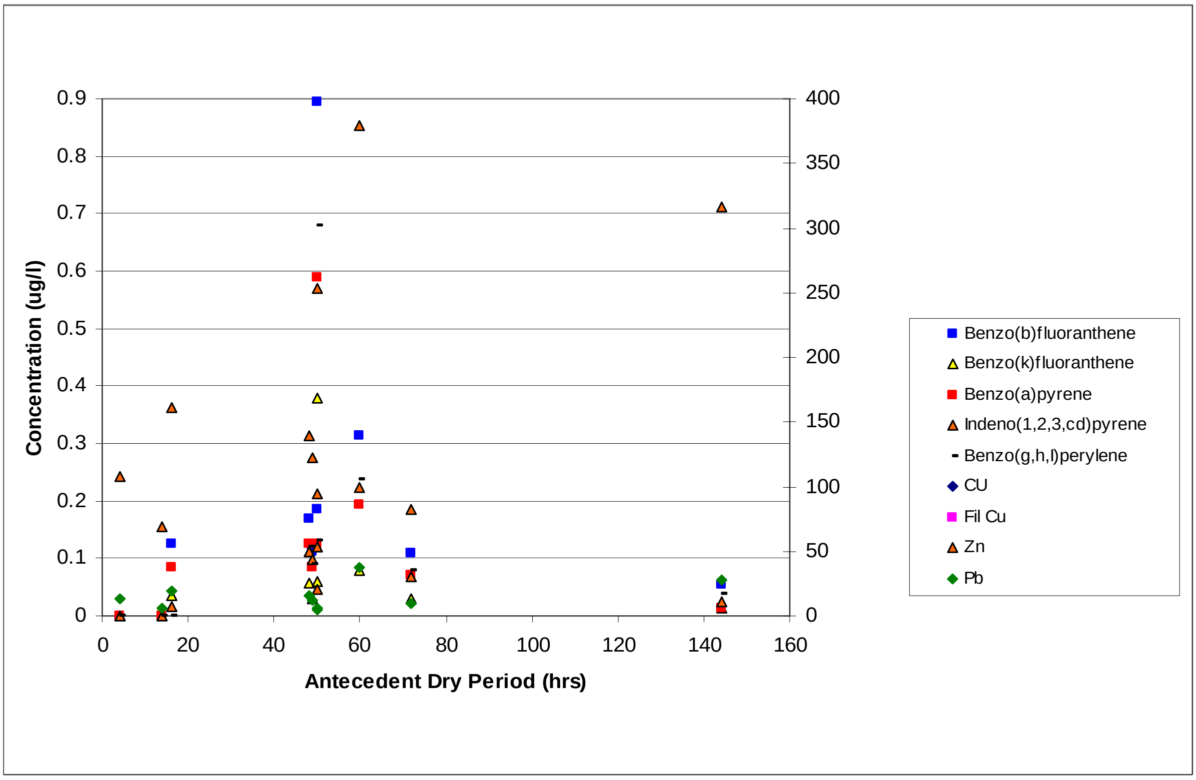
A417/River Frome - Key determinands v ADP



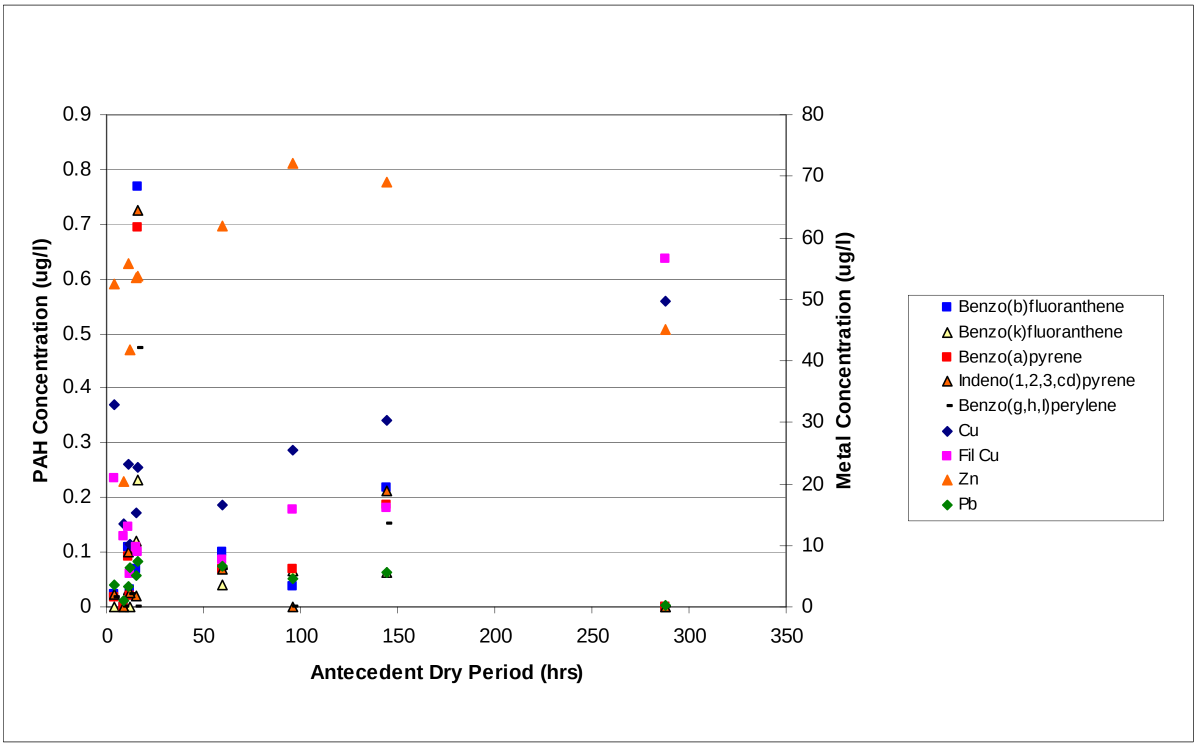
M4/River Ray - Key determinands v ADP



M40/Souldern Brook - Key determinands v ADP

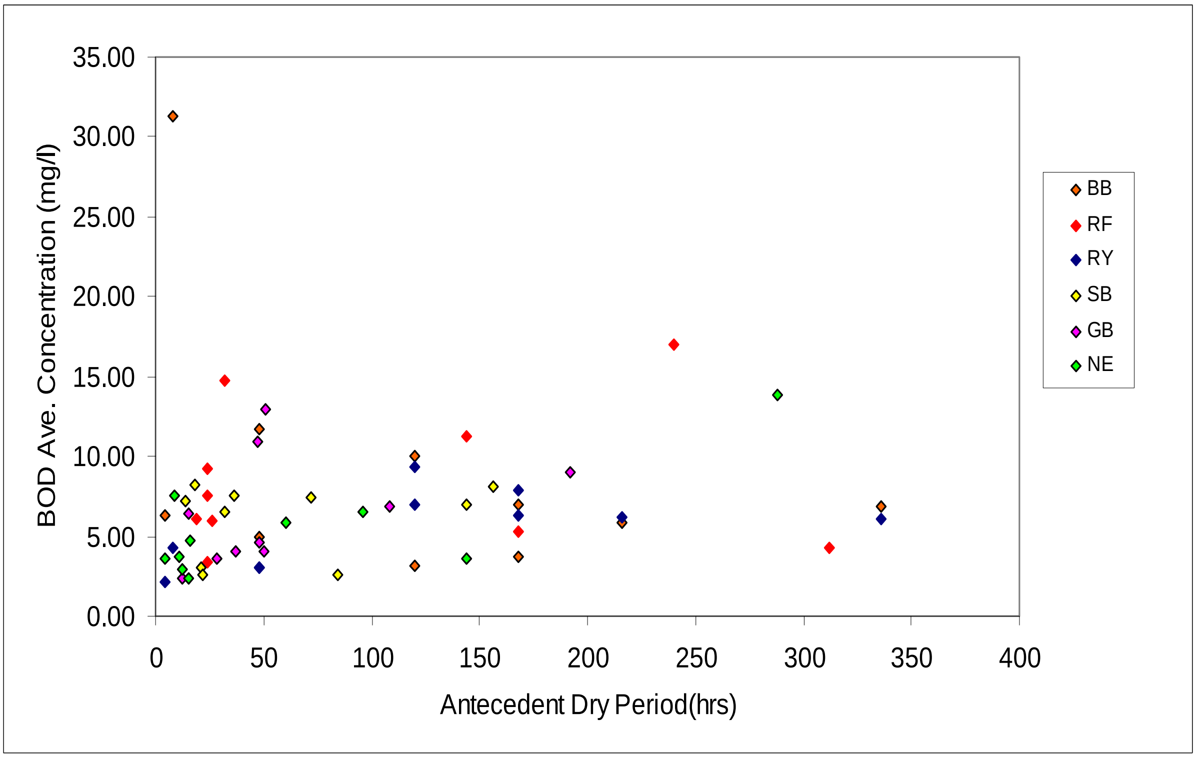


A34/Gallos Brook - Key determinands v ADP

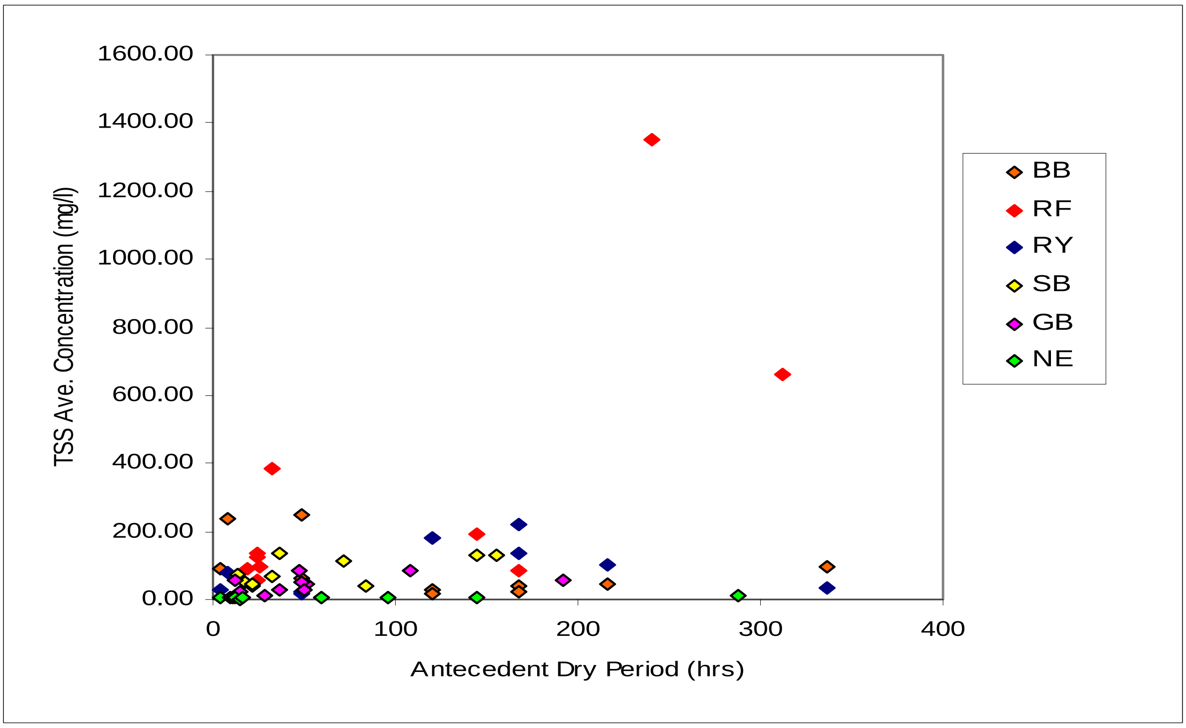


A34/Newbury - Key determinands v ADP

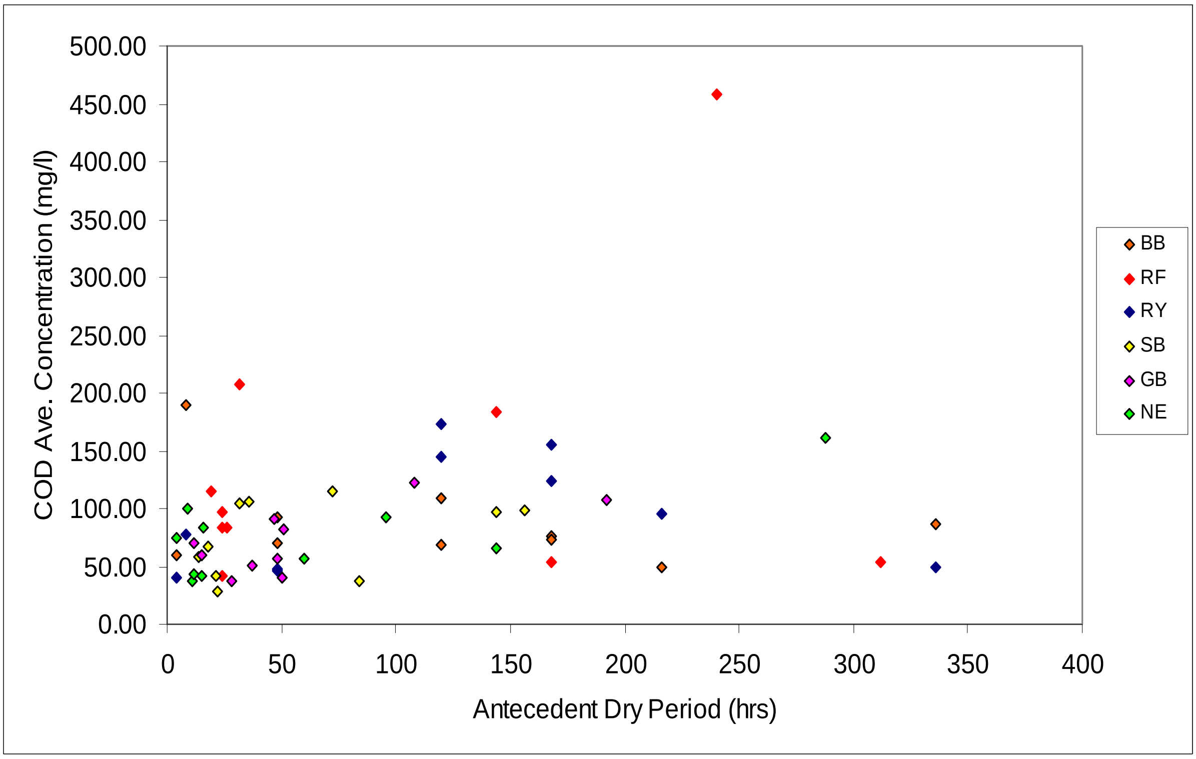
APPENDIX J ALL SITES EVENT DISCRETE DETERMINANDS V ANTECEDENT DRY PERIOD



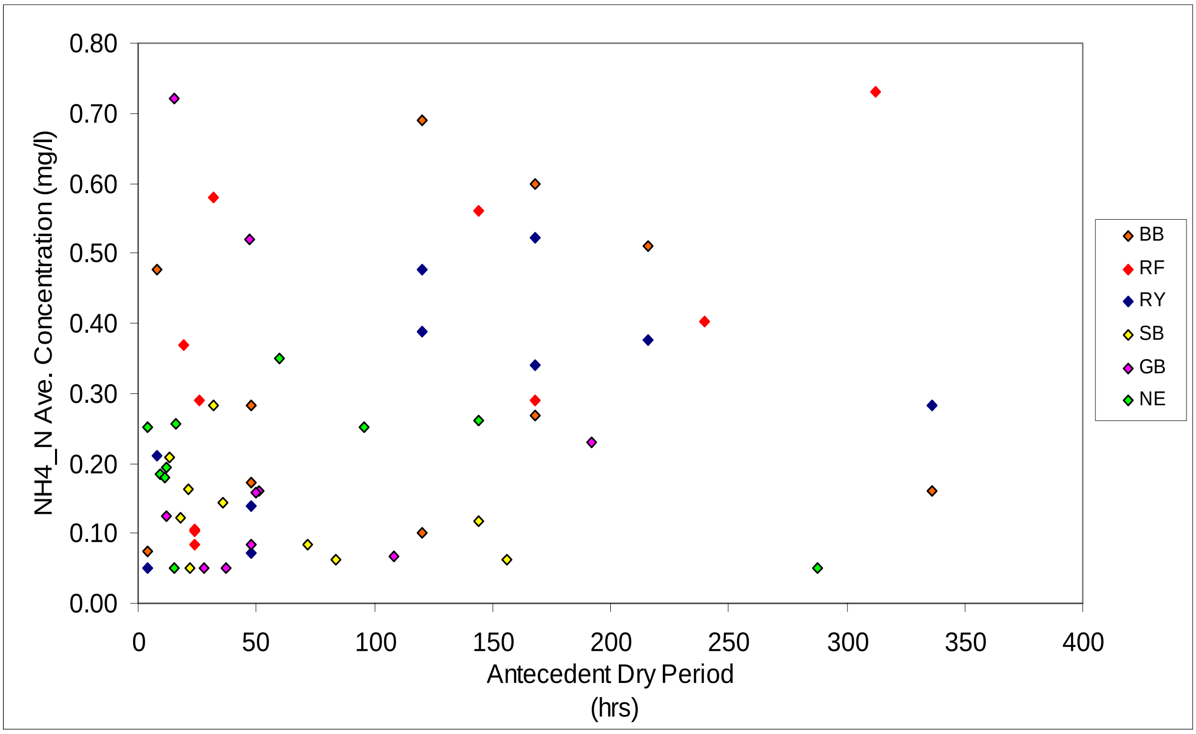
All sites BOD v ADP



All sites – TSS v ADP



All sites COD v ADP



All sites NH_4-N v ADP