PART B

SUDS Performance Data Summary Sheets

Contents

This section provides basic information on the various sites where flows and loads monitoring have been carried out.

Sites monitored

Number	Name	Brief description
1	Clayland Pond	Pond serving busy motorway
2	Newbridge Pond	Pond serving busy motorway
3	Hallbeath Pond	Regional pond serving retail park
4	Linburn Pond	Regional pond serving mixed residential/ commercial
5	Stenton Pond	Former flood pond serving housing estates
6	NATS	Permeable paving car park
7	RBS South Gyle	Permeable paving car park
8	Detention Basin D/M	Detention basin serving highway
9	Detention Basin G	Detention basin serving highway
10	Lang Stracht	Filter drain on a 750m stretch of busy urban road
11	Broxden	Filter Drain serving housing estate
12	Walker Dam	Filter Drain serving housing estate
13	Emmock Woods	Roadside Detention
14	West Grange	Roadside Detention

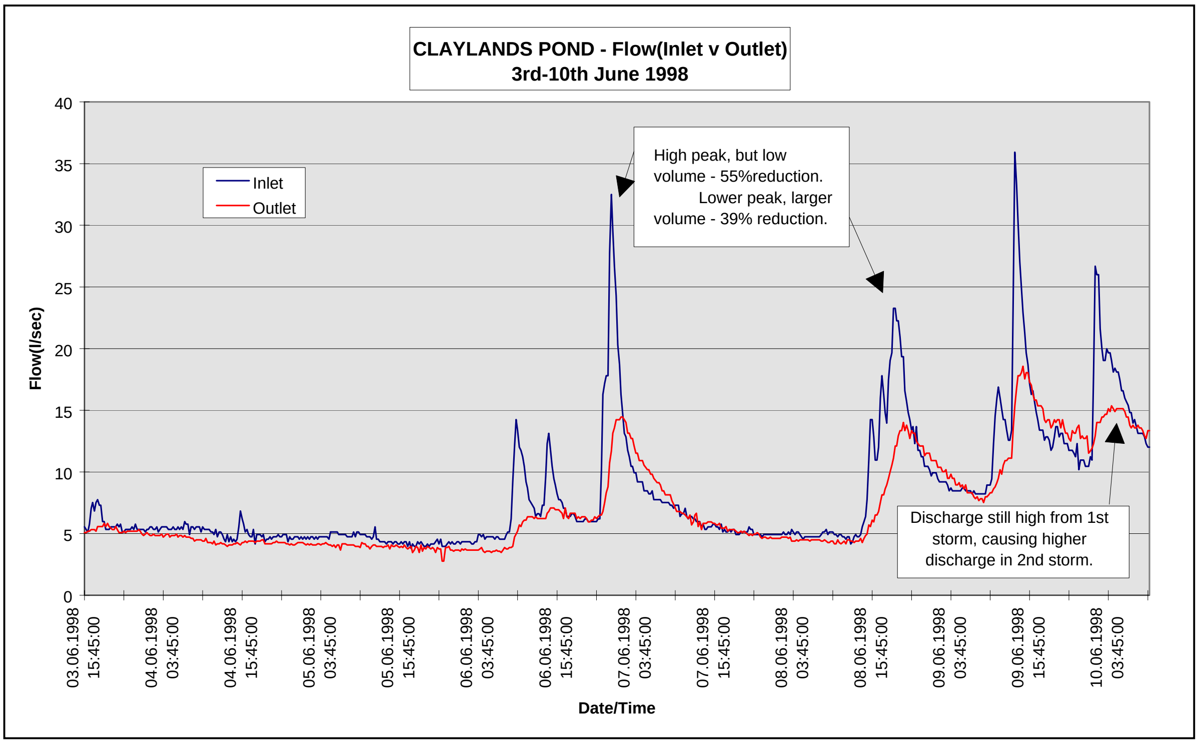
Clayland Pond, Edinburgh

Name	Clayland Pond, Newbridge, Edinburgh	System	Converted agricultural pond (1995)
Serving	Heavily used motorway	Cont. Area	Approx 1 mile of two lane motorway
Hydrology	Rainfall (3km); Thin plate weirs with water level sensors and Isodaq VF1e loggers		
Period(s)		Events	Example events analysed
Quality	Buhler-Montec 1011 auto-samplers on inlet and outlet; Event triggered Two Hydrolab DS4 sondes; DO, pH, turbidity, temperature, conductivity		
Period(s)	Several periods Feb 98 - Jan 99	Events	3 x Metals; 1 x Hydrocarbons
Comments	Data from Neil McLean (neil.mclean@sepa.org.uk)		

Claylands Pond, on the western approaches of Edinburgh, receives runoff from a length of **motorway** which carries 48,000 vehicles per day. The pond, which has a volume of 2,070m^3, has been in existence for over twenty years and was originally a farm irrigation pond constructed on a small stream. When the M9 motorway extension was built in 1994, the pond's location was convenient enough to be used as part of the drainage scheme. There is a small continuous flow from a stream.

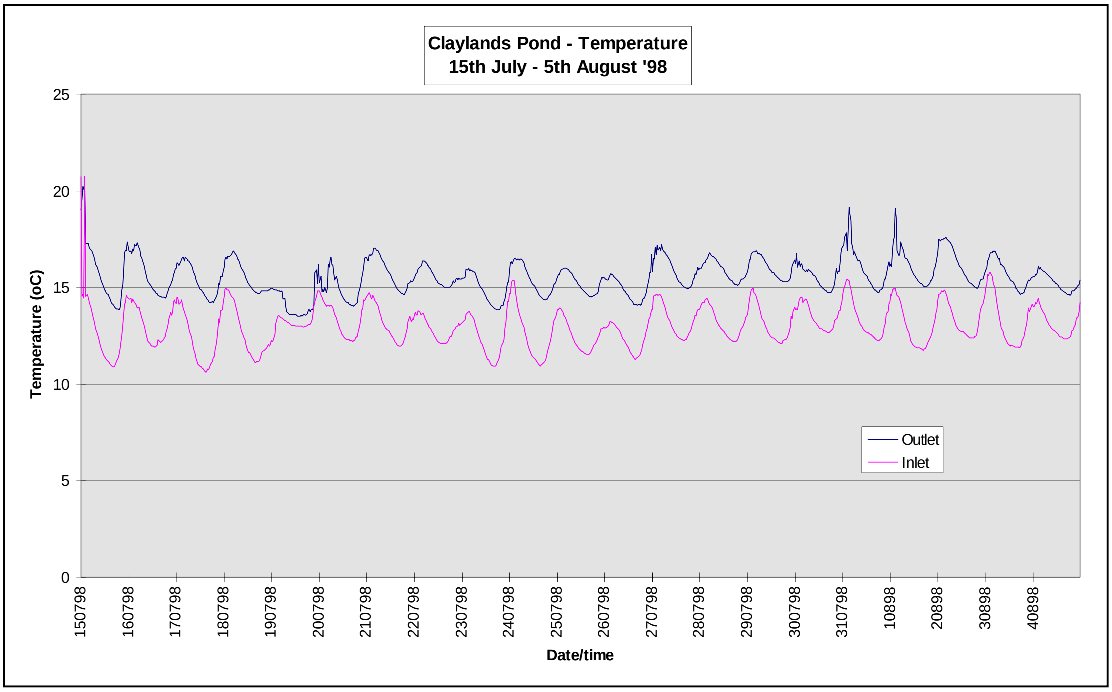
Flowrate

Typical flowrates during a number of events are plotted below. Peak flows were reduced by an average of 43%



Temperature

Diurnal variations in temperature were note in summer 1998 with a range of ± 5°C.



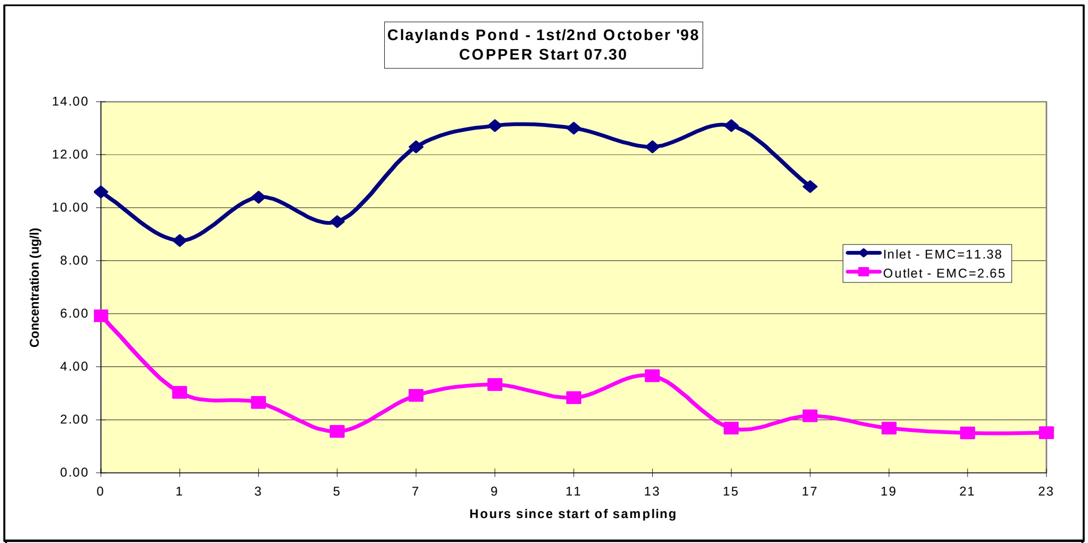
Metals

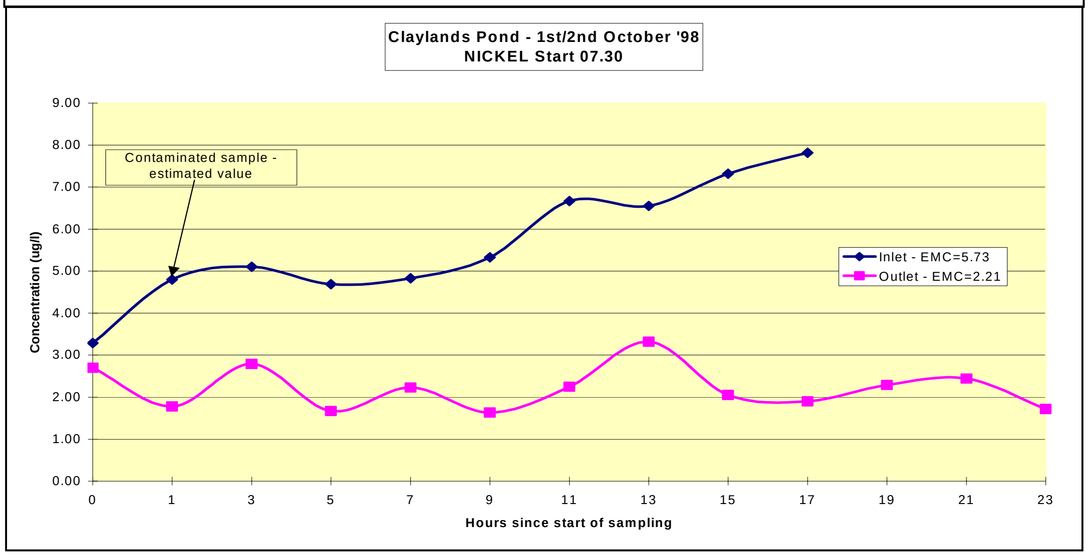
Metals concentrations were measured from samples at inlet and outlet. Reductions in event mean concentration are shown and variations of copper and nickel are plotted. This presentation is open to the criticism that the time period considered may not have been sufficiently long to take into account all of the pollutant load. Most were calculated over a 24h time period and no significant outlet peaks were noted.

Percentage reduction of key determinands measured at Claylands.

Determinand	No. of events used	Reduction (%)
Chromium (EMC*)	1	80
Copper (EMC)	3	77
Lead (EMC)	2	75
Zinc (EMC)	3	42
Nickel (EMC)	2	61
Hydrocarbons (EMC)	1	Too close to limit of detection
Turbidity (EMC)	12	75

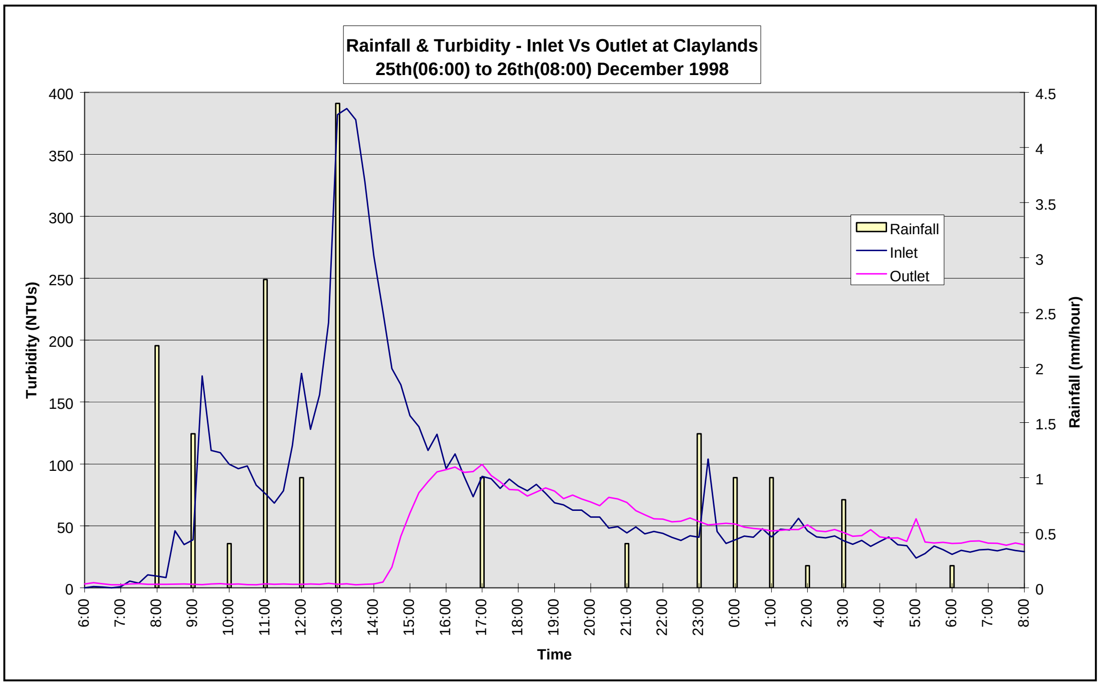
*   EMC = Event Mean Concentration





Turbidity

Turbidity at inlet & outlet, and rainfall intensity over a two day period are shown below. This is typical of events monitored, but under dry weather conditions, outlet turbidities were observed to be higher than inlet conditions.



Newbridge Pond, Edinburgh

Name	Newbridge Pond, Edinburgh	System	Purpose built treatment pond
Serving	Heavily used motorway	Cont. Area	9.8 Ha (63% impervious)
Hydrology	Rainfall (3km); Rectangular weir plates and Isodaq 2xVF1e on inlet and outlet,		
Period(s)		Events	
Quality	Buhler-Montec 1011 auto-samplers on inlet and outlet; Event triggered Two Hydrolab DS4 sondes; DO, pH, turbidity, temperature, conductivity		
Period(s)	May 99	Events	2 x Metals; 1 x Hydrocarbons
Comments	Data from Neil McLean (neil.mclean@sepa.org.uk)		

This pond receives runoff from the **Newbridge** motorway interchange which to the west of Edinburgh. The pond has a design volume of 27,000m^3 and receives runoff pumped from the interchange. The majority of road runoff is drained through roadside filter drains prior to being pumped to the pond. The overall catchment is approximately 9.8ha of which about 3.6ha is permeable area making approximately 63% of the total catchment impervious. The traffic density is 44,000 vehicles per day and particularly severe pollutant loads might be expected since a speed restriction means that most vehicles brake at the interchange. The pond lies within 400m of the end of the main runway of Edinburgh airport.

Pollution from aircraft is an issue since the catchment is at the west end of Edinburgh airport. The pond margins are designed to prevent wildlife habitats by the suppression of ground cover and peripheral vegetation which reduces the habitat for many birds which might nest in such surroundings.

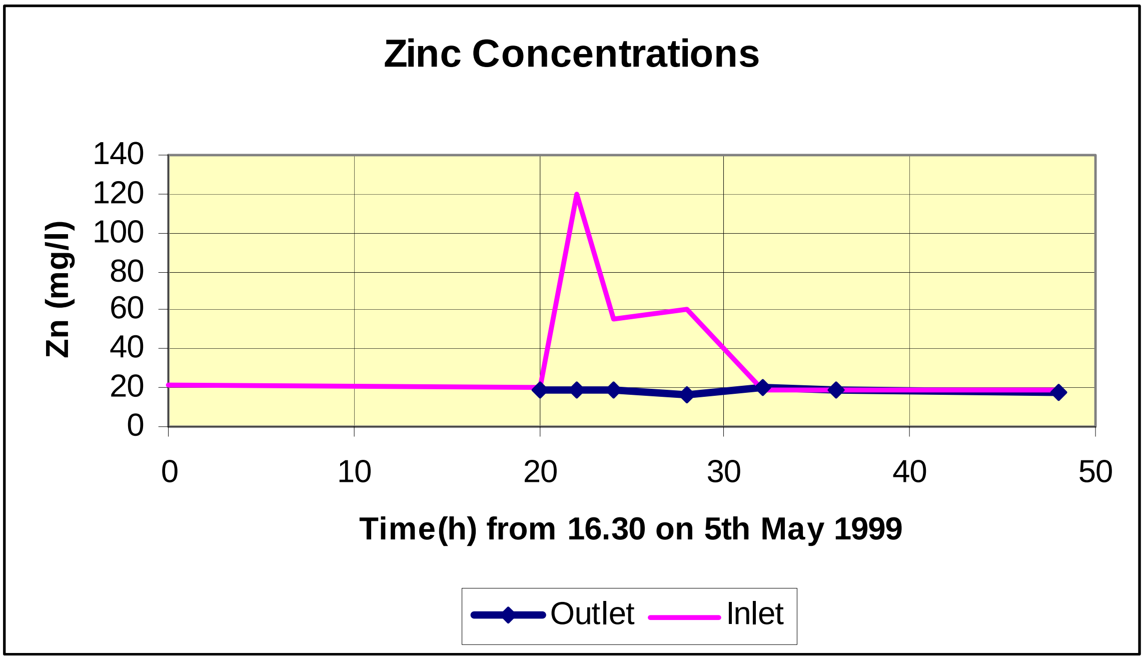
A limited programme of analysis for metals concentrations was undertaken. Concentrations were expected to be higher due to the location of the pond and a small amount of data were gathered using samplers. Estimated reductions of metals and hydrocarbons are shown in the following table, although limited reliance should be placed on these data.

Reduction of key determinands measured at Newbridge

Determinand	No. of events monitored	Reduction (%)
Cadmium (EMC)	1	65
Copper (EMC)	1	84
Lead (EMC)	1	58
Zinc (EMC)	2	68
Hydrocarbons (EMC)	1	80

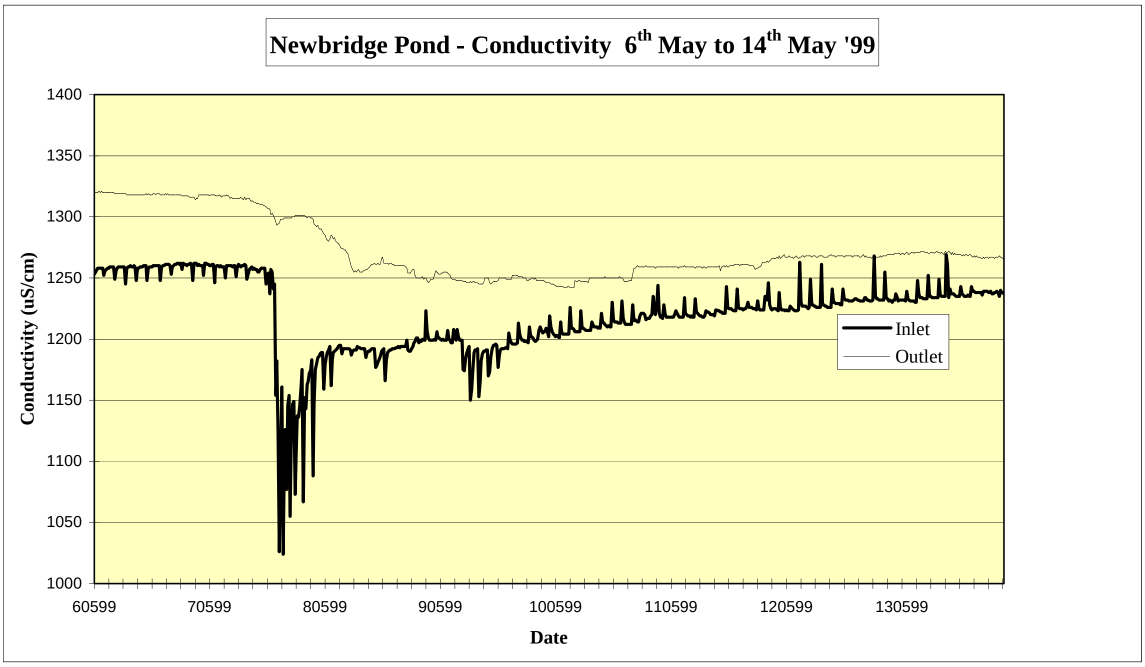
Zinc

Zinc concentrations were recorded during one minor event;



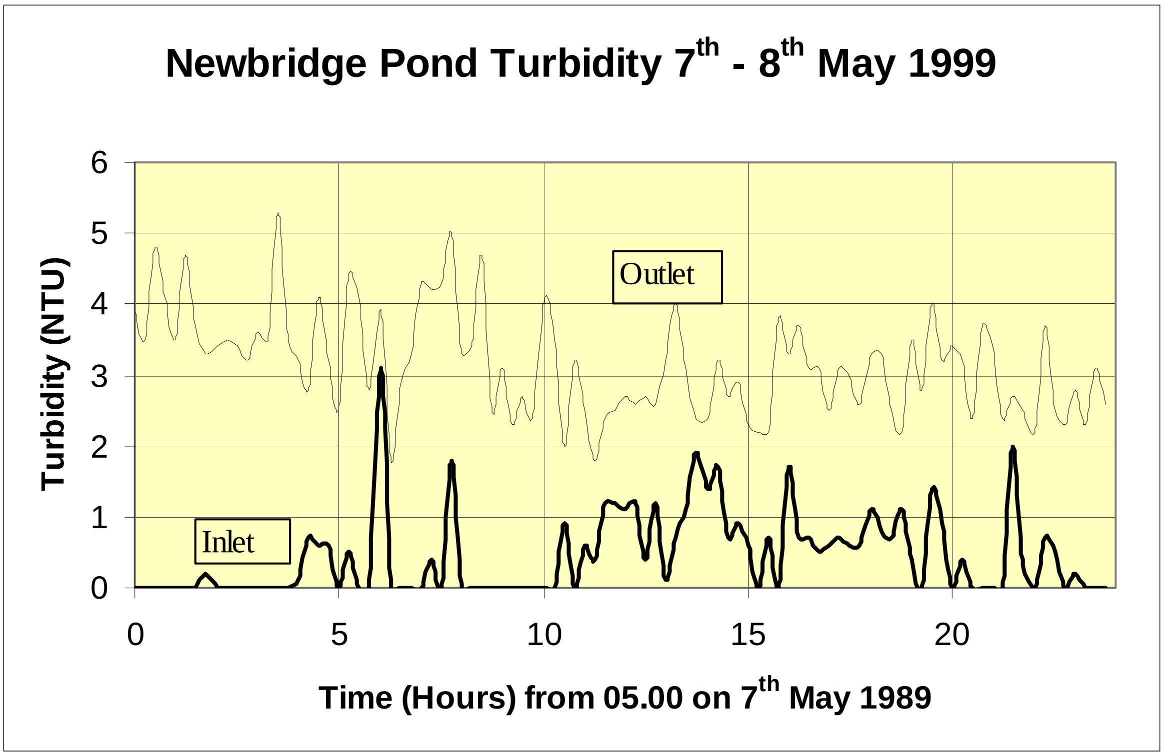
Conductivity

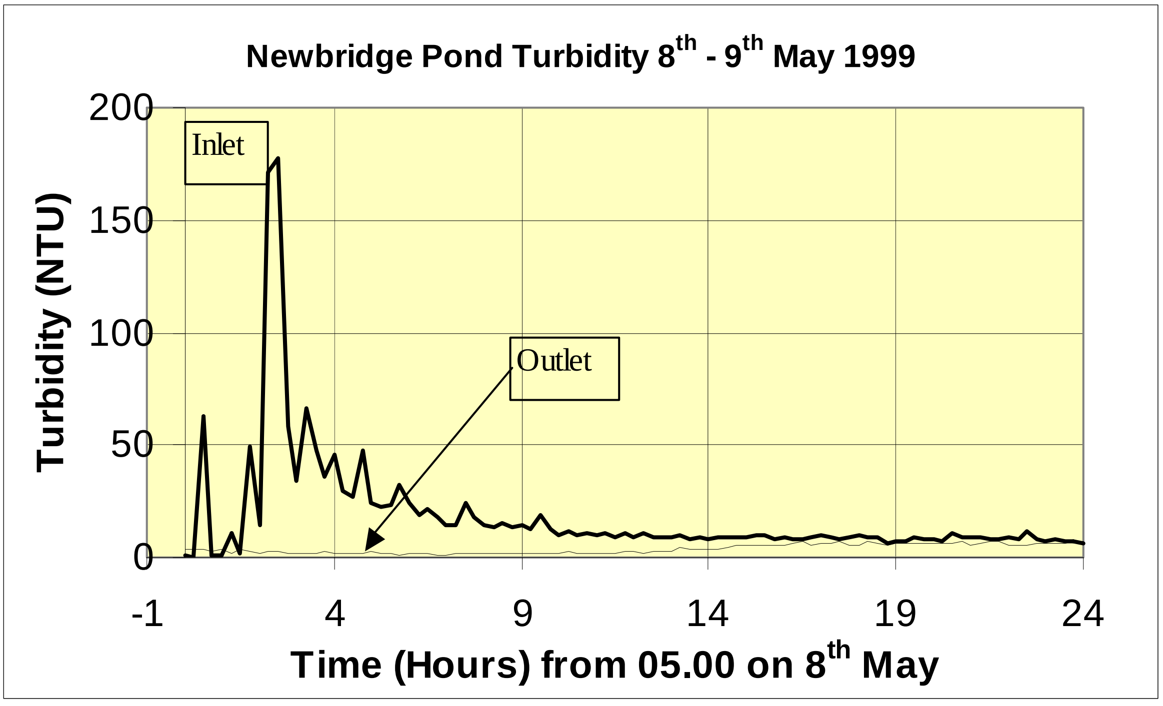
Data from sondes installed at inlet and outlet are plotted below. A low conductivity flush occurred with rainfall on 8th May 1999 and the attenuation of concentration may be observed in the outflow.



Turbidity

Under low flow conditions, as shown on 7th – 8th May 1999, outlet turbidities at the pond outlet are normally higher than at the inlet, reflecting biological and other activity in the pond. The plot from 8th – 9th May indicates that one principal function of this pond is the attenuation of pollutants.





Halbeath Pond, DEX, Dunfermline

Name	Halbeath Pond, Duloch Park	System	Regional Pond for retail park
Serving	Commercial/ retail park	Cont. Area	13.5 ha (11.7 during study period)
Hydrology	Rainfall; Flow and level measurement on outlet, Flow measurement on inlet		
Period(s)	May 1999 – May 2003 (ongoing)	Events	Almost complete inlet/ outlet record
Quality	Vegason sonde and Epic samplers for targeted periods on inlet and outlet, weekly background		
Period(s)	Sondes Target periods throughout; Epic June 2000, May – Jun 2001	Events	Continuously recorded during target periods
Comments	Comprehensive biology and social surveys underway. 5 year studies funded by Wilcon Homes		
Data Source	Data from Adolf Spitzer a.spitzer@tay.ac.uk or Chris Jefferies c.Jefferies@tay.ac.uk		

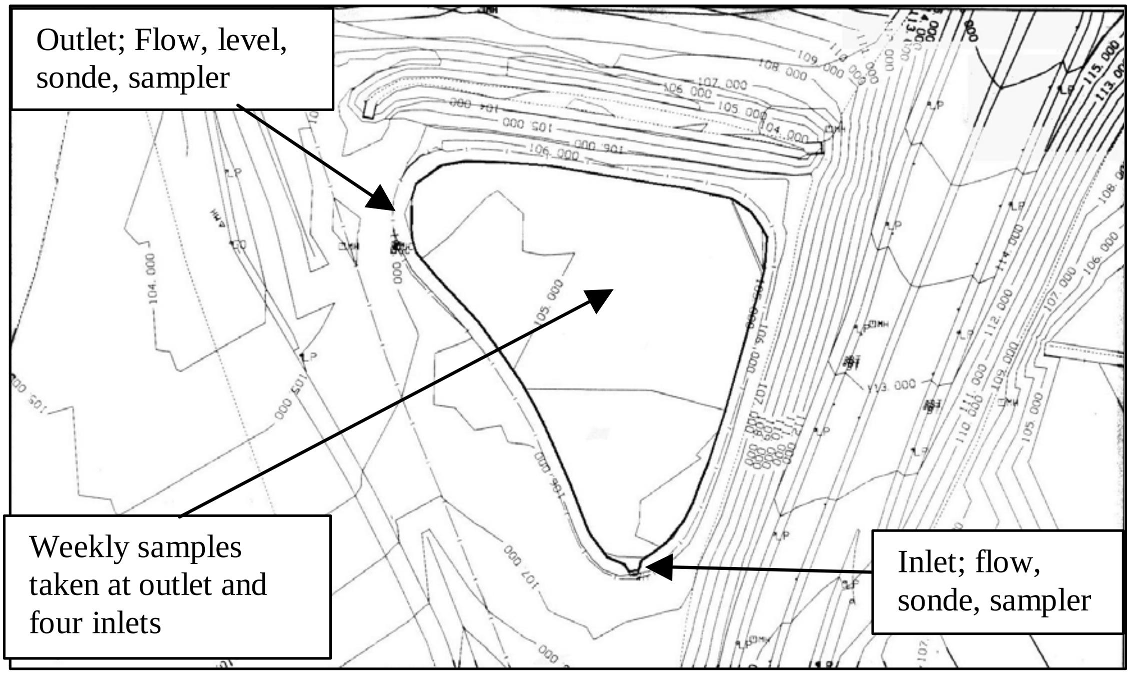


Figure 3.1 Plan of Halbeath Pond

Figure 3.2 Halbeath Pond over a four year period

Halbeath Pond

Halbeath pond was constructed at the end of 1997, aquatic planting for the ponds was carried out during June and July 1998. Halbeath pond catchment area is 13.5 ha with very low gradients. Runoff is from a leisure park and road surfaces. To date the built up surface area comprises approximately 60 % of the catchment total. Halbeath pond has a total surface area of ≈ 3200 m^2 and a volume of 4600 m^3. Data suggest that the ponds remove orthophosphate and total oxidised nitrogen, the best removal rates being during the summer months, but information on nitrogen removal is inconclusive. There appears to be no removal of chlorides in the retention ponds, but data show that conductivity at the outlets is usually much lower than at the inlets, probably due to dilution. Removal of suspended solids is excellent, always below 30 mg/l and below 32 NTU turbidity, although sediment loads of 32000 mg/l have been measured at the inlet. Table 3.1 shows water quality information obtained during four weeks of sampling.

Figure 3.3 Outlet Details – located in a Manhole

Parameter	Min Inlet	Max inlet	Min Outlet	Max Outlet
PH	6.55	7.75	7.02	7.54
El. Conductivity (μSiemens/cm)	75	21,100	1,960	3,440
Total suspended solids (mg/l)	4	32,792	0	26
Turbidity (FTU)	11	16,960	0	12
Chemical oxygen demand (mg/l)	62	756	95	630
Biological oxygen demand (mg/l)	0.32	80.48	1.70	11.21
Ammoniacal nitrogen (mg/l)	0.00	216.00	0.01	1.04
Orthophosphate (mg/l)	0.01	0.11	0.00	0.00

Table 3.1 Results of physical and biochemical determinations

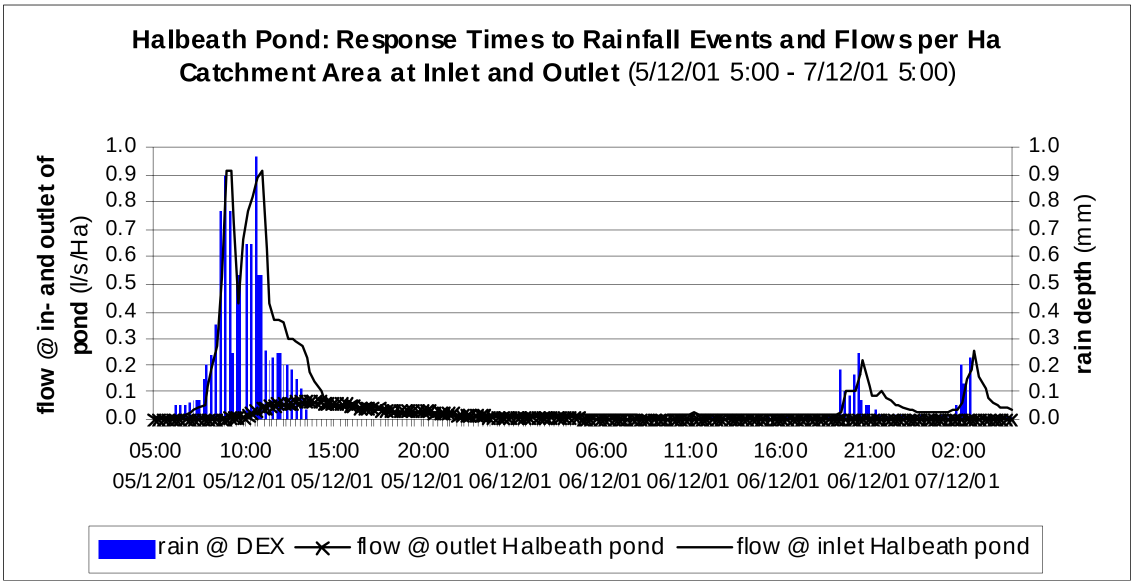


Figure 3.4 Comparison of flows at inlet and outlet at Halbeath Pond

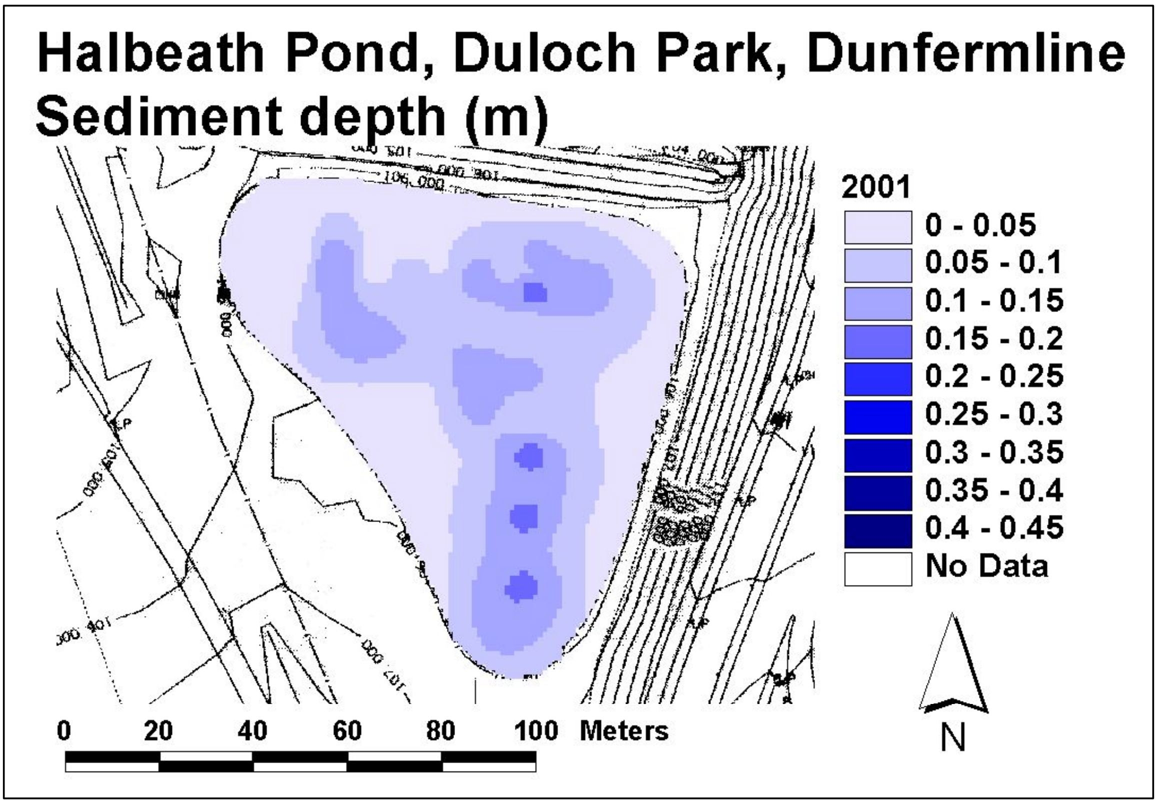


Figure 3.5 Halbeath Pond Sediment Accumulation 2001

Water Volume	4,600 m^3	Annual wet sed. input	16.2 m^3
Catchment area	13.5 Ha	Annual mass of sed. input	51 t
Area developed	70%	Current estimate for pond to fill	285 years

Table 3.2 Sediment accumulation details

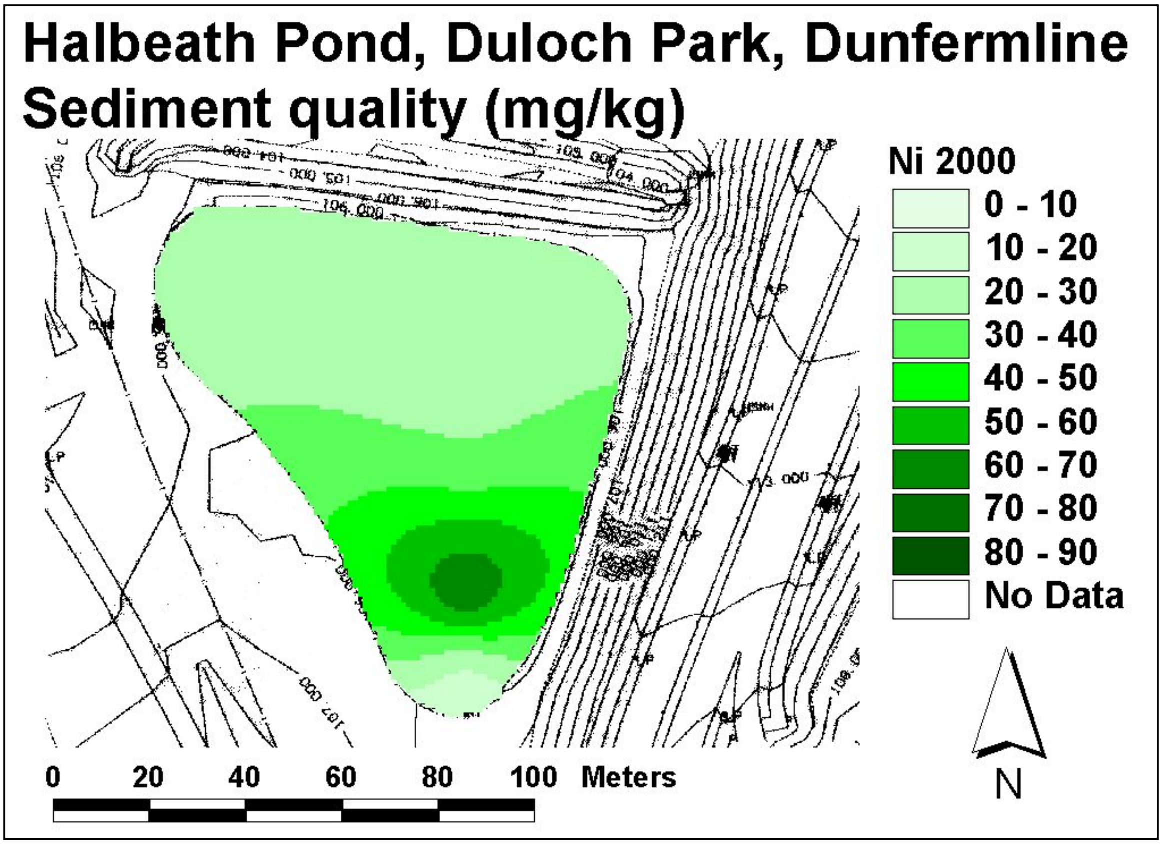


Figure 3.6 Halbeath Pond Sediment Quality - Nickel 2001

Metal	Cd	Cr	Cu	Ni	Pb	Zn
Con'n (mg/kg)	0.11	33.6	14.5	33.5	13.9	49.3
ICRLC Trigger Conc'n (mg/kg)	15	1000	130	70	2000	300

Table 3.3 Mean Heavy Metal Concentrations in Sediments in Halbeath Pond

(For greater detail see Heal K.V. & Drain S. Proc. 2^{nd} Int'l SUDS Conference, Coventry 2003)

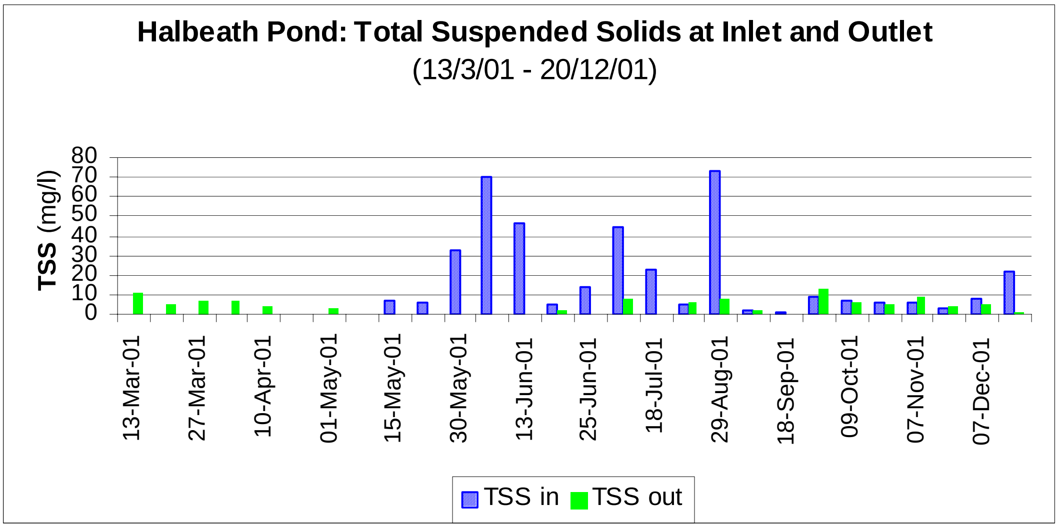


Figure 3.7 Comparison of Inlet and Outlet Concentrations (Typical)

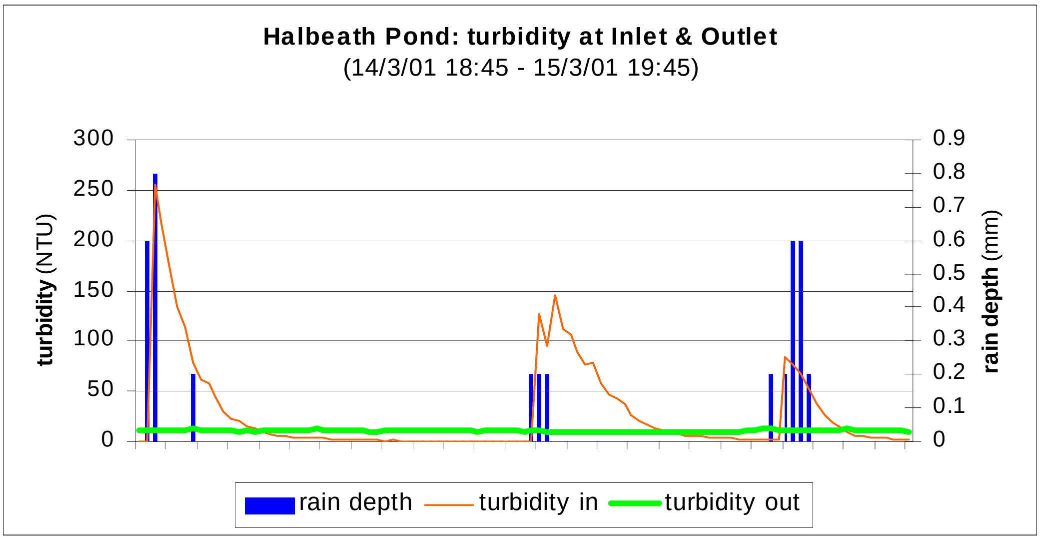
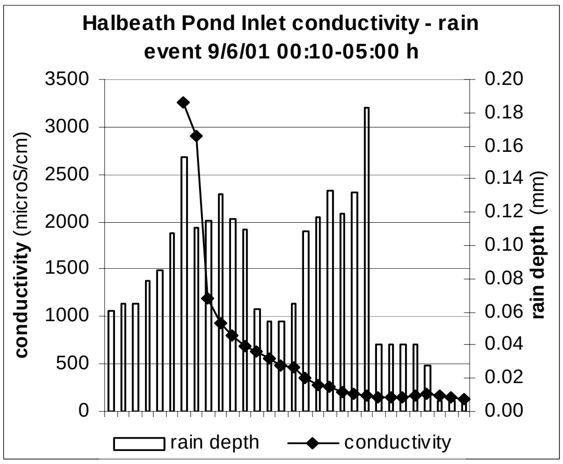


Figure 3.8 Typical inlet and Outlet Turbidities



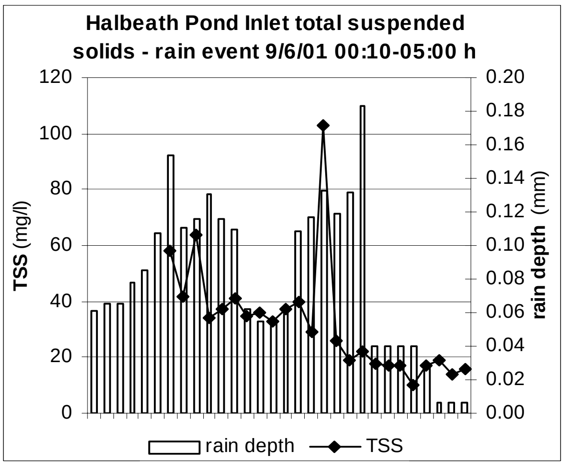


Figure 3.9 Inlet TSS and Conductivity During an Event

Table 3.4 List of macroinvertebrate taxa collected from Halbeath pond at Duloch Park, Dunfermline (Oct. 1999 – Oct 2002) showing their mean abundance and percentage of the total fauna (see note 4). (Thanks to Jill Lancaster and Wilcon Homes)

		1999 Mean	%[4]	2000 Mean	%[4]	2001 Mean	%[4]	2002 Mean	%[4]
CRUSTACEA									
Gammarus pulex	L.					0.1		34.4	21.1
Ostracoda (undet.)[1]						579.3	81.0		
Anostracea [2]								4.3	5.1
* *Asellus aquaticus*	L.								
MOLLUSCA									
Gastropoda									
Gastropoda (undet.)[1,4]		192.2	65.3	140.2	57.1				
Physa fontinalis	L.			0.6	0.5			0.3	0.3
Planorbus albus	Müller								
* *Planorbus planorbus*	L.								
Lymnaea stagnalis	L.	7.2	7.1	26.9	25.6				
Lymnaea peregra	Müller	47.4	46.5	7.8	7.4				
Lymnaea palustris	Müller					0.9		0.9	0.5
Potomopyrgus jenkinsi	Smith								
Bivalvia									
Pisidium sp.									
INSECTA									
Ephemeroptera									
Baetidea sp		1.0	1.0	18.3	17.4				
Cloeon dipterum	L.	3.0	3.0			118.7	16.6	35.0	22.3
Cloeon dipterum	L.								
* *Caenis horaria*	L.								
Odonata									
Ischnura elegans	Vander Linden	0.5	0.5	7.9	7.6	0.3		5.6	3.4
Pyrrhosoma nympula	Sulzer			0.2	0.2				
Hemiptera									
* Gerridae nymphs[1]								0.2	0.2
Notonecta maculata	Fabricus			0.1	0.1				
Corixinae nymphs[1]		0.2	0.2			0.2	<0.0	0.2	0.2
Sigara lateralis	Leach	0.9	0.9			0.1	<0.0		
Sigara concinna	Fieber	1.9	1.8			0.1	<0.0		
Sigara fossarum	Leach								
Sigara distincta	Fieber					0.3	<0.0		
Sigara dorsalis	Leach								
Sigara falleni	Fieber								

[1] Individuals too small/immature for accurate identification
[2] Species identification difficult and beyond the scope of this survey
[3] A conservative (minimum) estimate
[4] Calculated as % of total abundance excluding immature snails; immature snails calculated as % of total sample.

Table 3.4 (Continued)

		1999 Mean	%[4]	2000 Mean	%[4]	2001 Mean	%[4]	2002 Mean	%[4]
Hemiptera (cont.)									
Arctocorisa gemani	Fieber	0.6	0.5						
Corixa sp.		0.1	0.1						
Corixa punctata	Illiger					0.4	0.1		
Corixa dentipes	Thompson								
Corixa panzeri	Fieber								
Calicorixa praeusta	Fieber								
Trichoptera									
Limnephilidae sp.[1]		0.1	0.1	13.2	12.5	0.1			
Limnephilus politus	McLachlan								
Limnephilus marmoratus	Curtis								
Agrypnia obsoleta						0.4	0.1		
Phryganea bipunctata	Sulzer			0.3	0.3			0.9	0.6
Holocentropus picicornis	Stephens			0.2	0.2			0.1	0.1
Mystacides nigra	L.								
Coleoptera									
Hydroporus sp	L.	0.1	0.1	0.3	0.3				
Coelambus confluens	Fabricus	1.3	1.3						
Haliplus lineatocollis	Marsham	0.1	0.1						
Haliplus confinis	Stephens								
Haliplus fulvus	Stephens							0.1	0.1
Agabus nebulosus	Forster	0.1	0.1	0.8	0.7				
Hygrotus inaequalis	Fabricus							0.1	0.1
Potamonectes assimilis	Paykull								
Hyphydrus ovatus	L.								
Coleoptera larvae[2]		0.8	0.8	1.0	1.0	1.5	0.2	0.8	0.5
Megaloptera									
Sialis lutaria	L.							0.1	0.1
Diptera									
Chaoborus obscuripes	Wulp	15.8	15.5	8.2	7.8				
Ceratopogonidae[2]									
Tanypodinae sp.[2]								7.6	4.9
Chironomidae[2]		10.6	10.4	5.5	5.2	11.3	1.6	33.2	2.6
Chironomid pupae[2]								0.1	0.1
Tipulidae[2]				0.2	0.2				
Culicoides sp.[2]									
ACARINA									
Hydracarina[2]						0.1	<0.0	0.6	0.4
OLIGOCHAETA[2]				0.1	0.1	0.8	0.1	29.2	19.4
TRICLADIDA[2]								0.1	0.1
Total abundance		249.6		245.6		715		179.8	
above – snails		102.0		105.2		715		179.8	
Species richness		15		15		13		17	

[1] Individuals too small/immature for accurate identification
[2] Species identification difficult and beyond the scope of this survey
[3] A conservative (minimum) estimate
[4] Calculated as % of total abundance excluding immature snails; immature snails calculated as % of total sample.

Linburn Pond

Name	Linburn Pond	System	Retention Pond with five inlets
Serving	Mixed residential and commercial	Cont. Area	67.5 ha (Under development)
Hydrology	Rainfall, Level and flow at outlet (4 vee notches) Short periods at four inlets		
Period(s)	May 1999 – May 2003 (ongoing)	Events	Almost complete record at outlet
Quality	Outlet – Hydrolab Sonde; Epic Samplers; Weekly samples from main pond; inlets - target events.		
Period(s)	Separate periods throughout	Events	Target period May – June 2002
Comments	Comprehensive biology and social surveys. 5 year studies funded by Wilcon Homes		
Data Source	Data from Adolf Spitzer a.spitzer@tay.ac.uk or Chris Jefferies c.Jefferies@tay.ac.uk		

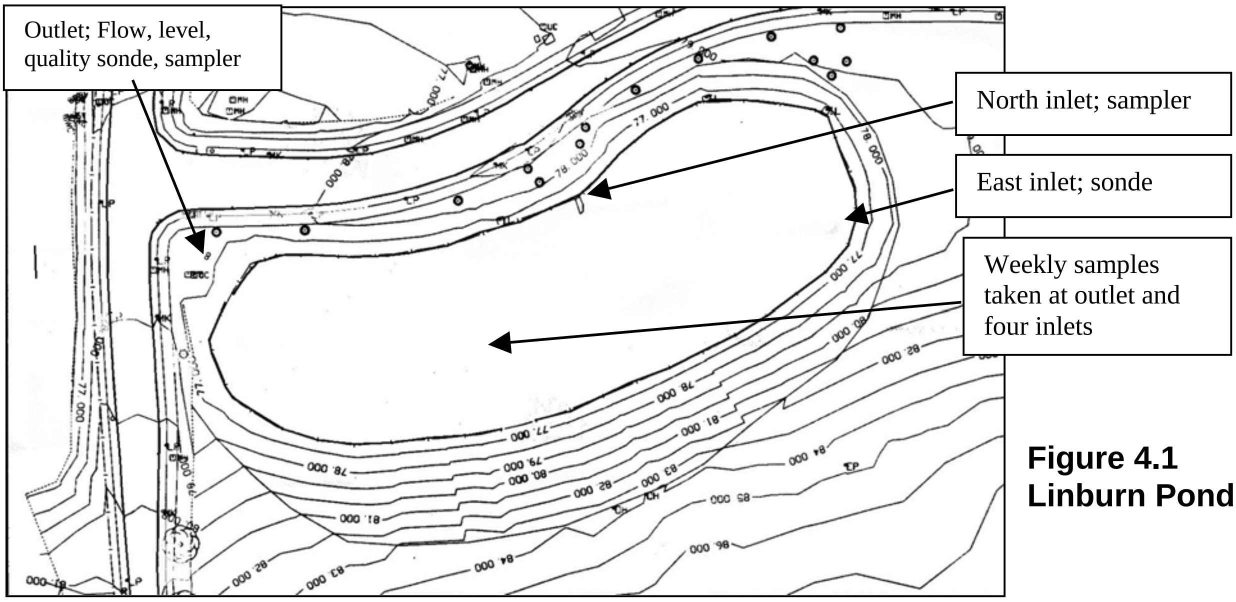


Figure 4.1 Linburn Pond

Linburn pond was constructed at the beginning of 1998. Aquatic planting was carried out during June and July 1998. There are four inlets and one outlet. All inlets draining development areas have detention basins upstream. The catchment area is 67.5 ha and there are six upstream detention basins interconnected by pipes. The surface area is ≈ 10,200 m^2 and the volume is 15,495 m^3.

Figure 4.2 Linburn Pond over a four year period

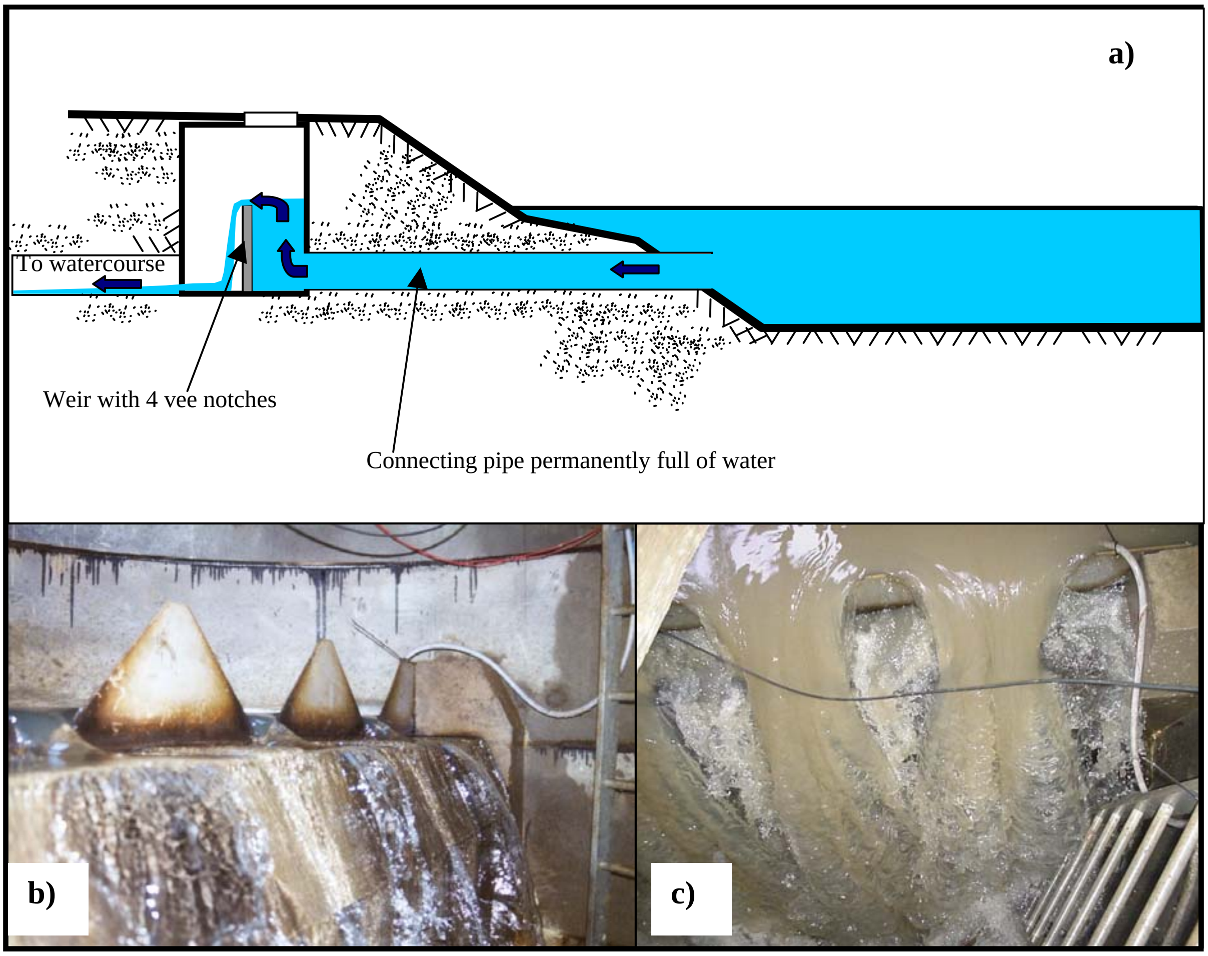


Figure 4.3 Linburn Pond Outlet Weir Details

a) Section through outlet pipe.

b) Three of the four vee notches during low flow conditions.

c) High flow over outlet weir from above.

The outlet control structure is located entirely underground in a large manhole. The chamber may be seen in Figure 4.3 a)

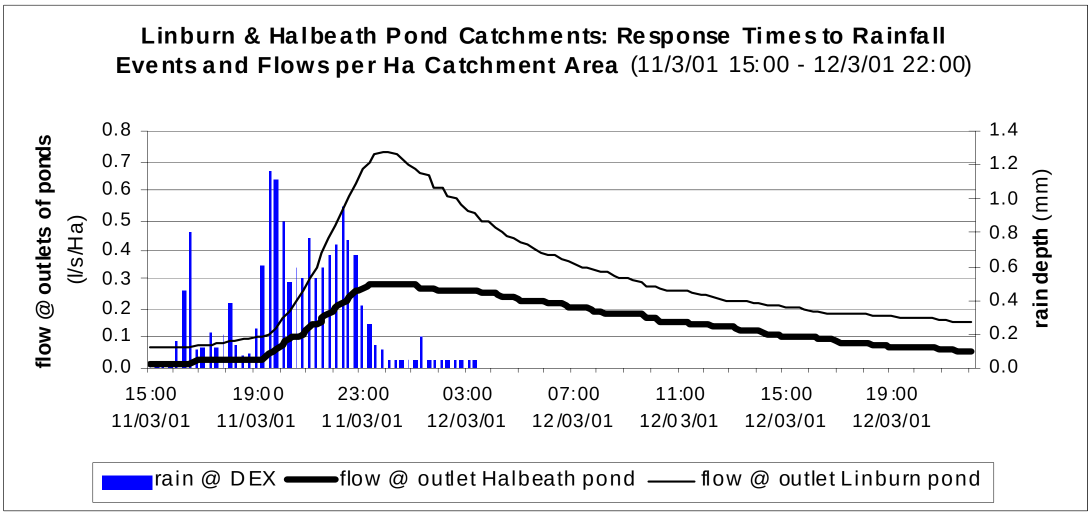


Figure 4.4 Flows at outlets of Linburn & Halbeath ponds showing flow attenuation

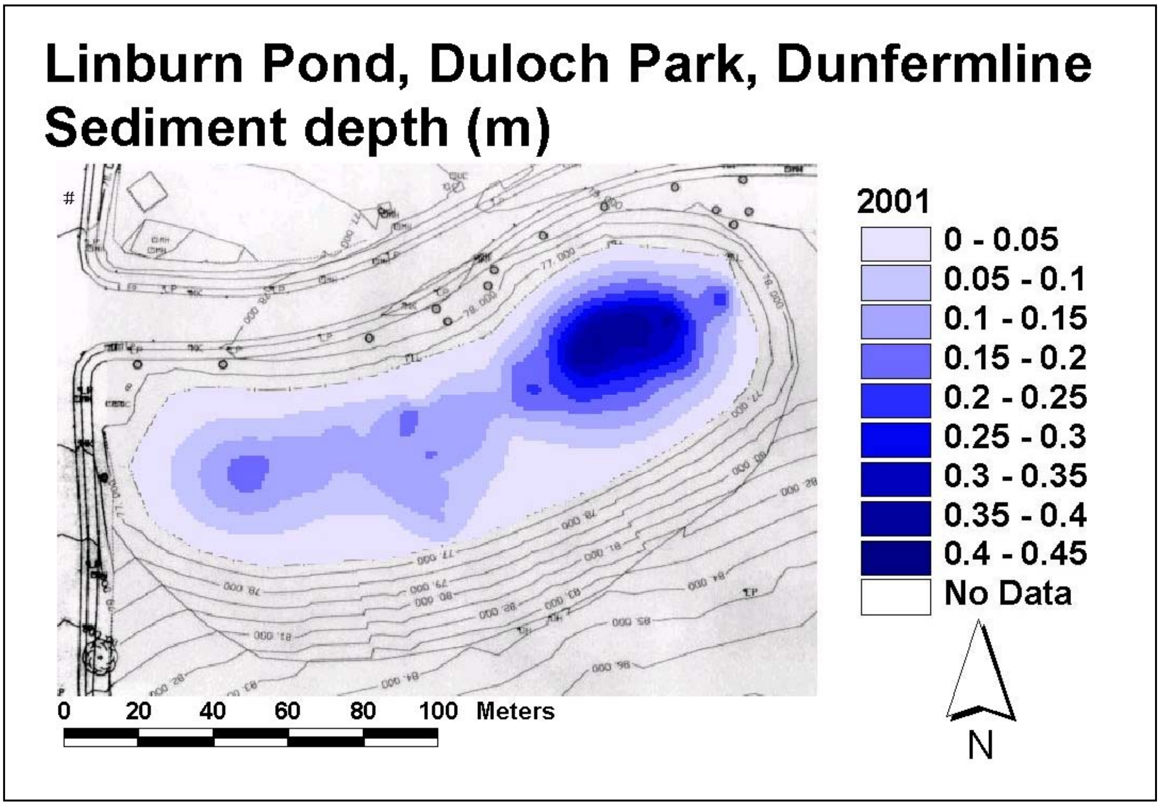


Figure 4.5 Sediment Accumulation 2001 (Thanks to Kate Heal and Wilcon Homes)

Water Volume	15,500 m^3	Annual wet sed. input	50.7 m^3
Catchment area	67.5 Ha	Annual mass of sed. input	126 t
Area developed	10%	Current estimate for pond to fill	305 years

Table 4.1 Sediment accumulation details

Metal	Cd	Cr	Cu	Ni	Pb	Zn
Con'n (mg/kg)	0.11	51.9	17.1	43.2	22.0	83.7
ICRLC Trigger Conc'n (mg/kg)	15	1000	130	70	2000	300

Table 4.2 Mean Heavy Metal Concentrations in Sediments in Linburn Pond

(For greater detail see Heal K.V. & Drain S. Proc. 2nd Int'l SUDS Conference, Coventry 2003)

This particular pond is likely to have relatively low rates of sediment input and deposition because all inflow passes through detention basins upstream apart from one site which was under development during monitoring.

Figures 4.6 and 4.7 are included to illustrate the consistency of the concentrations of the outflow from this pond. There are five separate inlets to the pond and it was not possible to monitor each. Consequently, the graphs are included to give typical concentrations of typical determinands at the outlet.

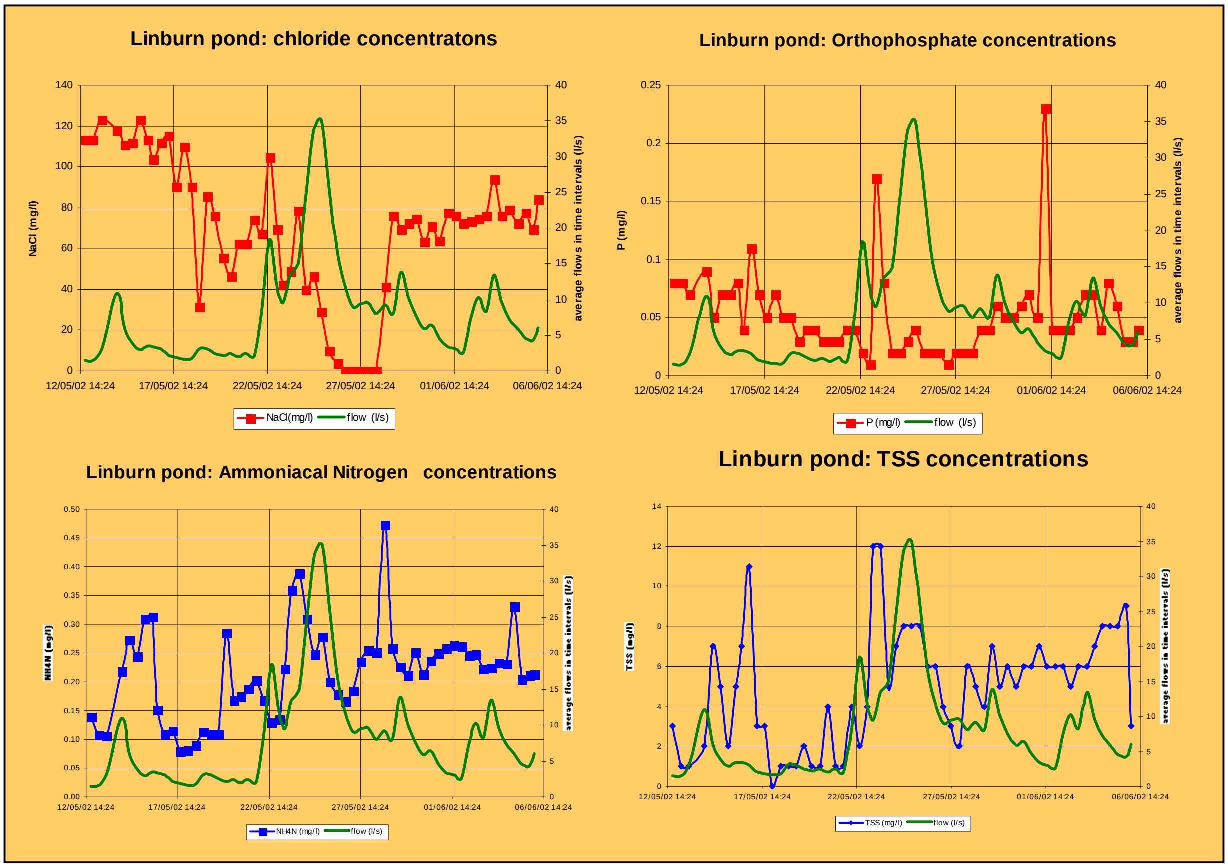


Figure 4.6 Linburn Pond Outlet - Flows and Concentrations during a four week period 12th May to 6th June 2002

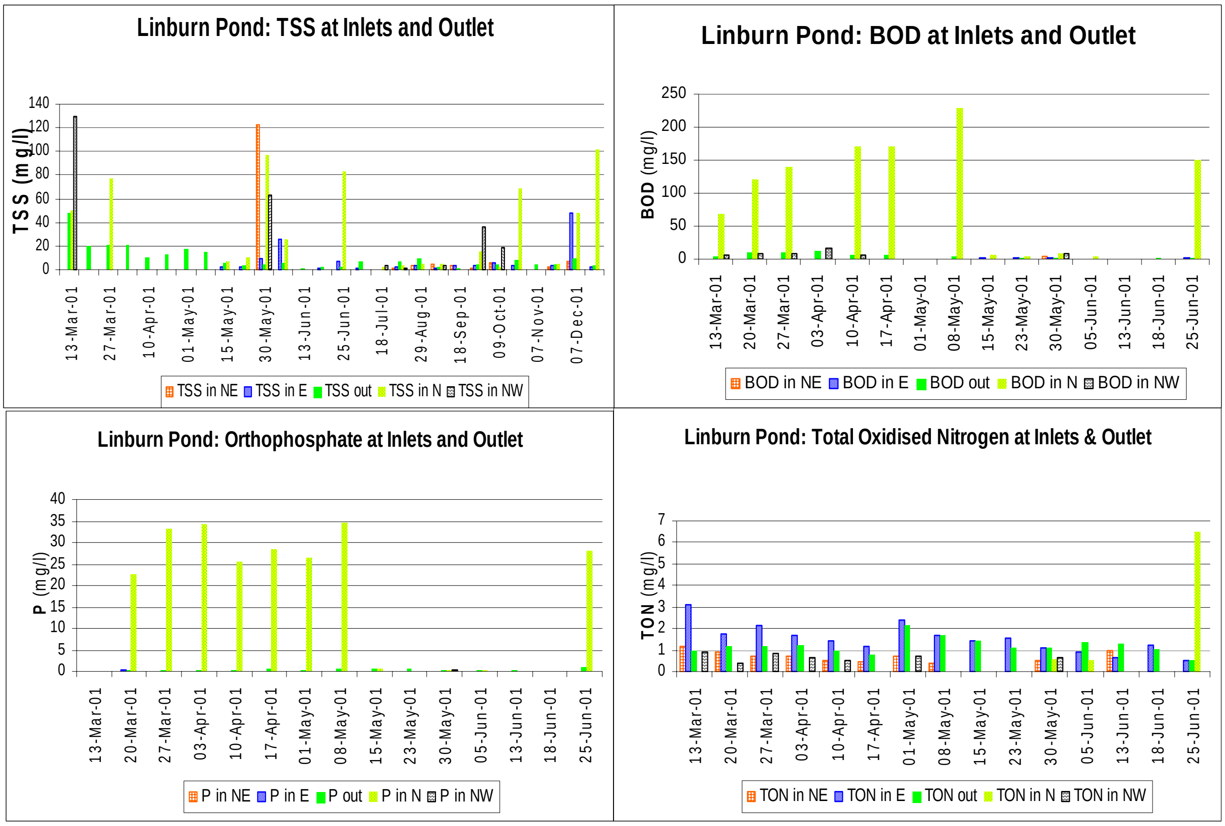


Figure 4.7 Linburn Pond Inlets and Outlet – Concentrations Measured from spot samples March – June 2001

Table 4.3 List of macroinvertebrate taxa collected from Linburn pond at Duloch Park, Dunfermline (Oct. 1999 – Oct 2002) showing their mean abundance and percentage of the total fauna (see note 4). (Thanks to Jill Lancaster and Wilcon Homes)

		1999 Mean	%[4]	2000 Mean	%[4]	2001 Mean	%[4]	2002 Mean	%[4]
CRUSTACEA									
Gammarus pulex	L.			30.7	7.9	295.4	24.2	284.7	78.6
Ostracoda (undet.)[1]						392.1	32.1		
Anostracea [2]								0.4	0.3
* *Asellus aquaticus*	L.								0.0
MOLLUSCA									
Gastropoda									
Gastropoda (undet.)[1,4]		20.3	19.4	292.5	75.0	11226	90.2	97.7	21.9
Physa fontinalis	L.	14.0	16.9	10.2	10.7	6.6	0.5	1.2	0.5
Planorbus albus	Müller	0.9	1.1	0.4	0.5	0.6	<0.0		0.0
* *Planorbus planorbus*	L.							1.6	0.6
Lymnaea stagnalis	L.			11.5	12.0				0.0
Lymnaea peregra	Müller	5.7	6.9	12.8	13.4	7.7	0.6	1.0	0.3
Lymnaea palustris	Müller					238.8	19.5		0.0
Potomopyrgus jenkinsi	Smith					201.3	16.5		0.0
Bivalvia									
Pisidium sp.				0.7	0.8	9.2	0.8	14.5	6.3
INSECTA									
Ephemeroptera									
Baetidea sp				2.4	2.5				
Cloeon dipterum	L.	10.8	13.1			6.6	0.5		
Cloeon dipterum	L.	5.9	7.1					1.8	0.7
* *Caenis horaria*	L.								0.0
Odonata									
Ischnura elegans	Vanderlinden			0.3	0.3			0.1	0.1
Pyrrhosoma nympula	Sulzer								0.0
Hemiptera									
* Gerridae nymphs[1]									0.0
Notonecta maculata	Fabricus			2.5	2.6				0.0
Corixinae nymphs[1]		6.7	8.1					0.1	0.1
Sigara lateralis	Leach	12.5	15.1	0.4	0.5				0.0
Sigara concinna	Fieber	0.1	0.2			0.5	<0.0		0.0
Sigara fossarum	Leach	0.6	0.8						0.0
Sigara distincta	Fieber					0.4	<0.0	0.3	0.2
Sigara dorsalis	Leach					0.1	<0.0	0.2	0.1
Sigara falleni	Fieber					0.1	<0.0		0.0

[1] Individuals too small/immature for accurate identification
[2] Species identification difficult and beyond the scope of this survey
[3] A conservative (minimum) estimate
[4] Calculated as % of total abundance excluding immature snails; immature snails calculated as % of total sample.

Table 4.3 (Continued)

		1999 Mean	%[4]	2000 Mean	%[4]	2001 Mean	%[4]	2002 Mean	%[4]
Hemiptera (cont.)									
Arctocorisa gemani	Fieber	0.2	0.3						0.0
Corixa sp.				0.4	0.5				
Corixa punctata	Illiger								0.0
Corixa dentipes	Thompson			0.6					0.0
Corixa panzeri	Fieber					1.3	0.1		0.0
Calicorixa praeusta	Fieber					2.0	0.2		0.0
Trichoptera									
Limnephilidae sp.[1]				0.4		0.1	<0.0		0.0
Limnephilus politus	McLachlan	0.1	0.2		0.7				0.0
Limnephilus marmoratus	Curtis								0.0
Agrypnia obsoleta				0.1	0.4				0.0
Phryganea bipunctata	Sulzer							0.1	0.1
Holocentropus picicornis	Stephens								0.0
Mystacides nigra	L.								0.0
Coleoptera									
Hydroporus palustris	L.					0.1	<0.0		0.0
Coelambus confluens	Fabricus								0.0
Haliplus confinis	Stephens							0.1	0.1
Haliplus fulvus	Stephens								0.0
Agabus nebulosus	Forster			0.1	0.3				0.0
Hygrotus inaequalis	Fabricus								0.0
Potamonectes assimilis	Paykull								0.0
Hyphydrus ovatus	L.								0.0
Coleoptera larvae[2]		6.7	8.1	0.3	0.6	1.2	0.1	2.1	0.7
Megaloptera									
Sialis lutaria	L.							0.3	0.2
Diptera									
Chaoborus obscuripes									0.0
Ceratopogonidae[2]								0.3	0.1
Tanypodinae sp.[2]								1.0	0.4
Chironomidae[2]		8.0	9.7	10.0		7.5	0.6	15.6	2.1
Chironomid pupae[2]									0.0
Tipulidae[2]				0.1	14.9				0.0
Culicoides sp.[2]									0.0
ACARINA									
Hydracarina[2]						0.4	<0.0		0.0
OLIGOCHAETA[2]				1.5		8.1	0.7	13.0	4.5
HYRUDINEA									
Glossiphonia complanata								0.3	0.1
Helobdella stagnalis				0.5	0.6	0.2	<0.0		0.0
TRICLADIDA[2]						41.3	3.4	4.3	2.3
Total abundance		104.4		390.1	2.9	12448		459.9	
above – snails		82.7		95.7	327.7	1221.7		359.9	
Species richness		12		14		21		18	

[1] Individuals too small/immature for accurate identification
[2] Species identification difficult and beyond the scope of this survey
[3] A conservative (minimum) estimate
[4] Calculated as % of total abundance excluding immature snails; immature snails calculated as % of total sample.

Stenton Pond, Glenrothes

Name	Stenton Pond, Glenrothes	System	Converted flood relief basin
Serving	Residential area with separate system.	Cont. Area	127 Ha.
Hydrology	Rainfall, Flow monitors on 2 inlets, level monitor on outlet for periods		
Period(s)	April 1998 – May 1999	Events	Numerous. A small number analysed
Quality	Epic samplers & sondes at inlets and outlet (pH, Cond, NH_4, DO, Turbidity). Baseline sampling		
Period(s)	Discrete periods June 1998 – Jan 1999	Events	Five sampled; several recorded (sondes)
Comments	Sewage contamination, north inlet; Funded by the Carnegie Trust & Scottish Water		
Data Source	Data from Kirsteen Macdonald k.macdonald@ewan.co.uk		

Stenton Pond and Environs

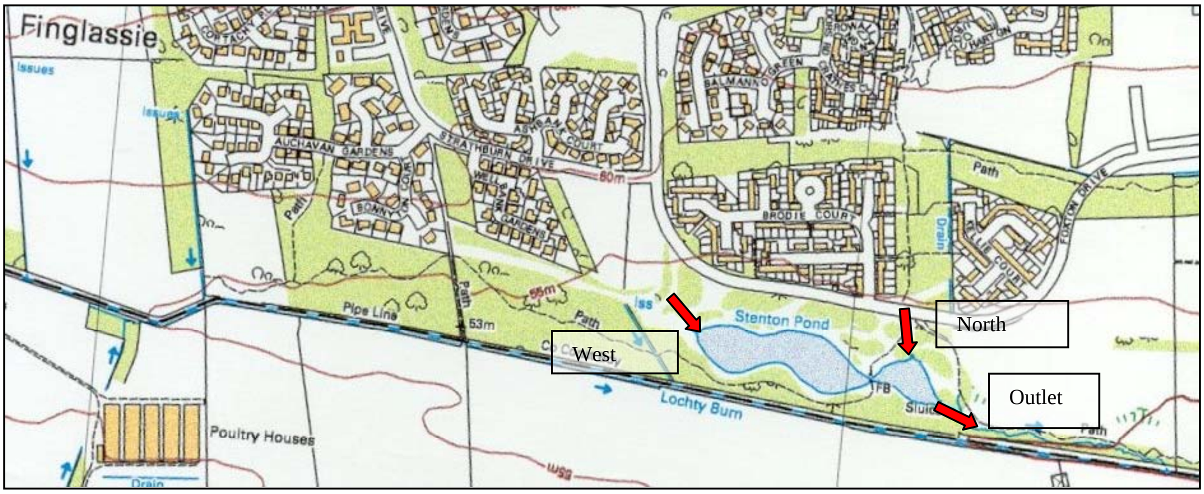


Figure 5.1 Stenton Pond Location

Stenton Pond has a permanent volume of 9000m^3 with an additional 4500m^3 storage for flood attenuation. The pond was designed as a flood detention basin in the 1970's to give flow attenuation for the Glenrothes New Town and was later converted to have a permanent pool for water quality protection. There is a well established habitat in and around the Pond, which in conjunction with the landscaping and shape of the pond results in a high amenity value. Algal blooms are occur annually. The shape of the pond leads to significant potential for short circuiting of flows. There are two inlets (west & north), both of which periodically receive amounts of foul sewage via combined sewer overflows.

Several monitoring programmes have been carried out at Stenton Pond. This has included routine baseline sampling for an extended period, and targeted periods to monitor specific events. Data are presented on an event by event basis since this best illustrates the pond performance.

Figure 5.2 Stenton Pond in Winter

Baseline Sampling

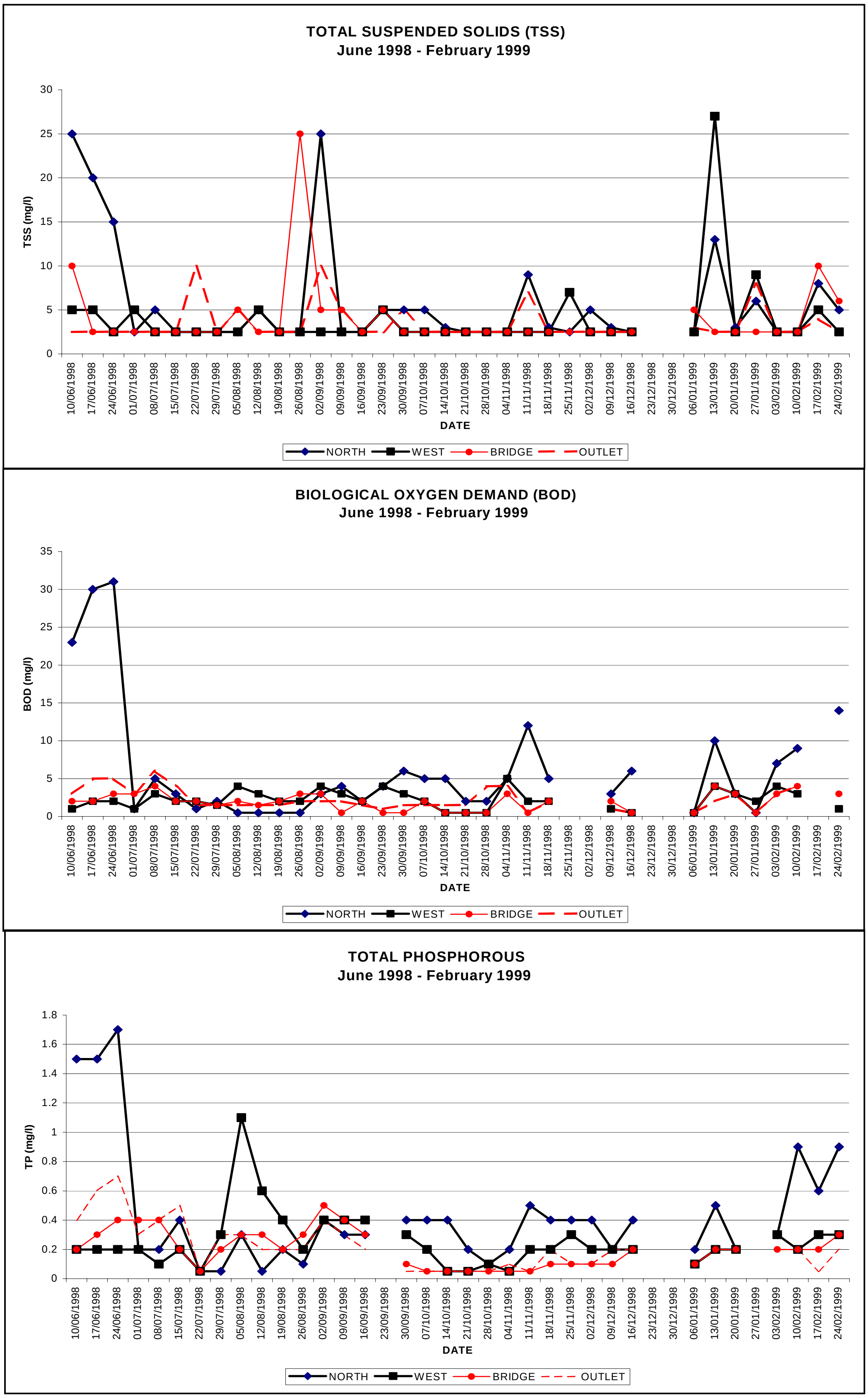


Figure 5.3 Stenton Pond – Routine Monitoring Results

Event of 19 – 20 July 1999

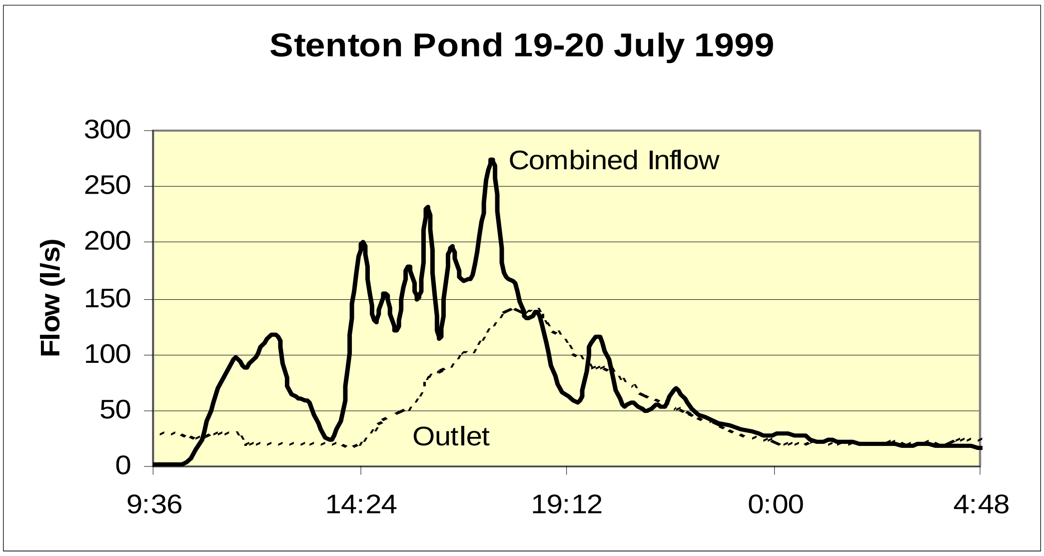


Figure 5.4 Flows During event of 19-20 July 1999

The flow from both inlets follows the same pattern, the flow from the north inlet being greater. The total rainfall was 18.2mm with a peak intensity of 6mm/h. For the period shown on the graph the inflow volume was 5200m^3, peaking at 293 l/s and the outflow was approximately 3500 m^3, peaking at 140 l/s illustrating the flow attenuation.

19-20 July	Cadmium µg/l			Copper µg/l			Lead µg/l			Zinc µg/l			Chromium µg/l			Nickel µg/l		
	N	W	O	N	W	O	N	W	O	N	W	O	N	W	O	N	W	O
11:00	1	2	1	16	15	14	6.3	26.5	9.4	27	80	42	1.8	9.4	3.9	2.1	10.1	5
12:00			1			16			14.1			57			4.6			6.1
13:00	5			20			20.7			40			5			1.9		
15:00		1			9.2			9.6			41			2.1			1.6	
17:00			1			14			3.1			17			0.5			1
22:00	1	2		25	9		4.2	8.7		29	32		3	3.1		3	2.8	
02:00	2	1	1	27	11.9	24	3.4	6.4	2.3	30	39	31	2.6	3.7	1.1	2.7	2.4	1.7

Table 5.1 Heavy Metals Concentrations During Event of 19 – 20 July 1999

Parameter		Total Suspended Solids	Biological Oxygen Demand	Ammoniacal Nitrogen
EMC (µg /l)	Inlet	15.15	4.2	0.14
	Outlet	15.2	2.3	0.33
Red./ Inc. (-/+)		+0.3%	-45.2%	+136%
Load (g)	Inlet	72431	20063	910
	Outlet	12670	1944	279
Red./ Inc. (-/+)		-82.5%	-90%	-69%

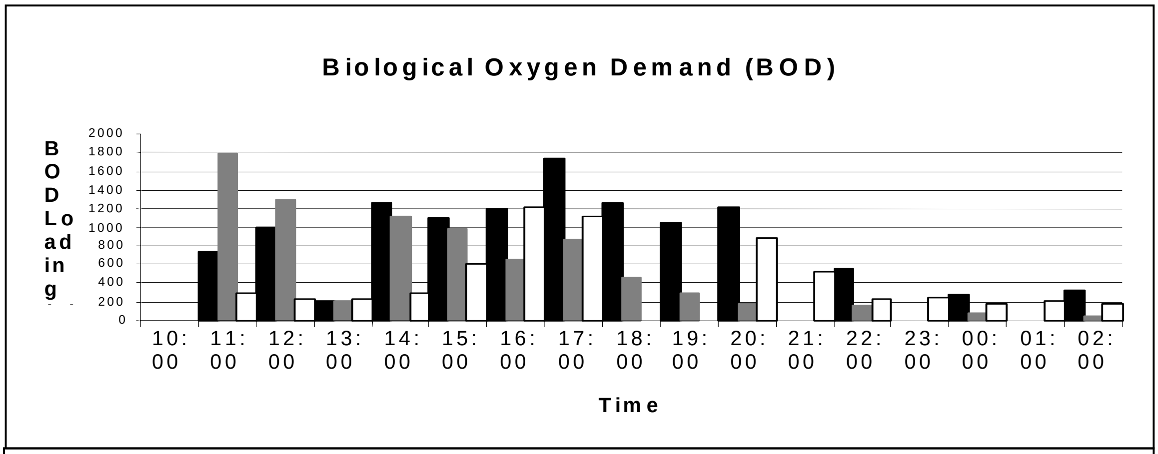
Table 5.2 Physical – Chemical Parameters

EMC for TSS remained almost the same at the outlet, BOD was reduced and Ammoniacal Nitrogen increased. However, the pollutant loads were all significantly reduced.

Parameter		Cadmium	Chromium	Copper	Nickel	Lead	Zinc
EMC (µg /l)	Inlet	2.2	3.74	16.12	2.9	12.25	40
	Outlet	1	1.16	16.4	1.8	4.27	24.96
Red./ Inc. (-/+)		-54.5%	-69%	+1.7%	-38%	-65%	-37.6%
Load (g)	Inlet	12.2	18.7	89.8	13.6	60.8	189.6
	Outlet	3.1	3.6	51.2	5.6	13.4	77.9
Red./ Inc. (-/+)		-74%	-81%	-82%	-87%	-93%	-87%

Table 5.3 Heavy Metals Loadings

EMC for Cu remained almost the same at the outlet, however all other metal concentrations were reduced. The metals loads were all significantly reduced.



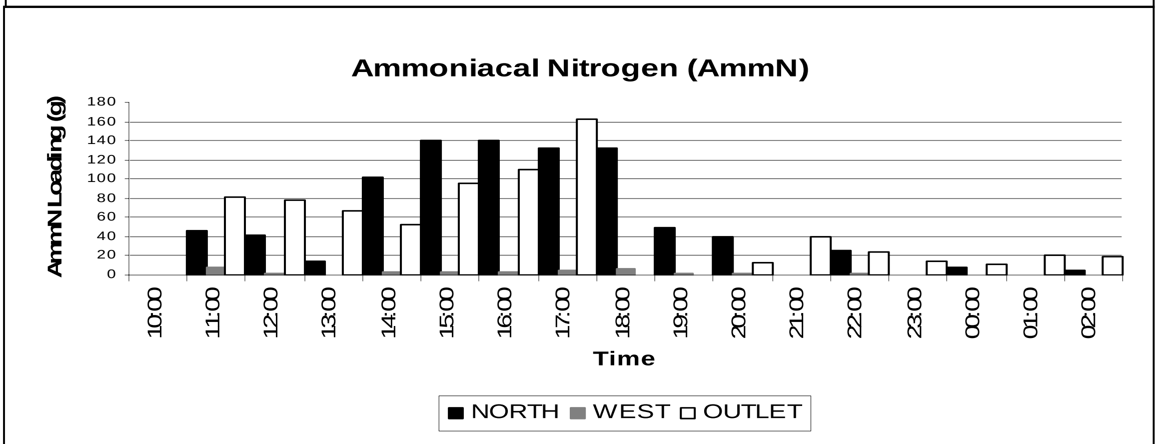
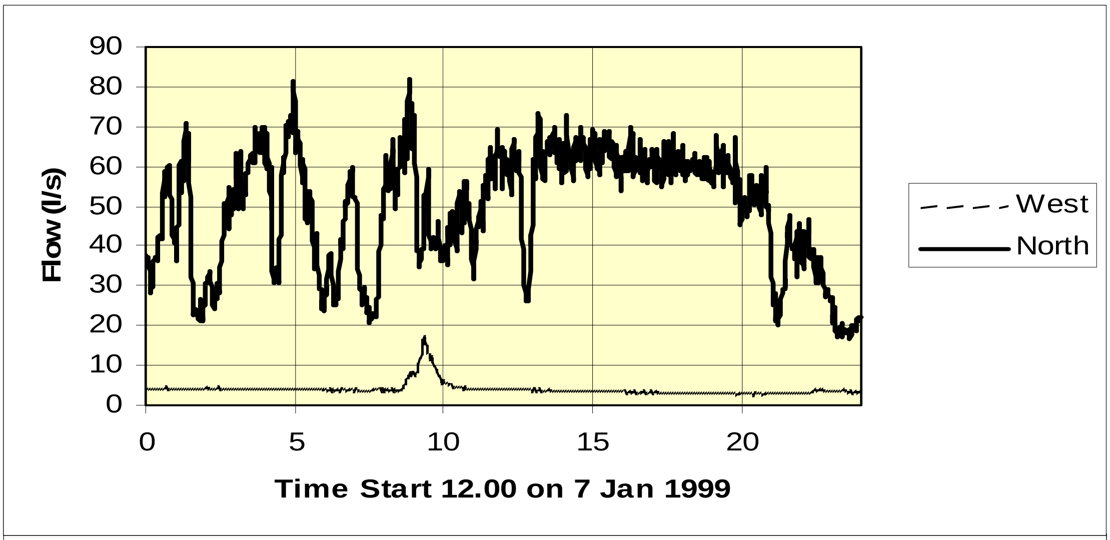
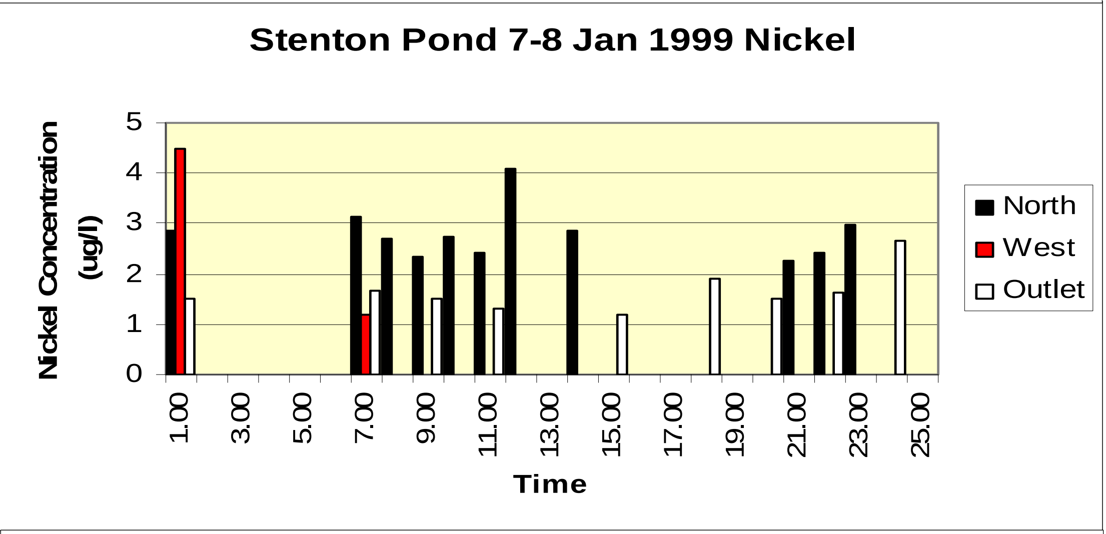


Figure 5.5 Water Qualities Event of 19 – 20 July 1999

Event of 7 Jan 1999

Heavy Metals concentrations were monitored during this event. The inflow hydrographs indicate a problem with the north inflow which was probably due to a malfunctioning combined sewer overflow.





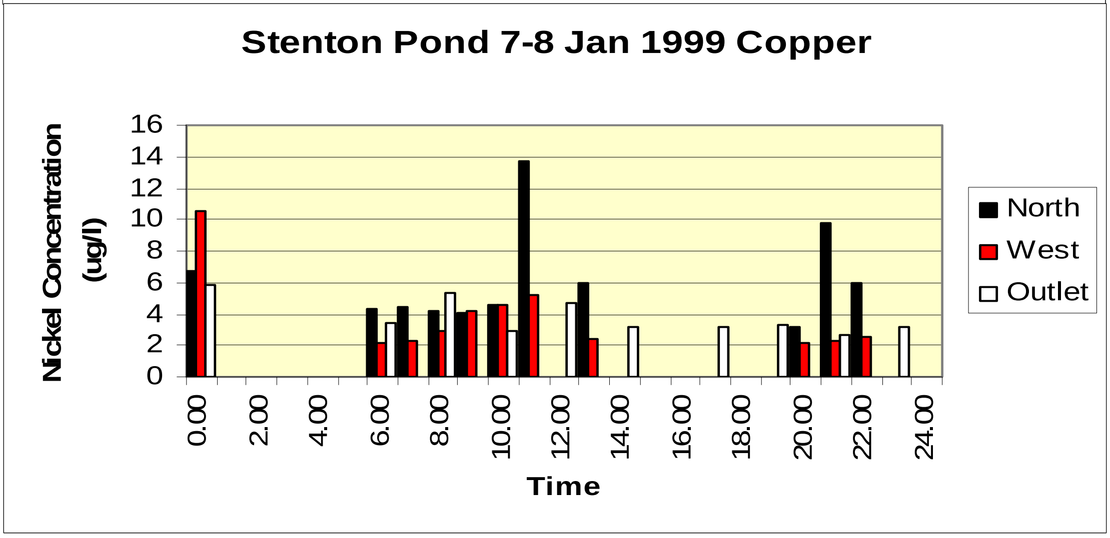


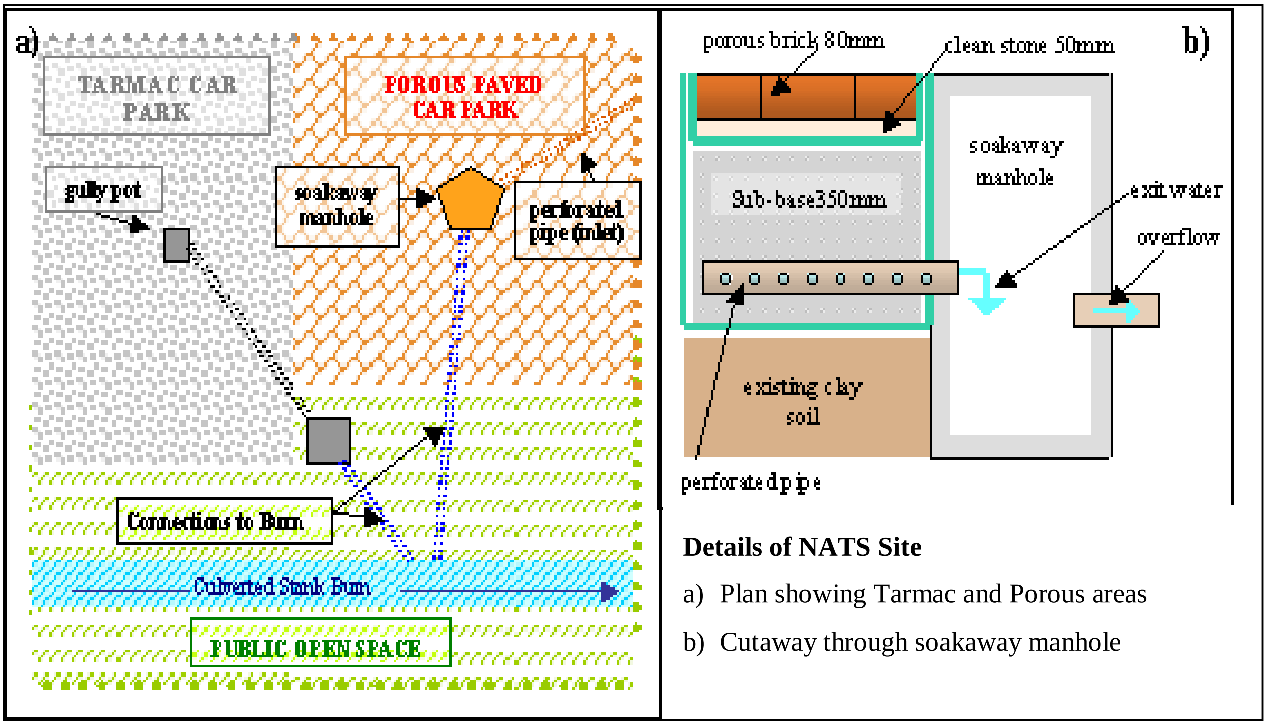
Figure 5.6 Observations During event of 7-8 Jan 1999

Scottish SUDS Monitoring Group

SUDS Performance Data Summary Sheet No. 6

NATS (Edinburgh)

Name	National Air Transport Services	System	Porous Paved Car Park (+asphalt)
Serving	Car Park extension	Cont. Area	1401 m^2 (+442 m^2)
Hydrology	Rainfall, tipping bucket flow monitors		
Period(s)	Apr 98 – Feb 99 & May – Aug 2000	Events	153 (min 2.5mm and 6h between)
Quality	Solomat sondes and Epic samplers on both tarmac and porous outflow		
Period(s)	Oct – Dec 1998; Feb – April 1999	Events	20 (various determinants)
Comments	Studies funded by The Carnegie Trust & SNIFFER		
Data Source	Data from Kirsteen Macdonald k.macdonald@ewan.co.uk		



Details of NATS Site

a) Plan showing Tarmac and Porous areas

b) Cutaway through soakaway manhole

Description

The Formpave car park at NATS was constructed as an extension of an existing tarmac car park. The underlying ground is of low permeability and little exfiltration is possible. Hydrological performance is shown in table 6.1. From a total of 145 rainfall events of 0.8mm or more (mean rainfall required to produce runoff at tarmac), only 58 produced outflow from the porous paved car park i.e. preventing runoff from 60% of the rainfall events. The effectiveness of the system was demonstrated during heavy rain on 26 April 2000, when many surrounding areas were flooded but there was no surface water on the permeable paving system.

Photographs of NATS Site

Details of NATS Site

a) Porous Paving Extension

b) Tarmac Original Car Park (same day as(a))

c) Porous Paving in Winter

Typical event monitored at NATS

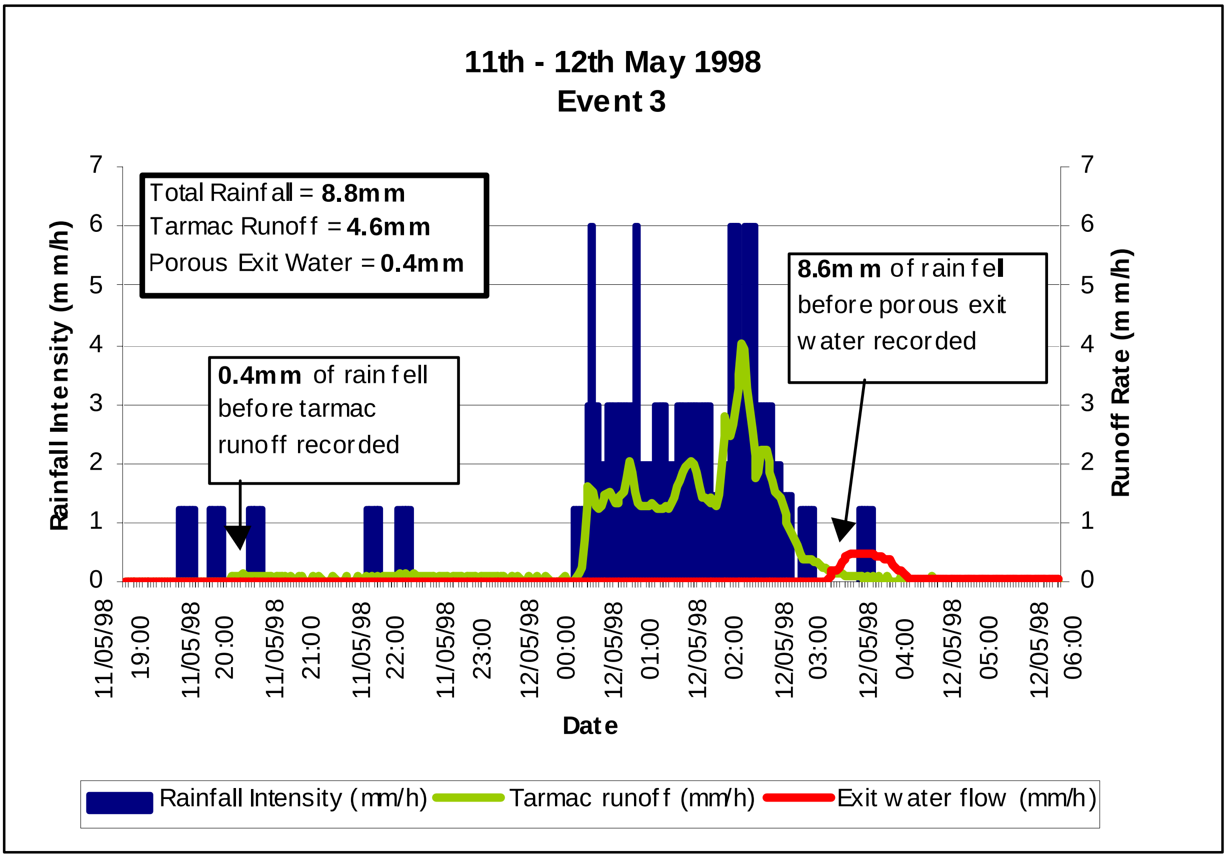


Table 6.1 Key hydrological parameters for NATS car park

	Percentage Outflow		Benefit Factor	Lag Time		Peak Flow Reduction			mm rain before runoff	
	Tarmac	Porous		Tarmac	Porous	Tarmac	Porous	% reduction	Tarmac	Porous
Min	21.4	2.5	6.5	-158	29	0.93	0.05	23.7	0	3.6
Max	72.8	66	91.2	123	600	17	3.3	98.4	2.6	18.6
Mean	**48.2**	**21.7**	**64.2**	**9.3**	**181.5**	**5.17**	**1.1**	**76.8**	**0.76**	**7.4**

Water quality results are given in table 6.2. Both sites monitored show relatively good water qualities resulting in some apparent reduction of quality. The EMC reduction of turbidity was –24% from the sondes and –32% for TSS from EPIC samples. The TSS load, per m^3, was 53.2% less from the porous than the tarmac car park.

Table 6.2 Water quality parameters – from samples collected

Parameter		**pH**	**Cond.**	**TSS**	**BOD**	**TON**	**o-phos**	**Chlor.**	**AmmN**
Unit			µS/ cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Average	Tarmac	6.7	49	35	4.3	0.7	0.03	8.3	0.2
	Porous	8	315	17	1.9	0.9	0.15	24.4	0.34
Range of EMCs	Tarmac	6.4–6.85	41-62	15.8-51	2.8-5.8	0.15-1.42	0.02-0.04	6.5-10.9	0.03-0.48
	Porous	7.73–8.2	210-416	9.8-24	1.2-2.6	0.36-1.36	0.05-0.53	5.1-57.6	0.03-1.13
EMC Red./ Inc. (-/+)		+1.4	+822%	-32%	-49%	+165%	+159%	+389%	-32%

Heavy metals concentrations are shown in table 6.3. There is excellent comparison with surface water environmental quality standards. Heavy metals concentrations are higher than for RBS site. It is suspected that this is due to the sub grade material used in construction.

Table 6.3 NATS outflow Key heavy metals concentrations

		Cd	**Pb**	**Cr**	**Cu**	**Ni**	**Zn**	**Hydrocarbons**
		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	mg/l
Outflow NATS (EMC)	min	0.12	0.93	3.85	3.76	0.95	17	0.15
	max	5.33	24.3	8.73	23.07	8.69	67	0.47
	mean	1.91	9.8	5.73	10.9	3.78	42	1.21
EQS 2	max	5	50	150	1	50	75	-
Service Reservoir	mean	<0.1	7.6	<1.7	23	0.6	8.2	-

Design Data
Treatment volume; Vt equates to 16.45m^3
Pore space volume of sub-base is approx. 98m^3, thus Vt is effectively only 60mm of the sub-base.

CIRIA (2001) guidance:	Sub-base >	450mm	time to half empty = 24-48 hrs
NATS monitored:	Sub-base	350mm deep	time to half empty = approx.3.5hrs.

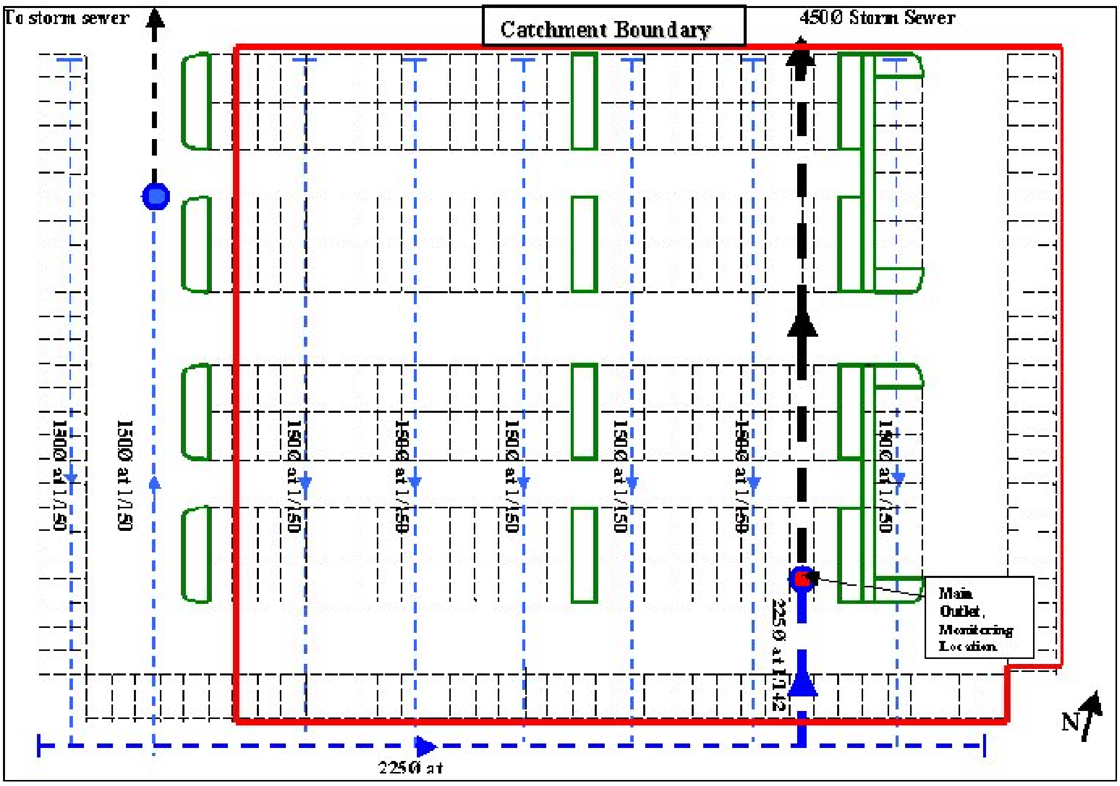
Scottish SUDS Monitoring Group

SUDS Performance Data Summary Sheet No. 7

Royal Bank of Scotland - South Gyle (Edinburgh)

Name	Royal Bank of Scotland	System	Porous paving car park
Serving	Car parking for employees	Cont. Area	0.62 Ha (306 car spaces)
Hydrology	Rainfall; Vee notch on outlet with Montec logger with ultrasonic depth measurement backup.		
Period(s)	February – August 2000	Events	Sixteen events
Quality	Outflow only - Epic autosamplers triggered by rise in level at vee notch. Periodic grab samples		
Period(s)	July – August 2000	Events	Seven events + spot samples
Comments	Base of system is lined. Studies part funded by FormPave Ltd.		
Data Source	Data from Wolfram Schlüter – w.schlueter@tay.ac.uk		

RBS Drainage Layout



This is a large car park for an office complex. There is a high water table in the area and the whole system was lined to prevent hydraulic contact with groundwater. Flows were monitored for 6 months from 16th February to 10th August 2000 and outflow quality from 5th June until 10th August 2000. Flow was monitored during sixteen events and samples were obtained during four events.

Hydrology

Typical hydrograph from the study site

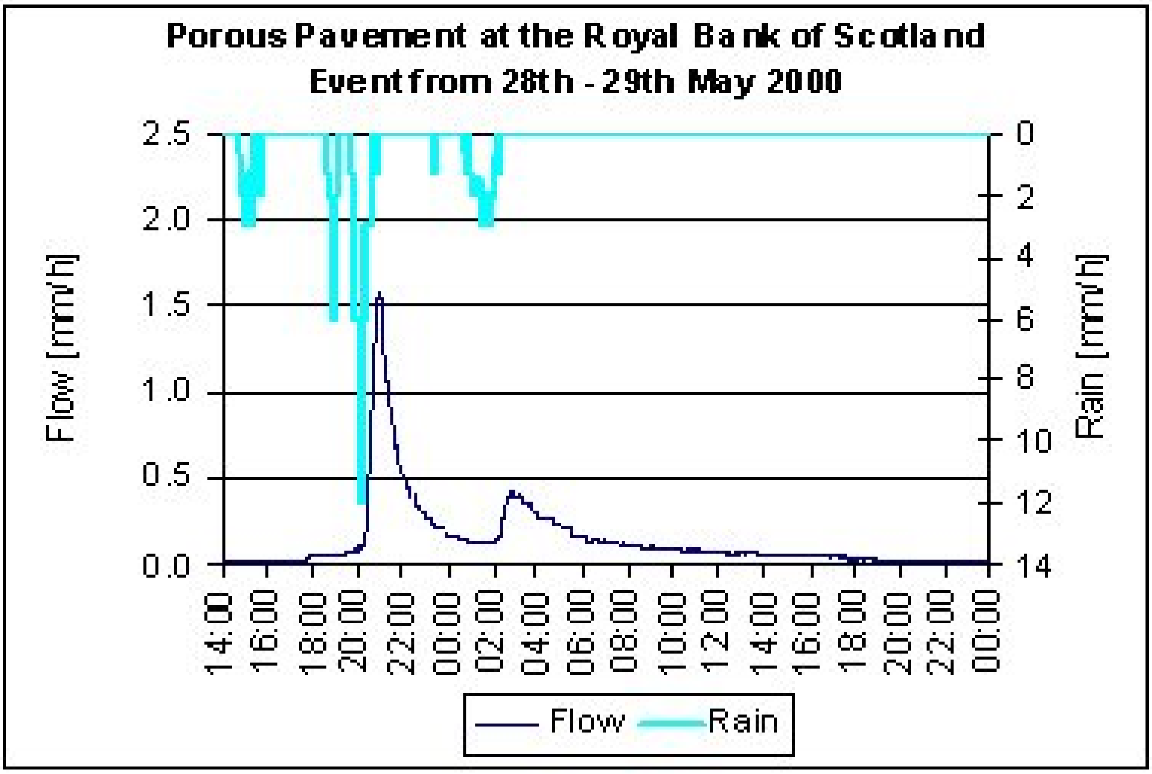
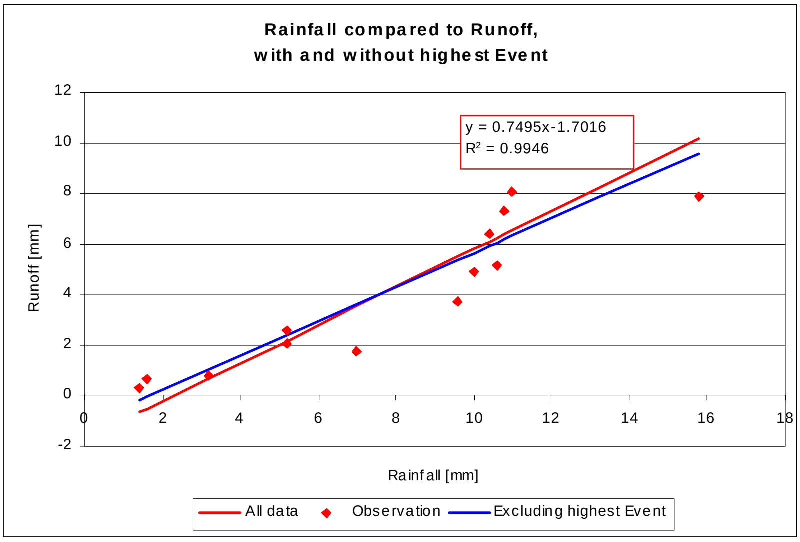


Table 7.1 Data obtained from Outflow Monitoring

No	Rain Event Start	Rain Event End	Duration	Recorded Rain		Recorded Flow	API5	Percentage Outflow**
	[dd/mm/yy hh:mm]	[dd/mm/yy hh:mm]	[h]	[mm]	[m³]	[m³]		[%]
1	25/04/00 03:36	26/04/00 22:50	43:19	99.6	460.2	337.9	3.65	76.2
2	15/05/00 12:12	15/05/00 13:08	0:56	3.2	14.8	2.1	0.02	14.2
3	17/05/00 02:58	17/05/00 12:34	9:36	10.4	48.0	17.0	1.90	35.4
4	27/05/00 01:06	27/05/00 15:52	14:46	10.6	49.0	23.9	1.22	48.7
5	28/05/00 14:56	29/05/00 02:18	11:22	10.0	46.2	22.7	4.12	49.1
6	01/06/00 15:06	01/06/00 15:50	44:00	1.4	6.5	1.5	0.43	23.2
7	03/06/00 23:00	04/06/00 12:26	13:26	15.8	73.0	36.5	0.73	50.0
8	06/06/00 08:08	06/06/00 16:14	8:06	10.8	49.9	33.8	4.12	67.0
9	09/06/00 13:20	09/06/00 17:32	4:12	5.2	24.0	9.4	2.94	39.2
10	10/06/00 21:58	10/06/00 23:08	1:10	1.6	7.4	2.7	3.85	36.5
11	09/07/00 09:54	09/07/00 14:56	5:02	13:2	61.0	48.5	6.95	79.5
12	09/07/00 20:10	10/07/00 01:14	5:04	11.0	50.8	37.4	16.54	73.6
13	31/07/00 10:06	31/07/00 13:00	2:54	9.6	44.4	17.2	1.21	38.7
14	01/08/00 02:48	01/08/00 07:50	5:02	5.2	24.0	9.5	8.40	39.5
15*	02/08/00 15:14	02/08/00 17:24	2:10	28.0	129.4			
16	09/08/00 05:26	09/08/00 13:42	8:16	7.0	32.3	6.9	0.80	25.8
*Event exceeded monitoring range of V-Notch weir ** Total Volume at outlet as a percentage of rainfall on the area							Average	46.5

Key hydrological results are: Average percentage outflow of just under 50%; lag times of 45 minutes for medium and 145 minutes for small events and; initial rainfall capacity in the order of 1.65mm. The antecedent precipitation index API_5 shows that the porous pavement is heavily influenced by antecedent conditions.



Water Quality Results and Analysis

The salient features of the water analysis are outlined in table 7.2. pH results show that the outflow was always slightly alkaline and there is very little variation of pH. Total suspended solids were generally higher during events than from spot samples. The maximum TSS concentration was 16.1 mg/l from spot sampling in comparison to 68 mg/l during events and this may be due to the flush effect during increased flows. BOD values were generally very low, around 2 mg/l, and ammoniacal nitrogen values were similar. One extreme nitrogen result was obtained during the peak of event 8 with a maximum concentration of 0.57 mg/l, whereas other results indicate nitrogen concentrations of 0.02 mg/l.

Table 7.2 Water quality result for sanitary parameters

Start & End Time of Sampling		**06/06/00 11:00 - 07/06/00 10:30**			**09/07/00 19:30 – 09/07/00 23:00**			**09/08/00 11:30 - 10/08/00 11:00**			**Spot Sampling**		
		Event 8			**Event 12**			**Event 16**					
		min	max	mean	min	max	mean	min	max	mean	min	max	mean
pH	[-]	7.8	8.2	8.0	8.1	8.2	8.1	7.9	8.6	8.1	7.4	8.2	8.0
Conductivity	[uS/cm]	281	615	447	550	581	553	365	929	541	358	730	544
TSS	[mg/l]	6.6	39.9	23.2	3.7	8.2	6.0	0.0	68.0	11.6	1.0	16.1	8.2
BOD	[mg/l]	1.6	3.0	1.96	3	10	4.38	2	2	2	0.7	3	2
NH4N	[mg/l]	0.03	0.57	0.11	0.04	0.06	0.05	0.02	0.20	0.10	<0.02	0.04	0.03
Ox-Nitrogen	[mg/l]	1.05	2.04	1.58	2.75	3.02	2.92	1.23	1.23	1.48	1.15	2.15	1.53
O-phos	[mg/l]	0.05	0.23	0.14	0.04	0.11	0.07	0.02	0.24	0.06	0.01	0.04	0.03
Chloride	[mg/l]	13.5	32.7	23.8	20.2	24.3	21.8	6.4	42.6	20.0	8.5	34.9	24.8
No of Samples	[-]	22			5			42			9		

Hydrocarbons

Results from the event of 31st July show hydrocarbons concentration between 0,375 and 3.35 mg/l, in contrast to results from event 9th August which resulted in concentrations below the detection limit (<0.1 mg/l). Table 7.3 gives details of the hydrocarbons results obtained. One reason for the great difference between events 13 and 16 might be the difference of the flow pattern. Event 13 produced a maximum outflow of 2.9 l/s in comparison to 0.7 l/s produced by event 16. The increased flow of event 16 most likely resulted in a flush effect and is more likely to be representative of event based behaviour.

Spot sampling and hydrocarbon analysis was carried out on six occasions and the results from four spot samples resulted in hydrocarbon levels below the detection limit. One hydrocarbons concentration was just above the detection limit and the maximum observed was 0.27mg/l. Sampling error may have caused this since equipment was being installed on this occasion, probably bringing solids into suspension. Some evidence was found to suggest the presence of hydrocarbons although no analysis was undertaken.

Table 7.3 Water quality results for hydrocarbons

Start & End Time of Sampling		**31/07/00 18:50 - 01/08/00 04:50**			**09/08/00 11:30 - 10/08/00 11:00**			**Spot Sampling**		
		Event 13			**Event 16**					
		min	max	mean	min	max	mean	min	max	mean
Hydrocarbons	[mg/l]	0.375	3.35	1.97	0.1*	0.1*	0.1*	0.1*	0.27	0.1
No of Samples taken	[mg/l]	12			12			6		
*values below detection limit										

Metals

A comparison of heavy metals concentrations with service reservoir (potable water) data in table 7.4 shows that most are within the range of the water service reservoirs. Hydrocarbon concentrations of up to 3.5mg/l during event sampling confirmed onsite observations of minor oil spillages under car engines. Spot samples and sampling during a small event resulted in concentrations below detection limit.

Table 7.4 RBS Outflow - Key heavy metals concentrations

		Cd	**Pb**	**Cr**	**Cu**	**Ni**	**Zn**
		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Outflow RBS	min	<0.066	0.9	1.7	1.7	0.81	9.0
	max	<0.066	2.6	4.5	9.5	4.0	32.0
	mean	<0.068	1.8	2.2	5.2	1.7	22.2
EQS 2	max	5	50	150	1	50	75
Service Reservoir	mean	<0.1	7.6	<1.7	23	0.6	8.2

Detention Basin D/M (DEX)

Name	Detention Basin D/M	System	Detention Basin
Serving	Road drainage	Cont. Area	0.88Ha
Hydrology	Rainfall, Depth monitoring at outlet		
Period(s)	Apr 2000 – May 2003 (continuing)	Events	
Quality	Sediment sampling at inlet and outlet only		
Period(s)		Events	
Comments			
Data Source	Data from Adolf Spitzer a.spitzer@tay.ac.uk or Chris Jefferies c.Jefferies@tay.ac.uk		

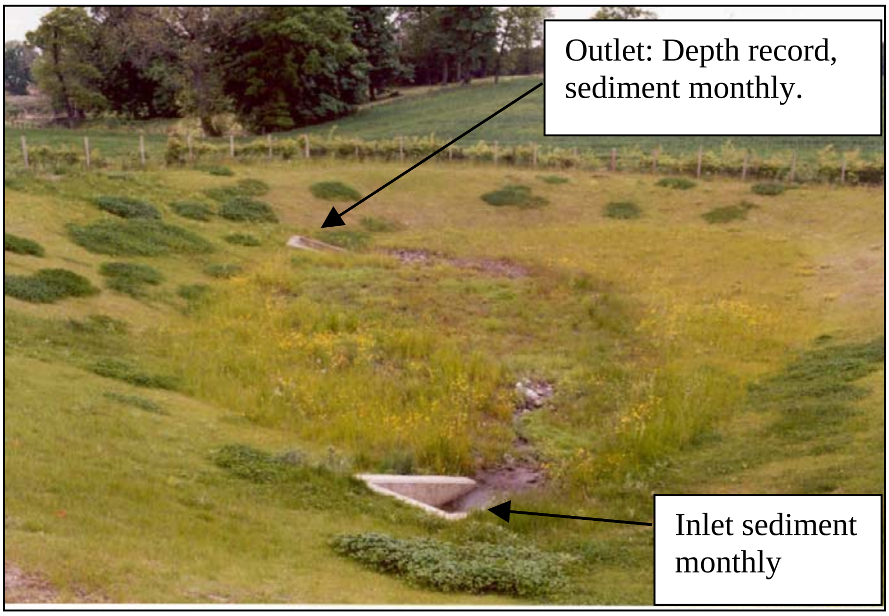


Figure 8.1 Detention Basin D/M

The outlet from this detention basin is at the invert level of the basin and flow is controlled by a Hydrobrake located in a manhole immediately downstream from the outlet structure. The Hydrobrake (see Figure 8.3 d)) was specified to pass 15l/s at a head of 1.8m. The outlet manhole (see Figure 8.3 c)) incorporates an overflow weir which permits excess water to flow out of the basin without causing damage.

The grass was not cut for long periods and there was no evidence that cutting grass assists with pollutant removal.

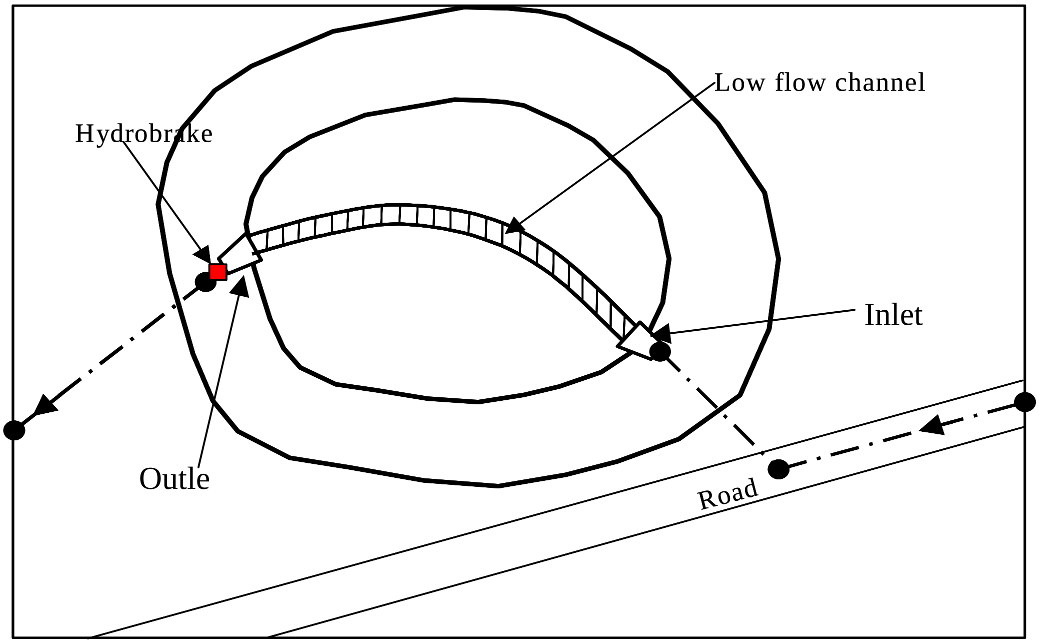


Figure 8.2 Detention Basin D/M Schematic Layout

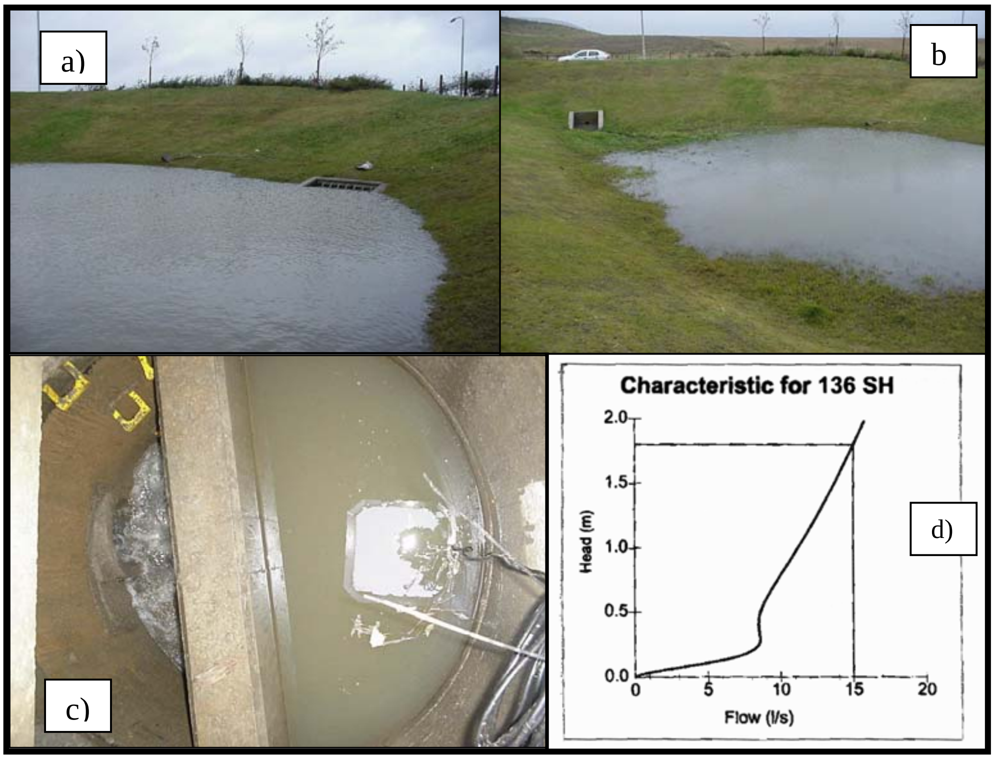


Figure 8.3 Detention Basin D/M in Operation

a) During heavy rainfall on 7 Nov 2000. Outlet nearly submerged

b) Inlet taken at same time as a).

c) Outlet manhole during same event. Wall (top to bottom) separates detention basin (Right) from continuation pipe(Left). Hydrobrake is in wall.

d) Hydrobrake head v flow curve.

Figure 8.4 Detention Basin D/M Sedimentation at Inlet

This series of photographs have been reproduced to show the amount of sediment deposition occurring over a 2 ½ year period. The basin serves only road runoff and construction has terminated by the start of the period of observation. The sediment has caused a general rise in level of the base of the basin by about 300mm and the inlet is now permanently submerged. Operation of the pipe system upstream is not affected since it has steep gradients. Hydraulic performance of the basin is not affected since the reduction in volume is less than 5%. However, the water quality performance will soon be reduced due to fine sediments reaching the outlet because the deposited material has created a gradient across the base, giving the flow an increased velocity during small events.

Sediment deposition at inlet impedes flow and threatens to eventually block inlet pipe. Sediment material at inlet is mainly sand and grit. Sediment at outlet is mainly silt and fine sand. Bigger particles are being deposited near inlet and sediment in middle of detention basin is mainly fine sand and silt. Mean sediment depth at inlet was 48 mm, at outlet 25 mm (measured on 12 June 2002). Largest rate of sediment accumulation between 1999/2001.

Period for sediment sampling was December 99 to June 2002

Hydro-Brake 136 SH in outlet (see flow characteristics on graph in figure 8.3). Maximum flow at outlet = 11.2 l/s (Hydro-Brake was designed on the basis that this flow is reached at one metre water depth).

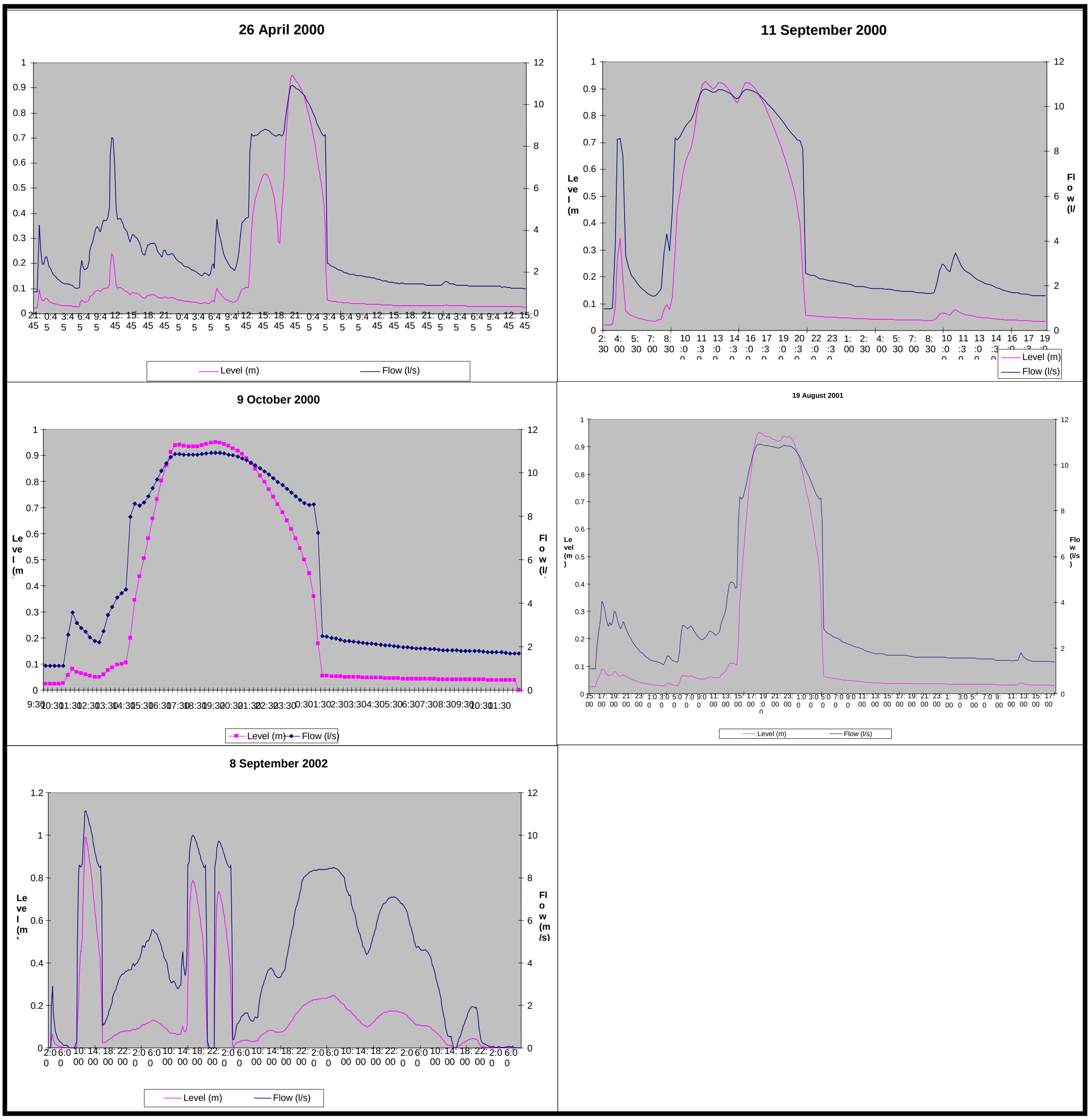


Figure 8.5 Detention Basin D/M Typical Event Hydrographs

The water level in the detention basin reached greater than 0.9m on six days in the three years of monitoring. Figure 8.3 a) & b) shows the water in the basin when the recorded depth was approximately 600mm. The debris line for the event of 7 Nov 2000 may be seen.

Detention basin G (DEX)

Name	Detention Basin G at Duloch Park	System	Detention Basin
Serving	Road runoff	Cont. Area	
Hydrology	Rainfall, Depth monitoring at outlet		
Period(s)	April 2000 – March 2002	Events	
Quality			
Period(s)	Grab samples of sediment only	Events	
Comments	Studies funded by Wilcon Homes		
Data Source	Data from Adolf Spitzer a.spitzer@tay.ac.uk or Chris Jefferies c.Jefferies@tay.ac.uk		

The outlet from this basin was blocked shortly after monitoring commenced. This was due to a large sheet of polythene becoming lodged at a location where access was not possible.

Figure 9.1 Detention Basin G September 2000

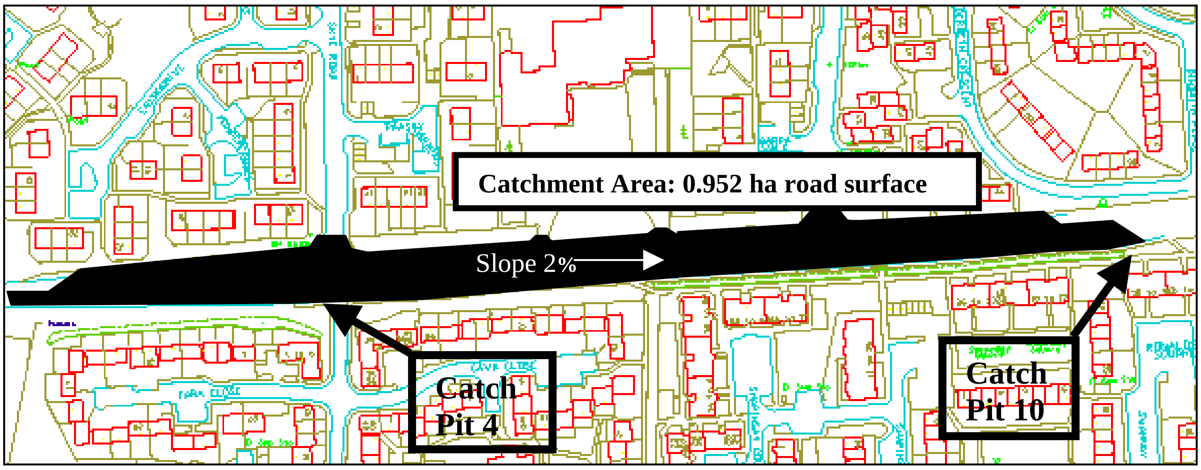
The outlet was blocked during almost the entire period of monitoring and still is. Blockage is caused by a plastic sheet in a downstream pipe. So far all attempts to remove the sheet failed. Water levels can be significantly above one metre over several days during wet periods and during cold periods the water surface in the basin was often frozen. Sediment deposition at both inlets is moderate to large. There is considerable accumulation of sediment in the centre and at the outlet of the basin. Sediment material at inlets is mainly sand and grit. Sediment at outlet is mainly silt and fine sand. Sediment in centre of detention basin is mainly fine sand and silt. Mean sediment depth at inlets = 70 mm, at outlet 40mm (measured on 12 June 2002).

Figure 9.2 Detention Basin G February 2002 – Still full!

Lang Straght, (Aberdeen)

Name	Lang Stracht, Aberdeen	System	Filter drain with throttled outlet
Serving	Busy road in medium density housing	Cont. Area	0.95 Ha
Hydrology	Rainfall; flow and depth at two locations		
Period(s)	Nov 1999 – Nov 2002	Events	124
Quality	Targeted periods using Epic samplers and sondes at two locations + grab samples		
Period(s)	April- July 2001; Nov 2001 – Feb 2002	Events	23 during two target periods
Comments	Outflow via Scottish Water's sewers		
Data Source	Data from Wolfram Schlüter – w.schlueter@tay.ac.uk		

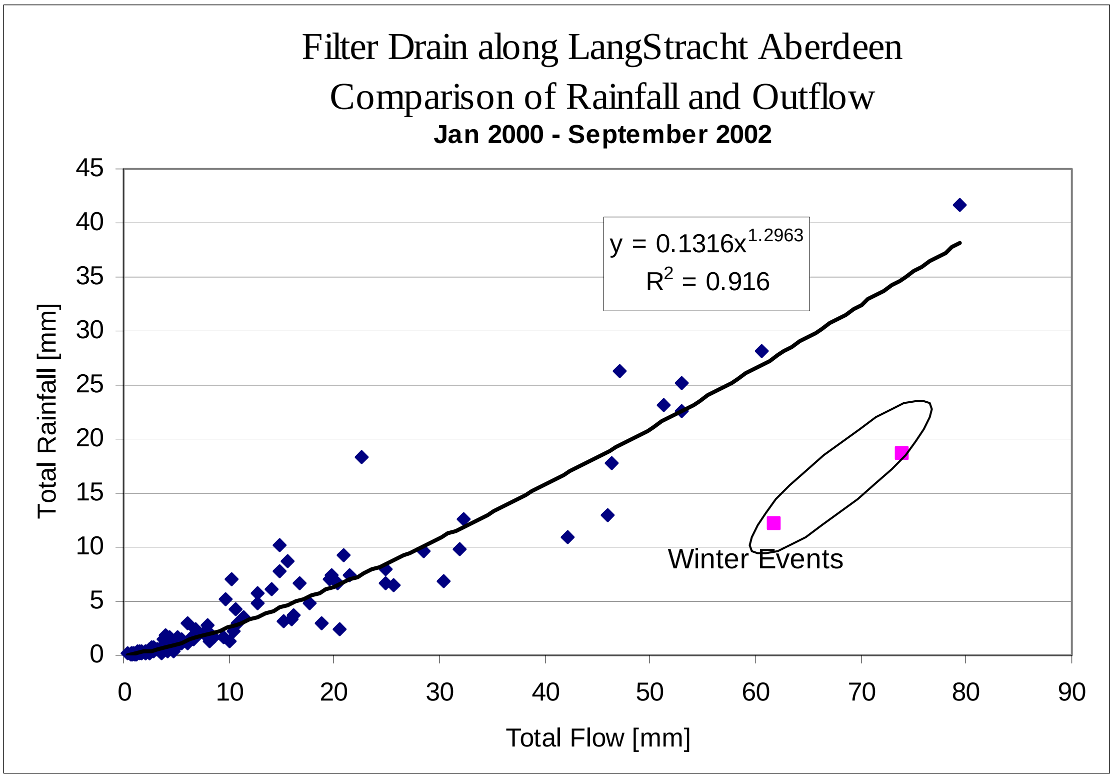
Lang Stracht site layout and monitoring locations



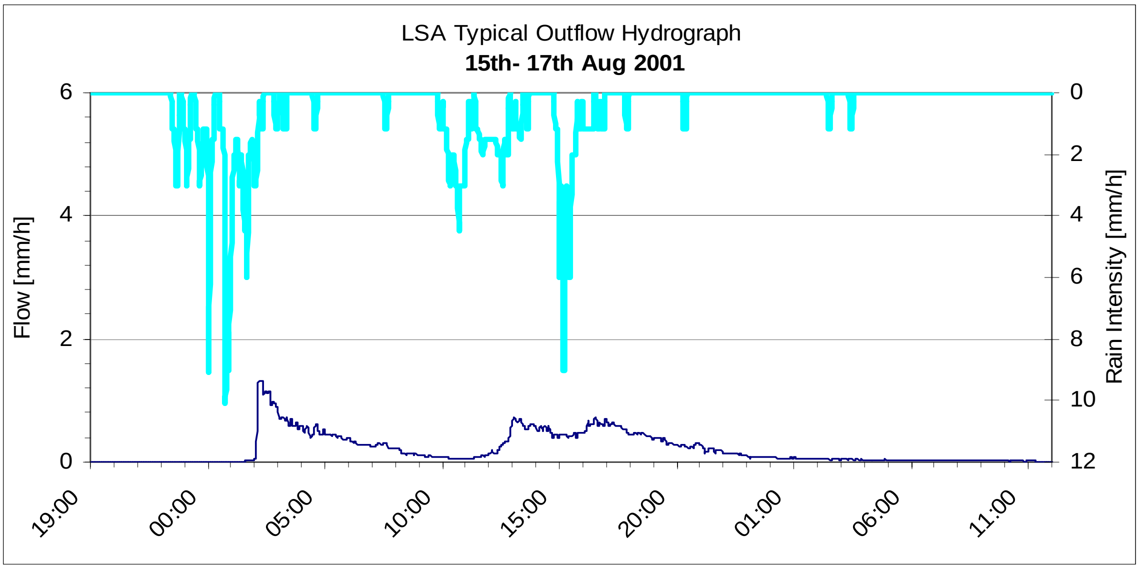
This filter-drain system is located alongside the A944 in Aberdeen where widening and resurfacing was carried out during spring of 1999. The system drains 750 metres of road via 44 trapped gully pots and 11 catch pits and has perforated pipes varying from 150 to 300 mm located in gravel 0.5 m x 1.5 m in cross section. Construction was completed well in advance of monitoring and the contributing area was a busy urban access route, any surfaces being relatively mature. Outflow from the system is to the Denburn sewer. The drainage is designed as an exfiltration system but the area has soil of extremely low permeability. The catchment area is 9,502 m^2, of tarmac road and footpaths. 124 flow events had been recorded by the end of November 2002 when investigations stopped due to suspected blockage of the inlets. A total of 23 events with water quality data were monitored during two periods.

The overall performance of this system in attenuating low intensity events (<12mm/h) was found to be excellent and maintainability was a key issue. Evidence was gathered concerning the water quality performance which became very poor after 2 ½ years of operation.

Rainfall compared to outflow



Typical hydrograph



Inlet Detail

The inlet detail used the outlet from a trapped gulley pot discharging directly into gravel media. It was found that leaves were able to become retained by the gravel and the inlets became blocked by September 2002. Improved 'maintainable' details are now used in the Aberdeen area where there is also a general presumption against in-ground systems of this nature.

Water Quality

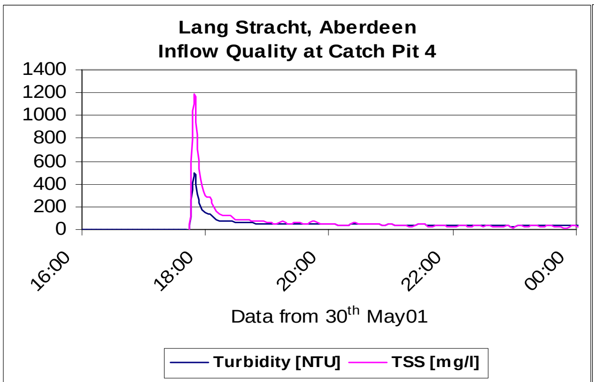
Water quality samples were taken at one inlet and at the outflow. Water quality sondes recorded data at five-minute intervals. Sampling was from April to July 2001 at the same locations at 10 min retrieval intervals. pH results show that there is little variation, minimum and maximum values being 6.7 and 8 respectively. TSS was reduced by an average of 74.3 %. The maximum TSS concentration at the inflow was 1,174 mg/l, which was reduced to 235 mg/l at the outflow. Turbidity results showed a similar pattern. The average peak reduction in turbidity was 58 % and maximum inflow and outflow values were 49 NTU and 461 NTU, respectively. Conductivity results show an average increase in peak of 73 %, maximum values being 2,950 µS/cm at the outflow and 1,072 µS/cm at the inflow. Table 1 shows the peak reduction of total suspended solids, turbidity and peak increase of conductivity.

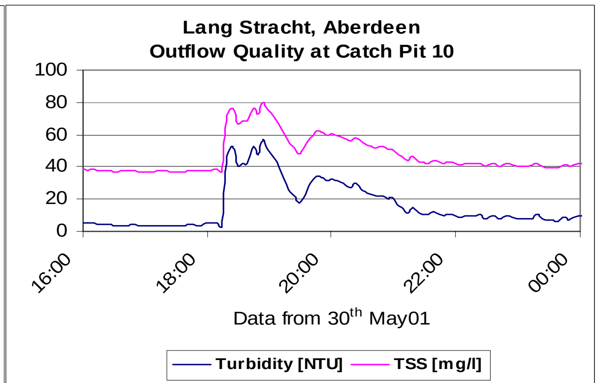
Table 1 Comparison of peak concentrations from in- and outflow

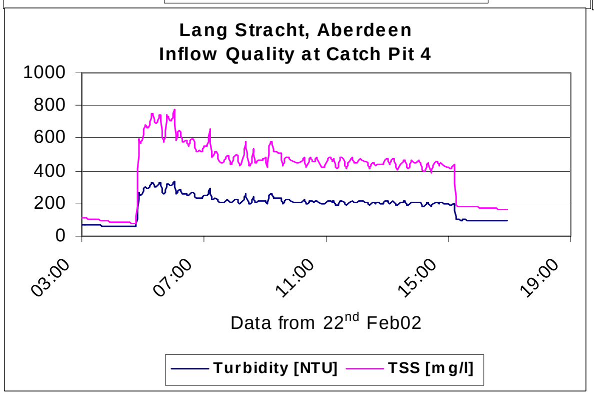
	Reduction		Reduction		Increase	
Date	**mean TSS**	**max TSS**	**mean Turb**	**max Turb**	**mean Cond**	**max Cond**
16/05/01	43%	60%	75%	60%	322%	164%
17/05/01	72%	81%	37%	58%	1073%	360%
30/05/01	97%	99%	90%	94%	985%	377%
06/06/01	64%	85%	74%	75%	142%	103%
19/06/01	90%	87%	58%	74%	427%	93%
Average	73%	82%	67%	72%	590%	220%

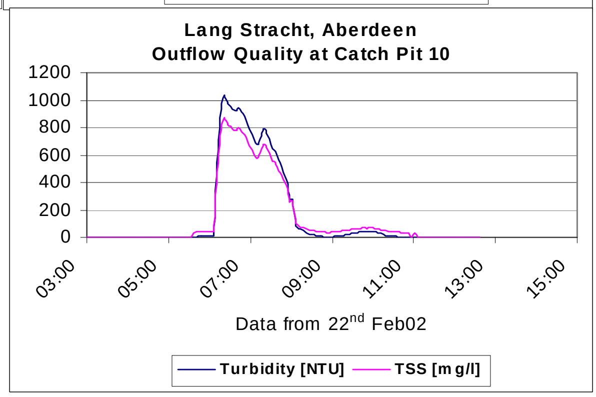
Example comparisons of inflow and outflow quality from two events

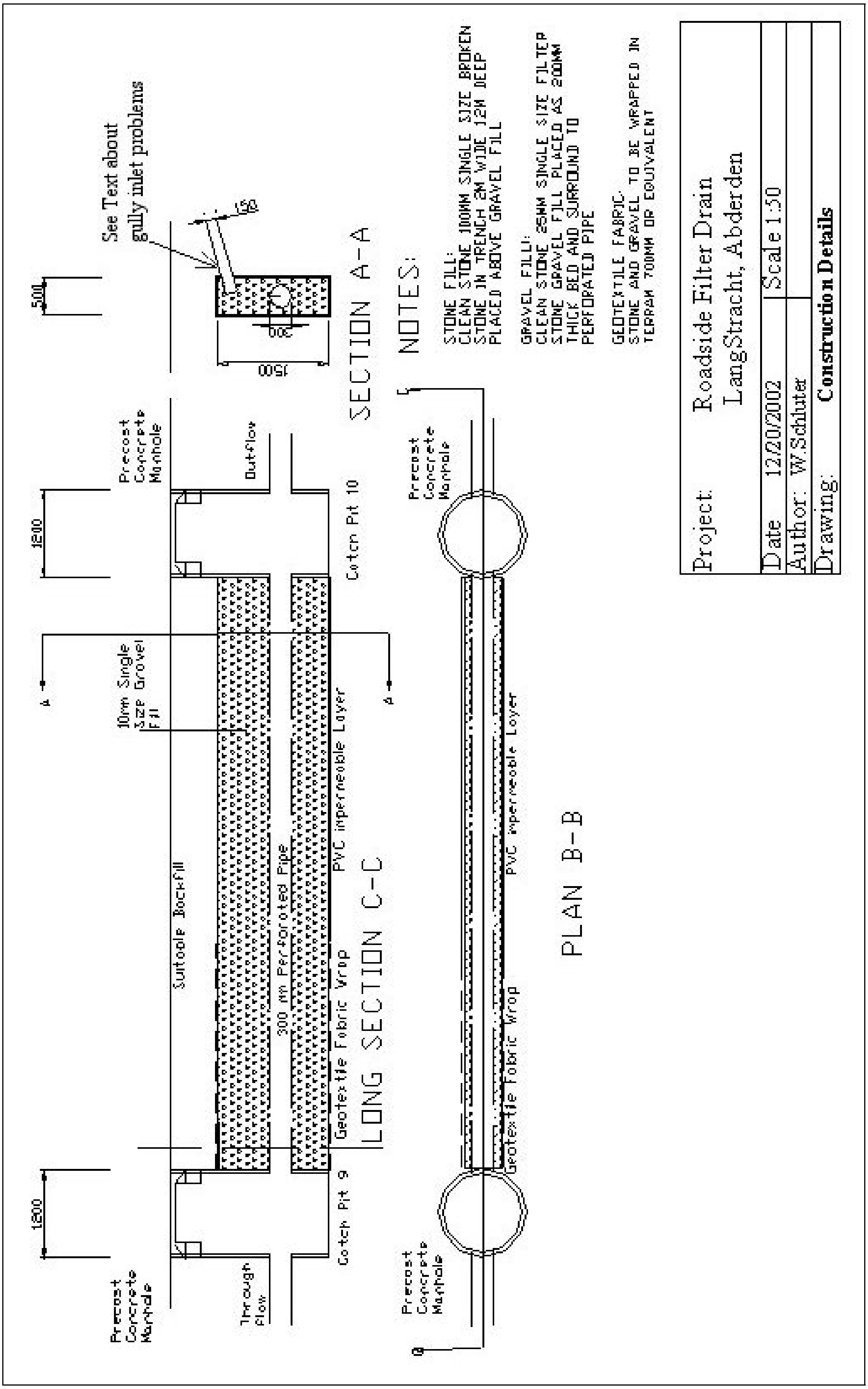
These graphs show the variable performance of this type of filter drain. TSS has been calculated from a derived relationship.











See Text about gully inlet problems
150
500
1500
300
SECTION A-A
NOTES:
STONE FILL:
CLEAN STONE 100MM SINGLE SIZE BROKEN STONE IN TRENCH 2M WIDE 12M DEEP PLACED ABOVE GRAVEL FILL
GRAVEL FILL:
CLEAN STONE 25MM SINGLE SIZE FILTER STONE GRAVEL FILL PLACED AS 200MM THICK BED AND SURROUND TO PERFORATED PIPE
GEOTEXTILE FABRIC:
STONE AND GRAVEL TO BE WRAPPED IN TERRAM 700MM OR EQUIVALENT
Project: Roadside Filter Drain LangStracht, Abderden
Date 12/20/2002
Scale 1:50
Author: W.Schluter
Drawing: Construction Details
Precast Concrete Manhole
Outflow
1200
Catch Pit 10
10mm Single Size Gravel Fill
A
Suitable Backfill
300 mm Perforated Pipe
PVC impermeable Layer
Geotextile Fabric Wrap
LONG SECTION C-C
Catch Pit 9
Through Flow
PLAN B-B

SUDS Performance Data Summary Sheet No. 11

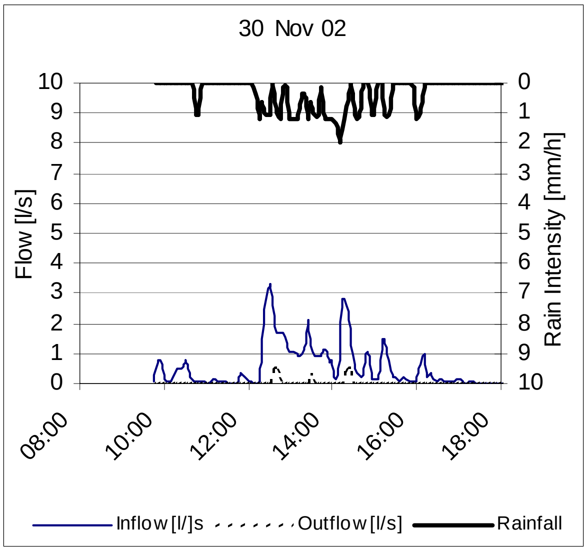
Broxden (Perth)

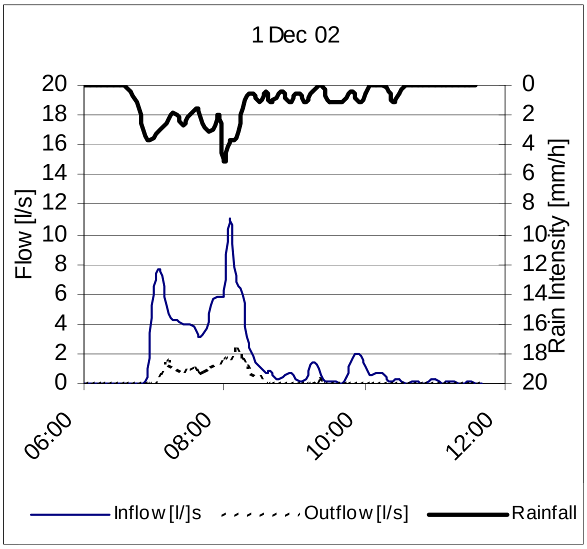
Name	Broxden Filter Drain	System	Gravel filled filter drain (1999)
Serving	Housing development roads and roofs	Cont. Area	0.3 Ha (measured) 0.3 Ha from modelling)
Hydrology	Rainfall; Sigma loggers on inlet and outlet		
Period(s)	Nov 2002 – Feb 2003	Events	26 (> 2mm total rain)
Quality	None		
Period(s)		Events	
Comments			
Data Source	Data frrm Wolfram Schlüter – w.schlueter@tay.ac.uk		

Photographs of Broxden contributing area and site of filter drain. The open cover is at the outlet manhole.

This filter drain is on a sloping site in primarily fill material. There is permanent water in the manholes due to the sealed manhole bases. The water table is below base of the system.

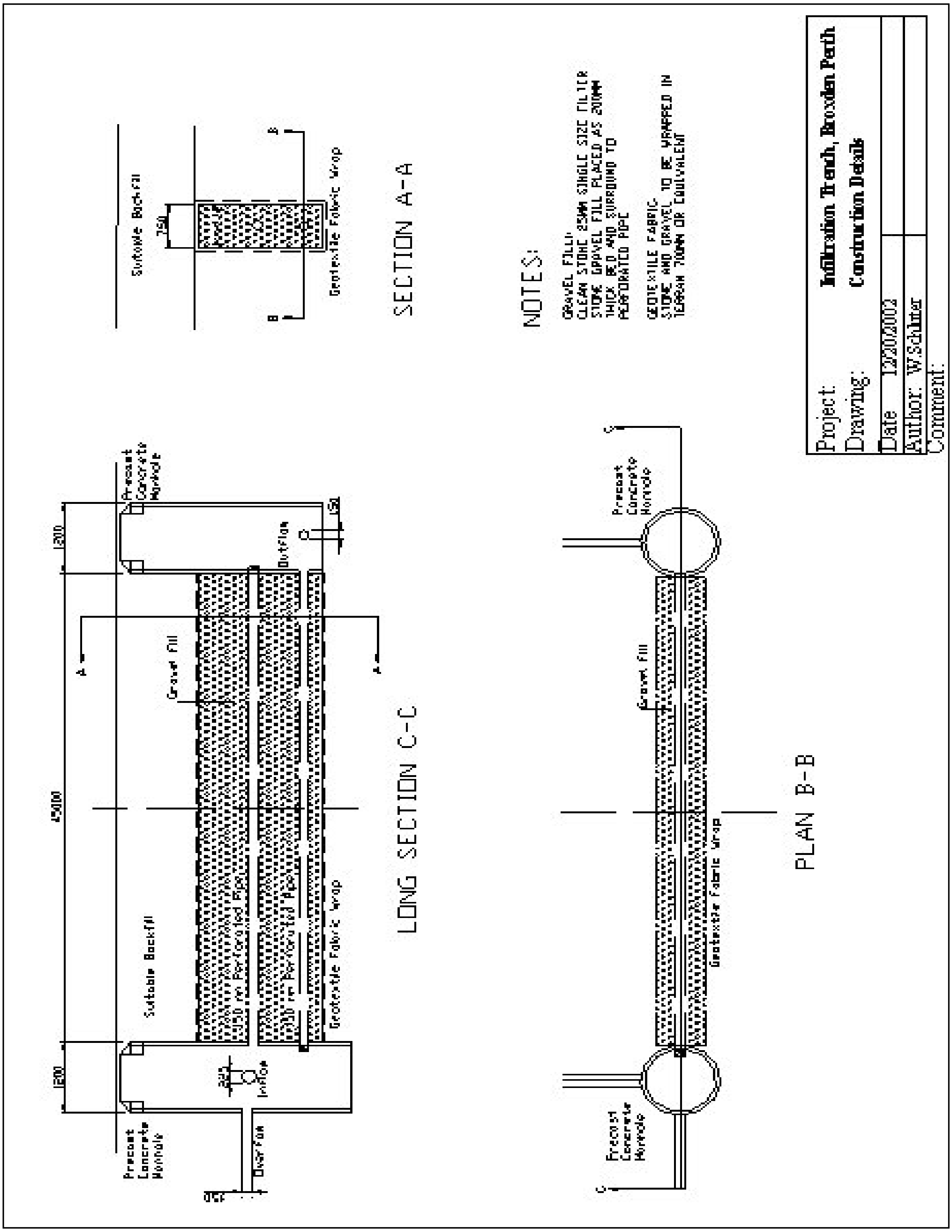
Inflow and Outflow Hydrographs





The example hydrographs show significant reduction both in peak flowrates and event volumes. The reduction in peak flows averaged 76% while the measured outflow averaged 25% of inflow to the filter drain over 26 events of 2.0mm or greater. There are two possible explanations for this these reductions; exfiltration through the filter media diverted flow away from the outlet pipe (beneficial!) or there was such a degree of attenuation that the outflow was too small for the accuracy of the monitoring equipment (again beneficial). Whichever argument applies, attenuation of flows was very significant.

Details of filter drain. Inlet and outlet perforated pipes extend for full length and are capped at alternate ends.



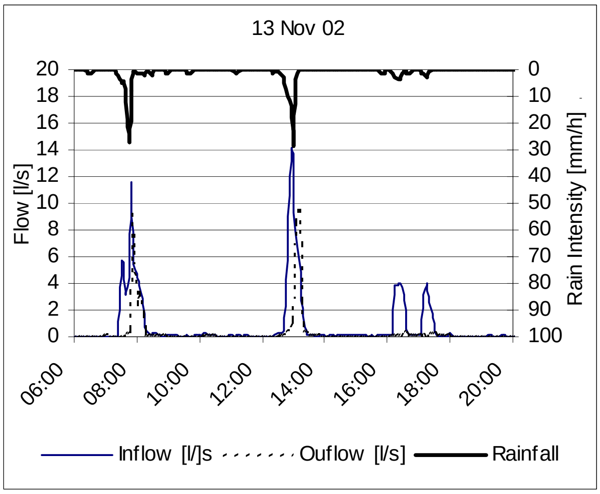
Walker Dam (Aberdeen)

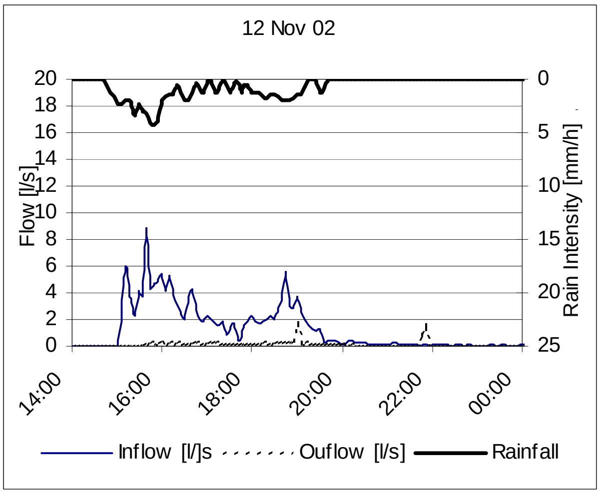
Name	Walker Dam Filter Drain	System	Gravel filled filter drain (199?)
Serving	Housing development roads and roofs	Cont. Area	0.35 Ha (measured) 0.70 Ha (derived from modelling)
Hydrology	Rainfall; Sigma Loggers on inlet and outlet		
Period(s)	Nov – Feb 02	Events	38 events Greater than 2.5mm
Quality	None		
Period(s)		Events	
Data Source	Data from Wolfram Schlüter – w.schlueter@tay.ac.uk		

Plan and Longitudinal Section of Walker Dam Filter Drain

The system has an inlet sump 575mm deep formed from manhole rings. Inlet perforated pipe extends only part way through gravel media and under drain is full length. Neither inlet nor outlet pipes can be jetted as there is no connection to the inlet sump. Both details superseded locally by details in data sheet 11. No overflow is provided and any excess inflow is conveyed over ground by the inlet pipe backing up and flow reaching the receiving water overland.

Sample Hydrographs showing rainfall together with inlet and outlet flows

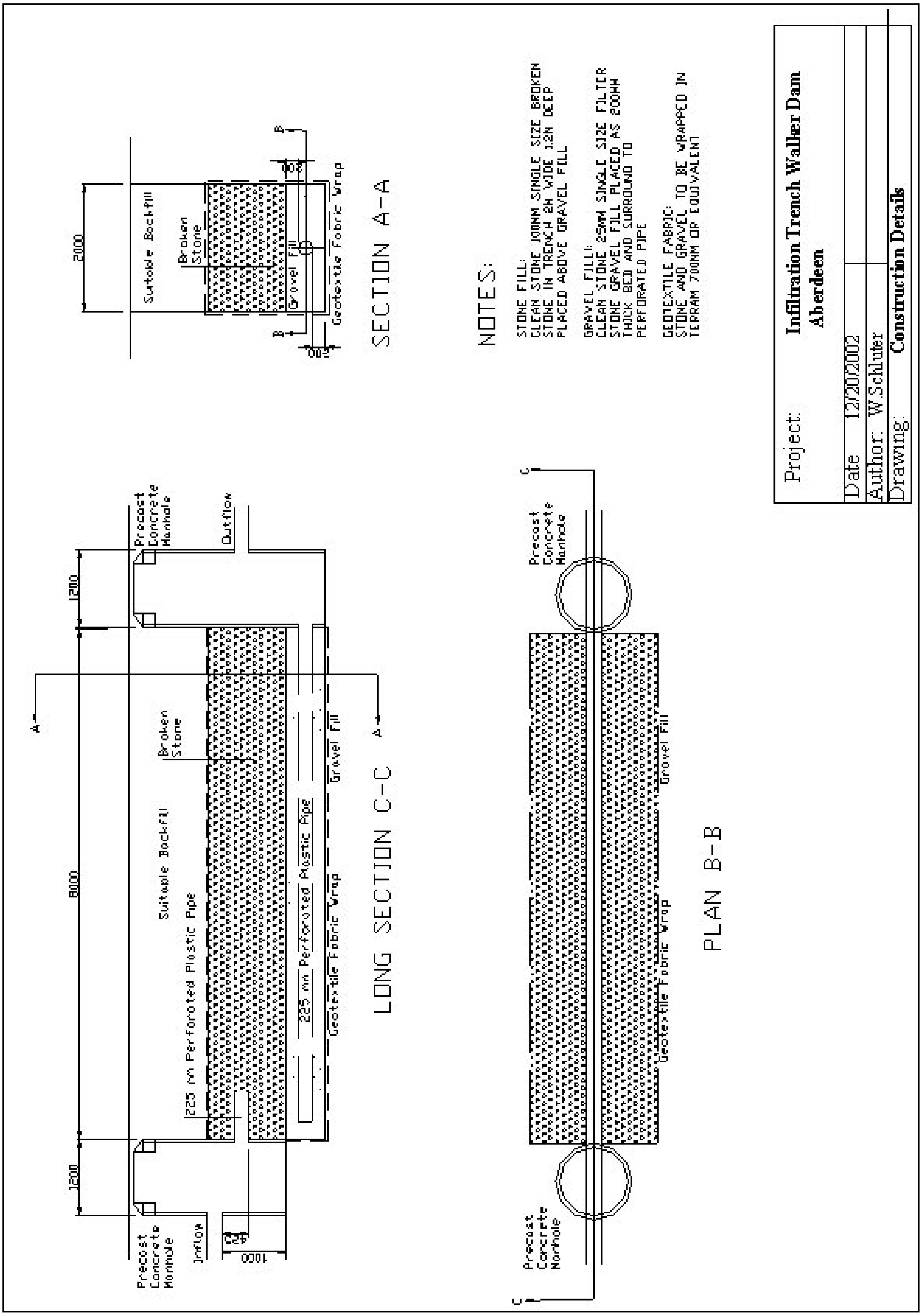




Significant attenuation of peak flows observed as illustrated in the sample hydrographs. Measured outflow from filter drain averaged 14% of inflow over 38 events greater than 2.0mm rainfall (Max 48%; min 3%). In spite of partial blockage of inlet, there was no evidence that hydraulic performance was affected.

Walker Dam Photographs - Clockwise from Top Left: Inlet sump with 400mm depth of gravel; Accessibility for jetting equipment; Inlet to perforated pipe prior to jetting; Inlet to perforated pipe after jetting.

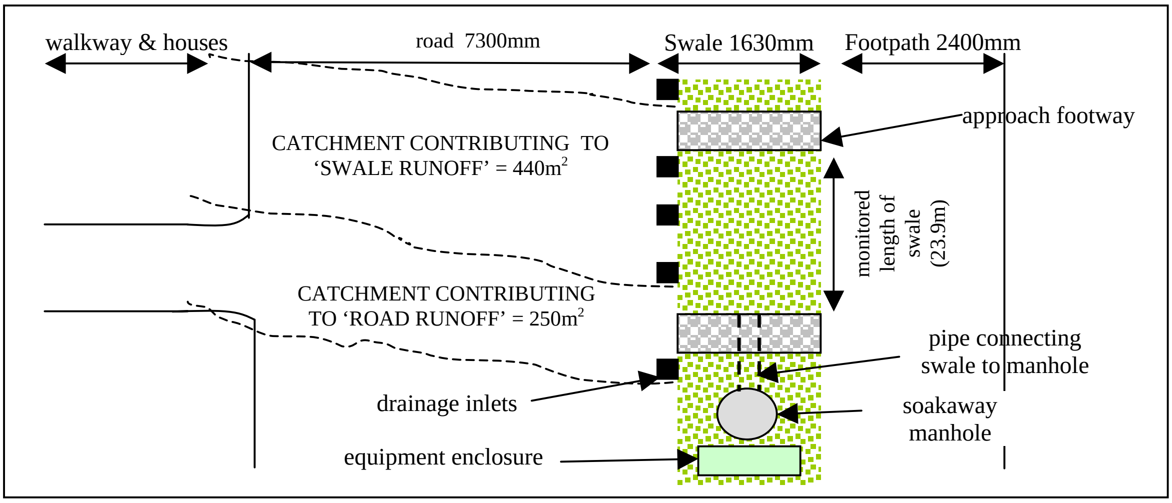
Note: In more recent details, the 'dead' ends of both inlet and outlet pipes have caps which can be removed during cleaning operations.


LONG SECTION C-C
Precast Concrete Manhole
Inflow
Outflow
Suitable Backfill
Broken Stone
225 mm Perforated Plastic Pipe
Gravel Fill
Geotextile Fabric Wrap
1200
8000
1000
SECTION A-A
2000
200
PLAN B-B
NOTES:
STONE FILL:
CLEAN STONE 100MM SINGLE SIZE BROKEN STONE IN TRENCH 2M WIDE 1.2M DEEP PLACED ABOVE GRAVEL FILL
GRAVEL FILL:
CLEAN STONE 25MM SINGLE SIZE FILTER STONE GRAVEL FILL PLACED AS 200MM THICK BED AND SURROUND TO PERFORATED PIPE
GEOTEXTILE FABRIC:
STONE AND GRAVEL TO BE WRAPPED IN TERRAM 700MM OR EQUIVALENT
Project: Infiltration Trench Walker Dam Aberdeen
Date 12/20/2002
Author: W.Schluter
Drawing: Construction Details

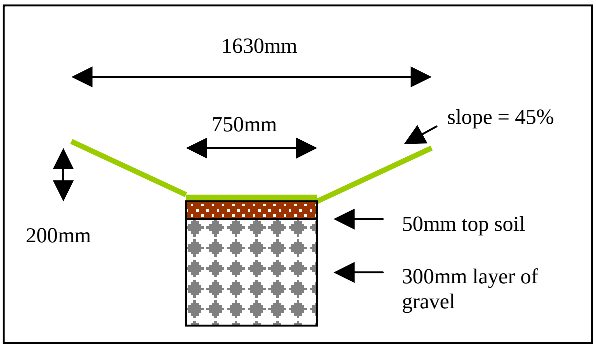
Emmock Woods Swale (Dundee)

Name	Emmock Woods access road	System	Roadside Detention (and road)
Serving	Access road to housing development	Cont. Area	440m^2 (250 m^2)
Hydrology	Rainfall; flow measured by tipping buckets for swale and road. Depth in soakaway.		
Period(s)	Feb 1999 – Aug 2000	Events	106 (52 resulted in swale runoff)
Quality	Sonde with occasional event samples (little outflow from swale)		
Period(s)	Periodic throughout period	Events	4
Comments	Studies funded by The Carnegie Trust & Dundee City Council		
Data Source	Data from k.macdonald@ewan.co.uk		

Emmock Woods Roadside Detention



This roadside detention is located alongside an access road to a housing estate. Runoff enters via Clearway™ drainage inlets located every 8 – 11m along the kerb. Runoff flows along the swale, through connecting pipes where necessary and into a soakaway manhole via a raised outlet. When full, the soakaway manholes overspill to a conventional drainage system. The water left in the chamber and above ground evaporates and exfiltrates into the surrounding ground. The length monitored was 23.9m, and the longitudinal slope was 2%.



Cross-section

The facility was constructed with a 300mm layer of gravel under the 50mm layer of top soil. The surface was not properly finished and natural vegetation (weeds) were allowed to establish. No maintenance was carried out during the monitoring period, but the performance did not appear to be affected by this lack of maintenance.

Emmock Woods Swale – Note gravel under layer before topsoiling

Hydrology

A total of 106 rainfall events were recorded at Emmock Woods, with events as small as 0.8mm producing runoff from the road. Runoff from the facility occurred from only 52 of these events and the low number of events causing runoff was found to be the dominant feature influencing performance.

Typical Event Recorded at Emmock Woods

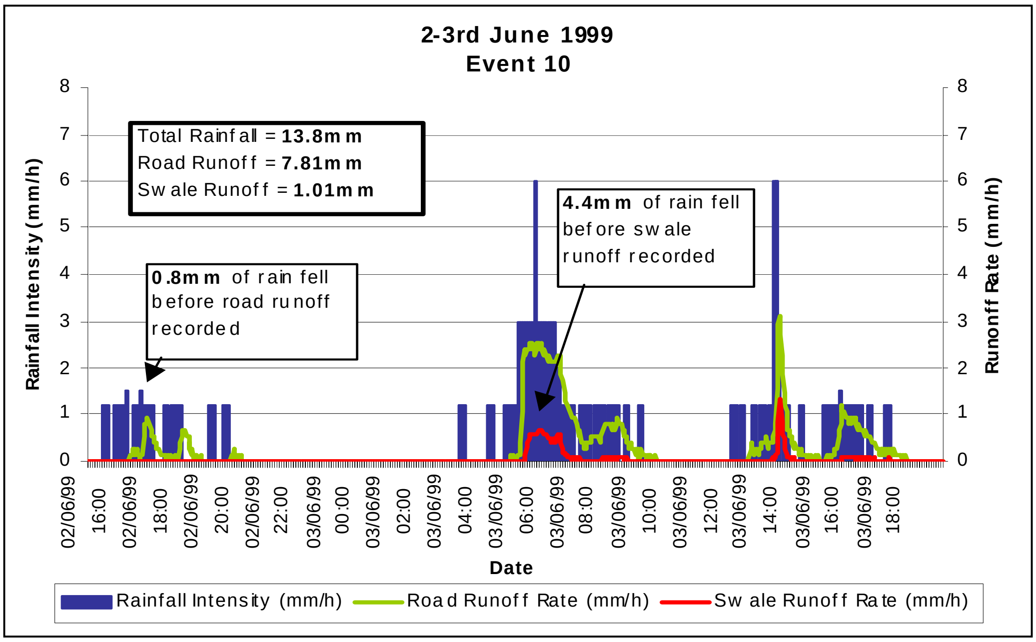
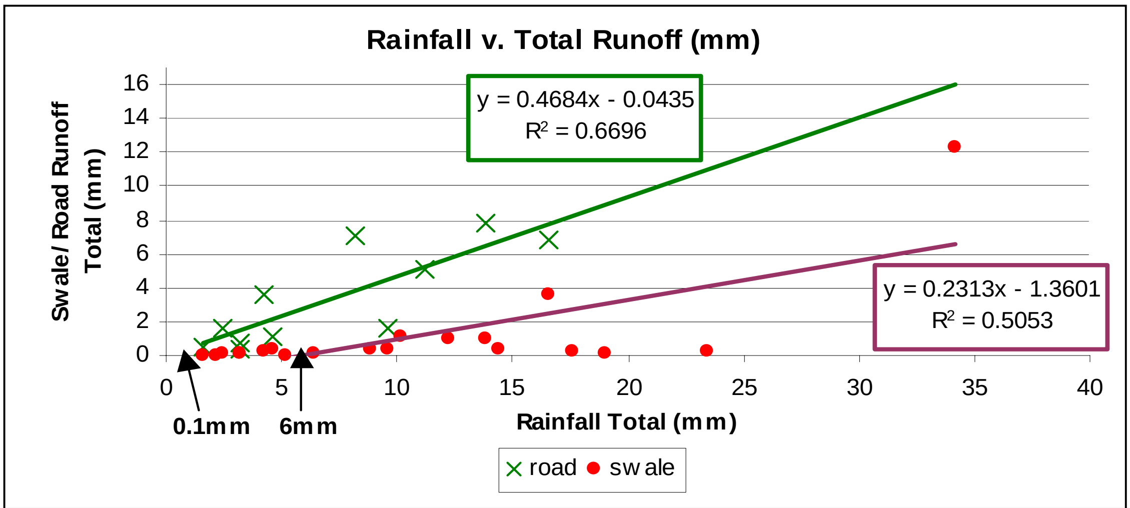


Table 1 Summary of Emmock Woods hydrological data – min, max & mean

	Total Rainfall (mm)	Duration (hrs)	Max. Intensity (mm/h)	Api5	Mm Rain before runoff		Total Runoff (mm)		% Runoff		Benefit Factor	Peak runoff intensity (mm/h)			Lag time (mins)Φ	
					Road	Swale*	Road	Swale*	Road	Swale*		Road	Swale*	% reduction	Road	Swale
Min	1.6	1.2	3	0	0.2	0.7	0.4	0.02	12.5	0.4	47	1.05	0.27	0	1.6	1.63
Max	34.2	32.2 5	30	6.23	2.8	12.4	7.8	12.3	86.9	36	99.3	9.6	4.78	95	21	29.7
MEAN	**10.6**	**13.1**	**11.7**	**1.57**	**0.75**	**3.9**	**3.55**	**1**	**44.3**	**6.53**	**82.4**	**4.06**	**1.6**	**52.2**	**9.2**	**11.6**

The data in table 1 have been derived from observations made during 26 rainfall events – although not all produced runoff from the detention basin.

Plots Showing Typical Derived Data



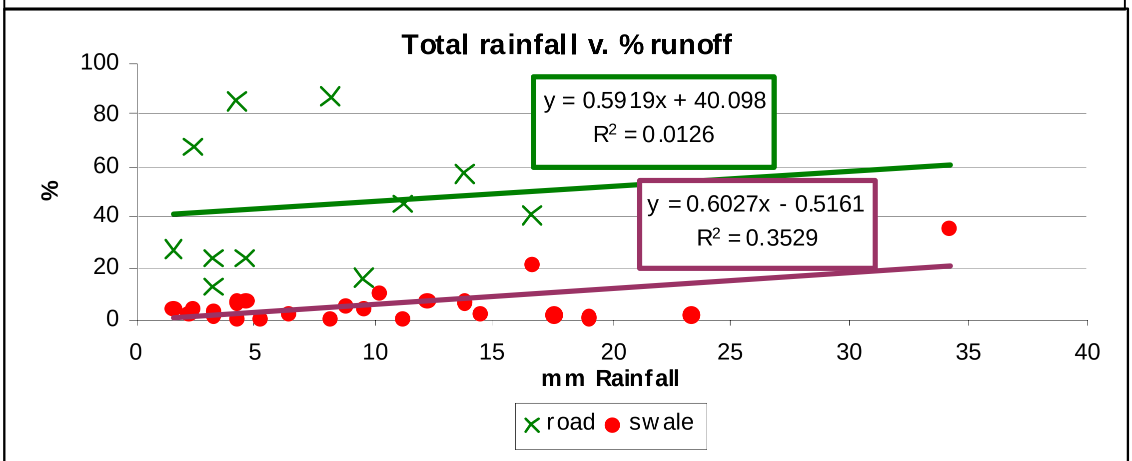


Table 2 Water Quality

Parameter	Unit	pH	Cond.	TSS	BOD	Amm.	TON	o-phos	Chlor.
			µS	mg/l	mg/l	mg/l	Mg/l	mg/l	mg/l
Average	Road	7.6	292	1057	2.4	1.11		0.28	
	Swale	7.41	167	299	2.4	1.21		0	

Only one event producing runoff from both the road and the SUDS system occurred at a time of site attendance. This indicates the exceptional hydrological performance of this type of system for source control of runoff. This meant that the data in table 2 derive from only one sample.

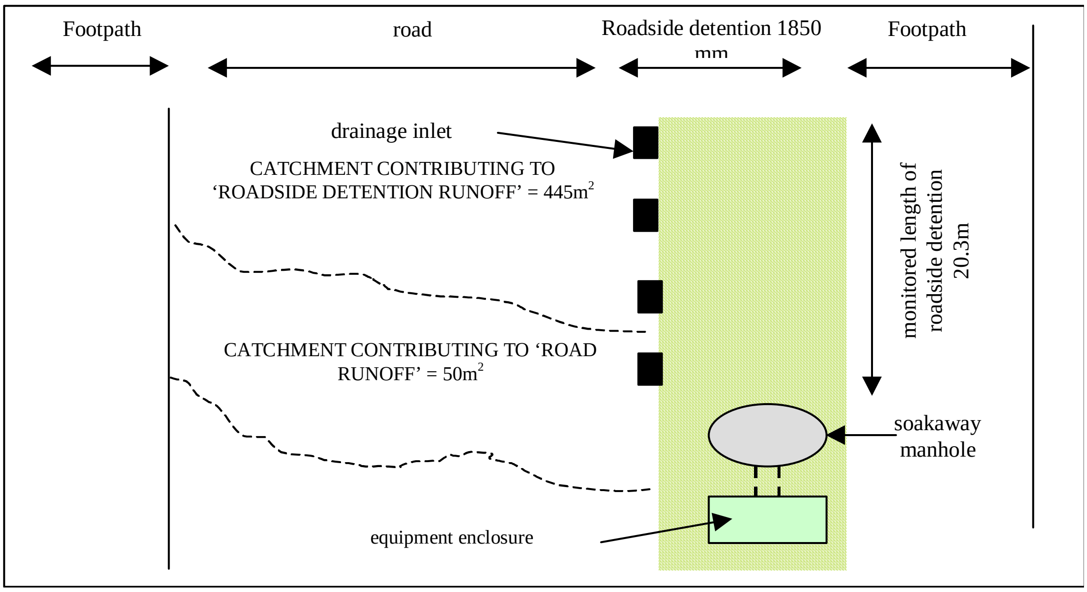
Design Information

- 300mm layer of gravel underlying soil.
- Surface not finished
- Slope = 2%
- Length = 23.9m
- No maintenance
- Treatment Volume Vt = 5.96m^3.
- Swale volume (inc. gravel pores) = 1.9 m^3. (i.e. 30% Vt)

West Grange (Dundee)

Name	West Grange access road	System	Roadside Detention (and road)
Serving	Access road to housing development	Cont. Area	445 m^2 (50 m^2)
Hydrology	Rainfall; flow measured by tipping buckets for roadside detention and road. Depth in roadside detention and soakaway.		
Period(s)	Sept 99 – Sept 2000 & Feb – Aug 2001	Events	106 (62 produced runoff) & 23
Quality	Vegason sondes and Epic samples on road and roadside detention runoff for targetted periods		
Period(s)	Periodic throughout period	Events	14
Comments	Various modifications to test different configurations. Studies funded by The Carnegie Trust		
Data Source	Data from k.macdonald@ewan.co.uk		

West Grange Roadside Detention



This roadside detention is very similar in concept to Emmock Woods facility, the chief difference being the absence of the gravel layer directly below the growing medium. The approximate longitudinal slope is 5% and the length monitored was 15.4m.

Swales at West Grange

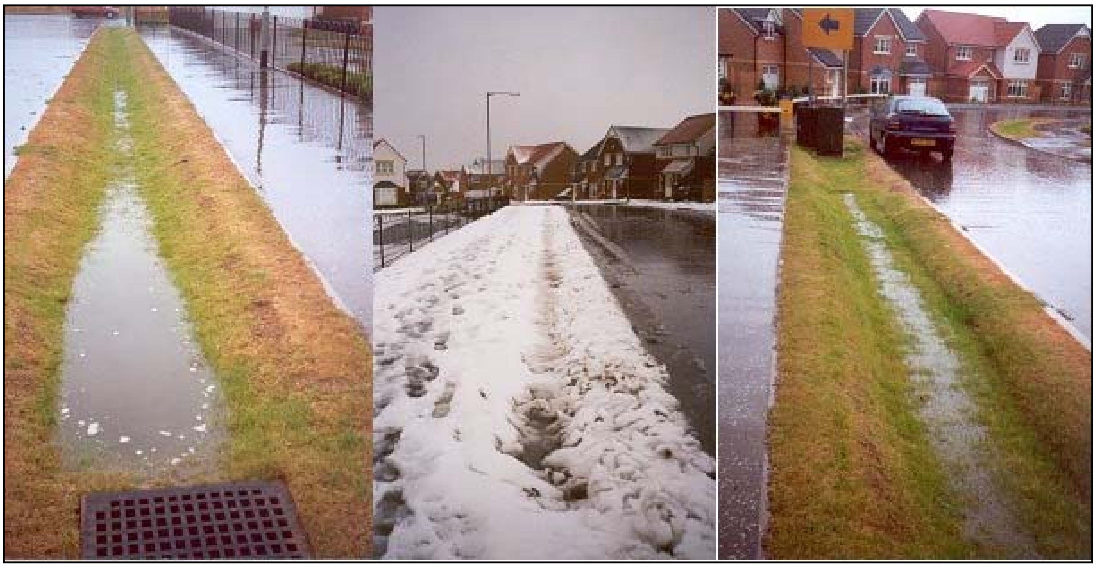
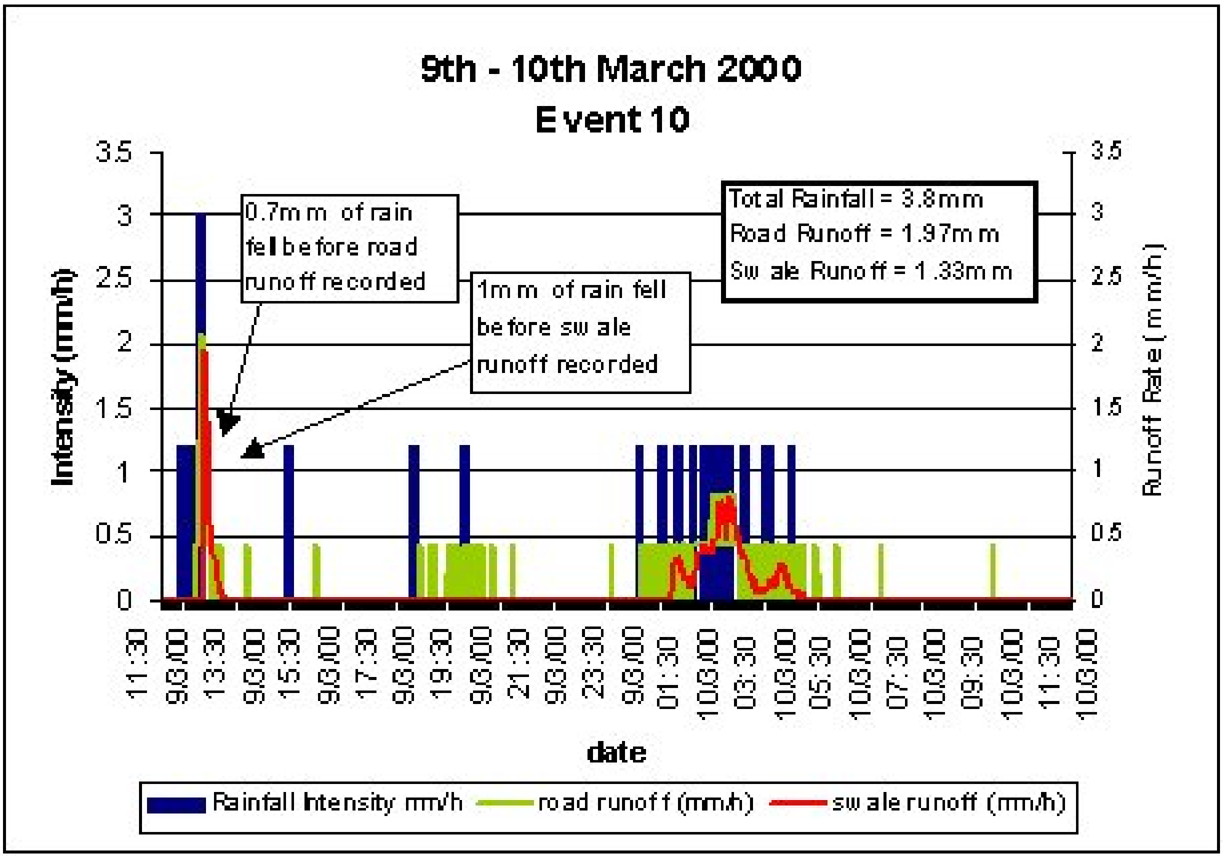


Table 14.1 Summary of West Grange Hydrological Data

	Total Rainfall (mm)	Duration (hrs)	Max. Intensity (mm/h)	Api5	Mm Rain before runoff		Total Runoff (mm)		% Runoff		Benefit Factor†	Peak runoff intensity (mm/h)			Lag time (mins)Φ	
					Road	Swale*	Road	Swale*	Road	Swale*		Road	Swale*	% reduction	Road	Swale
Min	0.6	1	1.2	0	0.2	0.6	0.15	0.06	25	5	4	0.42	0.16	-90	-74	-70
Max	23.8	46	24	7.3	1.4	2.2	12.6	12.8	93	95	80.5	13	7.2	62	77	87
MEAN	**6.7**	**11.6**	**8.2**	**1.31**	**0.4**	**1.09**	**4.36**	**2.97**	**53.1**	**36.7**	**44.6**	**3.9**	**3.1**	**1.2**	**3.7**	**14.3**

A total of 104 rainfall events was recorded at West Grange, with events as small as 0.2mm producing runoff from the road and all 104 events produced road runoff. Runoff from the swale occurred during 62 of the events and the data in table 14.1 are from 27 events.

Typical Runoff Event at West Grange



Water Quality

Water quality at West Grange was monitored using sondes and EPIC samplers. Data from a total of 14 events were collected. Seven events had sonde data, seven events had EPIC samples collected and manual samples were collected from four events, three of which were analysed in the UAD laboratory. Table 14.2 shows the determinands analysed for each event.

Table 14.2 West Grange Water Quality Parameters

	Parameter	pH	Cond.	TSS	VSS	BOD	Amm.	TON	o-phos	Chlor.
Average§	Road	7.6	139	343	123	5.1	0.41	0.38	0.079	12.4
	Detention	7.5	153	96	30	4.4	0.21	0.25	0.091	7.4
Range of EMCs	Road	7.17-8.1	90-196	30.1-957		2.2-12.3	0.056-1.96	0.164-0.68	0.05-0.107	2.2-30
	Roadside detention	7.1-7.85	53.1-426.1	21.5-156.5		1.75-7.3	0.015-0.755	0.07-0.63	0.042-0.159	0.05-16.3
EMC Red./ Inc. (-/+)*		-0.12	+17%	-55%	-76%	+24%	-33%	-33%	+42%	-45%

Table 14.3 Example Sonde Data from one event

Sonde values Event 17 30th January 2000							
No. of readings: **ROAD =**70 **SWALE =**34		Total (mm): **RAIN = 12.4** **ROAD = 6.25** **SWALE = 3.12**			**Notes:** No data for ammonium.		
Parameter	Unit	MIN		MAX		**MEAN**	
		Road	Swale	Road	Swale	Road	Swale
Temperature	°C	13.6	13.7	15.7	15.8	**14.6**	**14.5**
pH		7.04	7.08	7.91	8.66	**7.7**	**7.53**
Conductivity	µs	17.6	2.4	184.6	122.4	**85.7**	**58.6**
DO	%	24.4	24.6	96.5	85.3	**58.5**	**65.7**
Turbidity	NTU	23	34	209	150	**93**	**74**

Table14. 4 Sample Data from event in table 14.3

EPIC (sanitary suite) Event 17 6th June 2000							
No. of samples: **ROAD =** 6 **SWALE =**6		Total (mm): **RAIN = 1.6** **Swale** = 1.04					
Notes: 2.75 mg/l for BOD represents a value <3; 0.015mg/l for AmmN represents a value <0.02; 0.05mg/l for TON represents a value <0.1							
Parameter	Unit	MIN		MAX		**MEAN**	
		Road	Swale	Road	Swale	Road	Swale
pH		7.1	7.2	7.2	7.4	**7.17**	**7.3**
EC	µs/cm	49.8	53.4	165	117	**93.1**	**79.4**
TSS	mg/l	27.8	14	225	106	**114.7**	**51.8**
BOD	mg/l	6.1	2.75	15	8.2	**11.3**	**4.13**
AmmN	mg/l	0.015	0.015	0.142	0.105	**0.06**	**0.06**
TON	mg/l	0.05	0.05	1.21	1.14	**0.56**	**0.61**
o-phos	mg/l	0.06	0.039	0.177	0.115	**0.1**	**0.074**
chloride	mg/l	2.6	1.7	16.8	12.2	**9.8**	**7.08**

Table 14.5 Metals Concentrations – from Samples

EPIC values (metals) Event 22 31st July – 1st August 2000							
No. of samples: ROAD =11, SWALE =8		Total (mm): RAIN = 3.6, ROAD = 1.5			Swale = 0.5		
Notes: 2 batches of samples taken, one on 31st and second on 1st. The dissolved metals are from only 3 samples.							
Parameter	Unit	MIN		MAX		**MEAN**	
		Road	Swale	Road	Swale	Road	Swale
Cd	μg/l	0.071	0.121	0.293	2.9	**0.17**	**0.89**
Dissolved Cd	μg/l	0.112	0.24	0.25	1.7	**0.19**	**0.8**
Pb	μg/l	1.95	1.63	18.3	9.84	**8.15**	**4.64**
Dissolved Pb	μg/l	7.23	3.34	14.78	6.79	**10.5**	**5.31**
Cu	μg/l	10.1	12.8	52.5	178	**28**	**51.8**
Dissolved Cu	μg/l	22.8	21	39.4	70.4	**28.7**	**43.4**
Cr	μg/l	1.58	1.41	10.9	4.99	**5.4**	**2.83**
Dissolved Cr	μg/l	1.82	0.97	2.33	2.24	**2**	**1.69**
Ni	μg/l	0.76	0.98	12.4	5.18	**6.3**	**3.1**
Dissolved Ni	μg/l	2.53	2.15	4.36	3.74	**3.57**	**3.15**
Zn	μg/l	29	29	183	223	**82.1**	**93.7**
Dissolved Zn	μg/l	77	75	156	126	**111.3**	**102.7**
TSS	mg/l	7.8	7.3	133	46.1	**56.8**	**18.9**

Table 14.6 Hydrocarbons – from Samples

EPIC values (hydrocarbon) Event 16 29th May 2000							
No. of samples: ROAD =6, SWALE =5		Total (mm): RAIN = 3.2, ROAD = 1.04			**Swale = 0.92**		
Parameter	Unit	MIN		MAX		**MEAN**	
		Road	Swale	Road	Swale	Road	Swale
Hydrocarbon	mg/l	0.57	0.31	4.73	1.09	**1.47**	**0.6**

Design Information

- Turfed directly on to soil with no gravel (compare site summary 13)
- Slope = 5%
- Length = 15.4m
- Regular maintenance
- Treatment Volume Vt = 6.03 m^3.
- Swale volume = 1.25 m^3. (i.e. 20% Vt)