6. GROSS POLLUTANT COMPOSITIONS AND LOADS

Data from the monitoring program indicate that urban areas contribute approximately 30 kilograms per hectare per year of dry gross pollutants to the stormwater system. The majority of the pollutants monitored were organic (mainly leaves and twigs) and the remainder mainly paper and plastic food and drink items. The average density for the gross pollutants was 260 kilograms per cubic meter. For Melbourne this is equivalent to approximately 230,000 cubic meters of gross pollutants and between one and three billion items of litter annually.

Detailed analysis of the contents of 192 SEPTs revealed that more litter came from commercial areas per unit area than residential or light-industrial catchments. Organic loads caught in the SEPTs were relatively consistent over the whole catchment.

The large vegetation load of gross pollutants could potentially impact on the loads of nutrients (TP and TN) transported to receiving waters and be missed by conventional water sampling techniques. However, this study indicates that the contribution of TP and TN from organic gross pollutants was two orders of magnitude lower than the nutrient loads measured by conventional water samplers and therefore gross pollutants contribute little to the degradation caused by high nutrient loads.

6.1 COMPOSITION OF MATERIAL

In addition to being an effective stormwater management tool, the CDS unit is an excellent monitoring device for gross pollutants conveyed in stormwater systems because of its high capture rate (discussed in Chapter 7). Material was routinely cleaned from the device after runoff events and the quantities compared to storm characteristics.

The results reveal that organic material consistently represented the largest component of the gross pollutant load (Figure 6.1). The remainder of the monitored loads were primarily items associated with pedestrian and motorist activity (either paper or plastic). The results presented in Figure 6.1 are for the dry mass and it should be recognised that the density of litter material is lower than organic material and therefore contributed more volume proportionally compared to organic material. The large amount of leaves and twigs indicates a potential for nutrients to leach from the organic material into receiving waters, this issue is discussed further in Section 6.6.

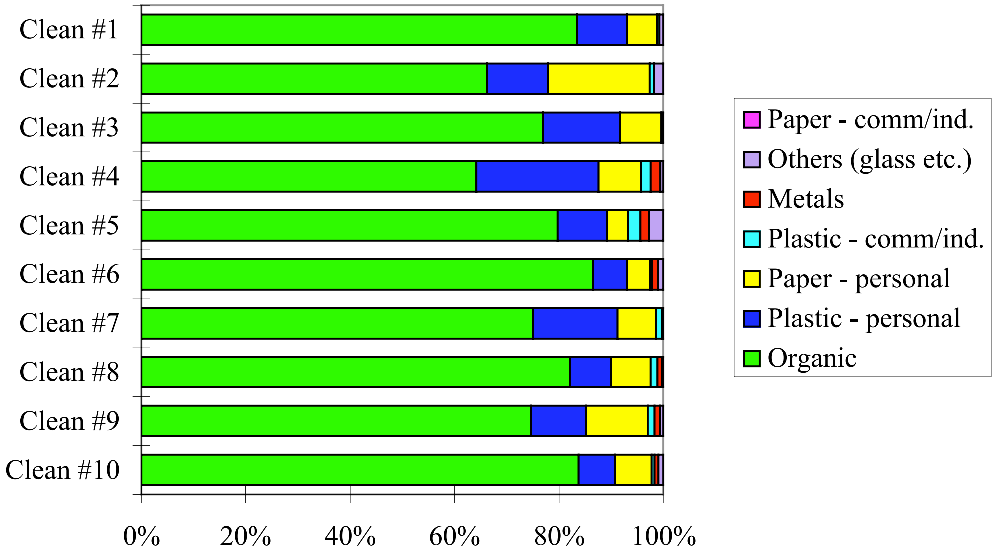


Figure 6.1 The composition of trapped material in the CDS device in Phase 1

Separating floating and sump materials during cleaning of the CDS device (Section 5.4.1) and comparing them revealed that approximately four times as much litter is suspended or sinkable (ie. sump materials) than that which floats (see Figure 6.2), the corresponding figure for organic material is in excess of ten.

Sump materials include all material except the floating items that were removed with a leaf-scoop. Once all of the floating items had been removed all other pollutants (including material suspended in the water column) are considered sump material.

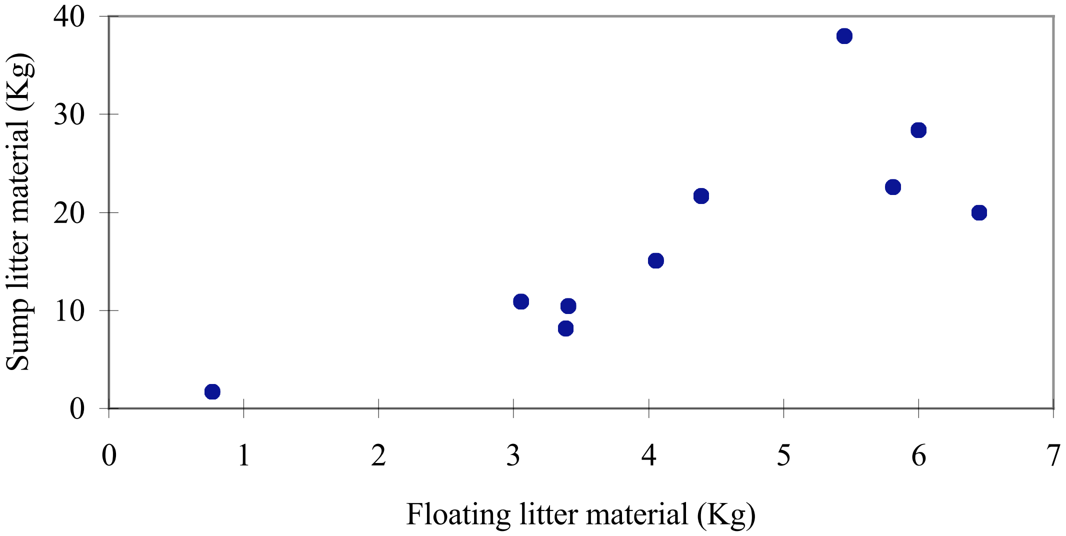


Figure 6.2 Floating litter versus sump litter caught in the CDS unit

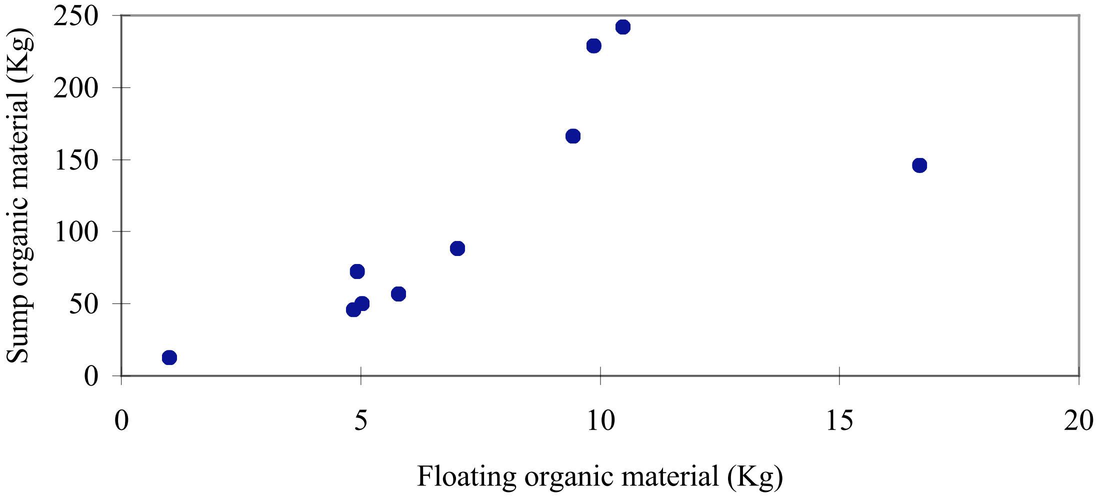


Figure 6.3 Floating organic material versus sump organic material caught in the CDS unit

The material that collects in the CDS collection chamber is kept wet for long periods (typically at least one week during this part of the monitoring), therefore, it is possible for the density of the collected pollutants to increase because of an increased water content and settle to the sump. This may account for the higher ratio of sump to floating material observed with the organic material (Figure 6.3) than with litter (Figure 6.2).

The data in Figures 6.2 and 6.3 imply that gross pollutant trapping techniques should be designed for both floating and suspended/ sinkable gross pollutants. The data also imply that floating gross pollutant traps could at best capture 20% of the litter load because only 20% of the load floats (even if 100% efficient for floating material) and less than 10% of the total load.

6.2 LOADS OF MATERIAL

Results show that considerable amounts of material entered the stormwater system. Annual loads for Melbourne are estimated to be approximately 30 kilograms, dry (100 kg/ha, wet) or 0.4 cubic meters (wet) per hectare for a complete year (by extrapolating the results in Table 6.1 and assuming they are typical for a complete year). This is equivalent to 230,000 cubic meters and 60,000 tonnes (wet) for Melbourne annually, and represent a large problem for clean-up campaigns. The majority of material is organic and could potentially be a nutrient problem (which is investigated in Section 6.6) and the majority of the litter items were cigarette, food and drink associated.

Based on the data gathered, gross pollutant movement appears to be highly influenced by rainfall and therefore trapping systems should be designed to operate during high rainfall and discharge conditions.

Table 6.1 presents details of the ten clean-outs performed manually. The following four figures illustrate data from Table 6.1. Figures 6.4 and 6.5 show the organic and total load plotted against rainfall volume and runoff volume; with a line of best fit drawn for the total load, while Figures 6.6 and 6.7 show litter loads plotted against rainfall and runoff. Other variables were plotted against the gross pollutant loads (maximum discharge rate, days between runoff events and a function describing the shape of the hydrograph) however these plots showed low correlations and are not presented here.

Table 6.1 Details of trapped material from ten clean-outs of the CDS device

Clean date	Runoff events	Days between cleans	Runoff (mm)	Rain (mm)	Gross pollutant volume	Total WET mass	Human derived DRY	Organics DRY	DRY MASS
		days	mm	mm	m3	kg	kg	kg	dry g/ha
13-May-96	1	7	5	20	0.39	176	11.1	37.5	972
22-May-96	1	10	1	9	0.27	62	7.4	13.0	408
24-May-96	1	2	1	3	0.08	14	0.9	2.2	62
21-Jun-96	1	28	3	12	0.34	95	13.2	17.2	608
27-Jun-96	1	6	21	48	0.99	253	18.4	62.7	1621
4-Jul-96	3	7	6	20	0.85	239	12.6	58.2	1417
10-Jul-96	1	6	2	8	0.32	51	4.4	10.9	307
18-Jul-96	1	8	3	13	0.33	77	6.1	16.3	447
24-Jul-96	1	6	2	11	0.32	55	5.3	8.8	283
2-Aug-96	2	9	13	39	0.73	163	13.2	42.3	1109
Total	13	89	56	181	4.6	1184	93	269	7233

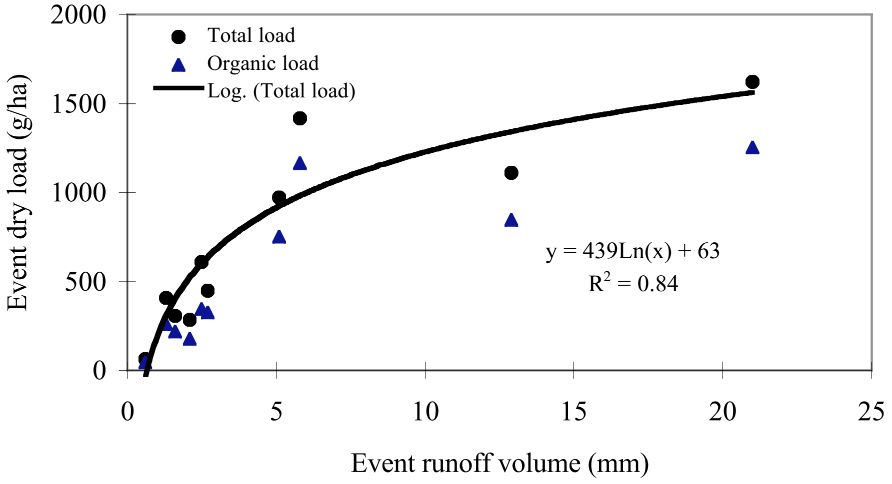


Figure 6.4 Runoff against total and organic loads for the ten clean-outs

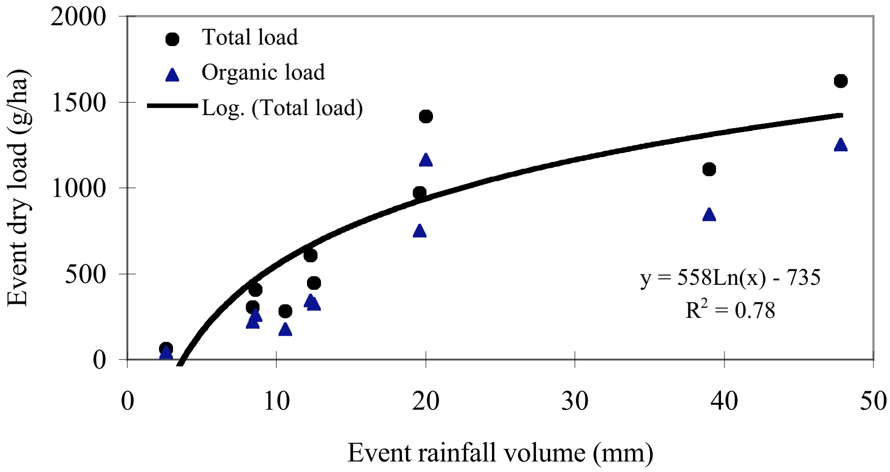


Figure 6.5 Rainfall against total and organic loads for the ten clean-outs

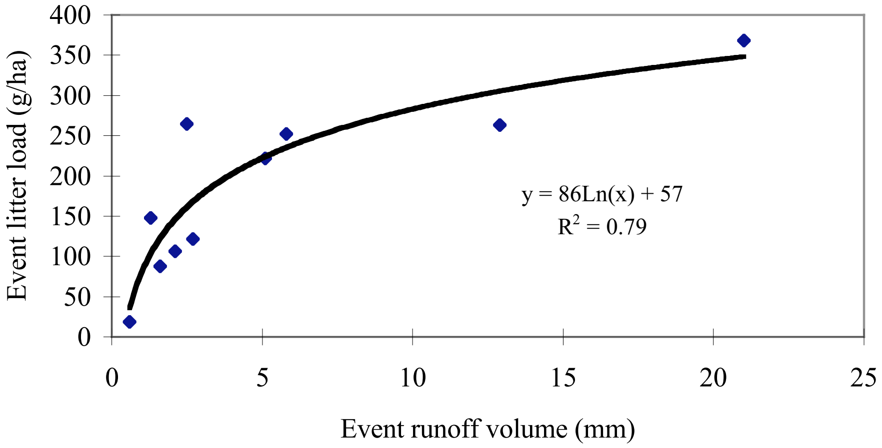


Figure 6.6 Runoff against litter loads for the ten clean-outs

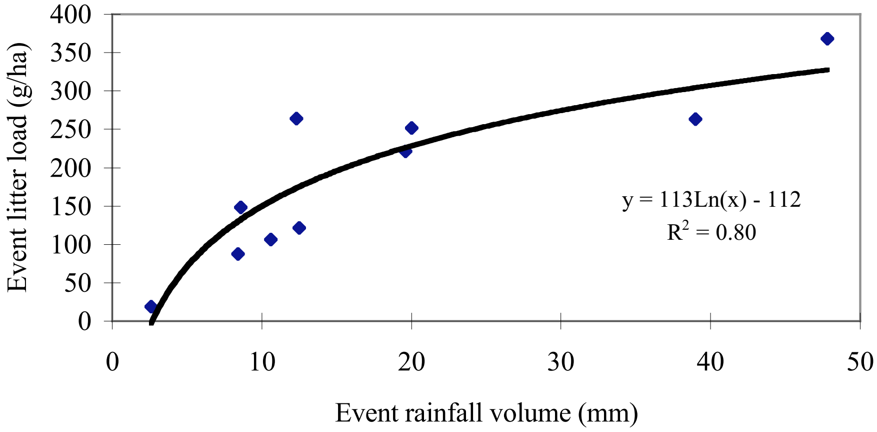


Figure 6.7 Rainfall against litter loads for the ten clean-outs

Analyses of the loads collected from the CDS device during monitoring show that both rainfall and runoff display a strong correlation to load. These relationships are used in the decision-support-system

(DSS) to derive daily loads. In the DSS rainfall is taken as the explanatory variable for gross pollutant loads because rainfall data are more widely available than runoff data.

It should be pointed out that these data were collected during only three months of monitoring. These data are used because they are the best data available in which the amount of gross pollutants conveyed in a stormwater system was measured. Due to the limited nature of the data, the relationship between rainfall and loads will need to be improved as more monitoring data become available.

6.3 SIZE DISTRIBUTION OF LITTER

A size grading was performed for a sample of litter trapped by the SEPTs in clean-out 4. Mesh sizes of 122, 68, 20 and 12 millimetres were used and the percentages of mass passing each screen are plotted in Figure 6.8 (these were the only mesh sizes available). This information is useful for government agencies when considering regulations for a minimum size of gross pollutant to capture; and for designing new trapping techniques for litter items. For example, Figure 6.8 implies that at least 90% of material (by mass) would be retained by a 20 millimetres size mesh screen.

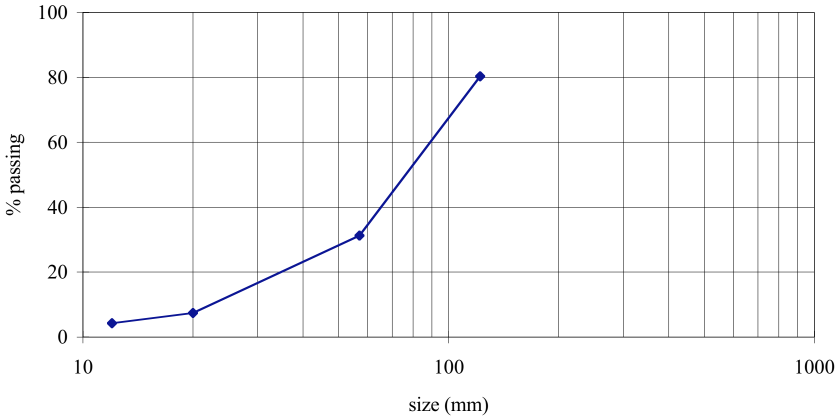


Figure 6.8 Size distribution of litter items caught by SEPTs

6.4 AN ITEM COUNT

A detailed item count of the trapped material was carried out for the first clean-out of the SEPTs and the CDS device together. In total 10,901 items were counted in the material collected over a 27 day period with 57mm of rainfall during the period. To compare these numbers with published data, the field results required extrapolation to the whole of greater Melbourne, for a typical year, using the sampling period and rainfall over that period to extrapolate the figures, as Table 6.2 shows.

Table 6.2 Extrapolated annual number of litter items in Melbourne's waterways

	Urban catchment area	Days accumulation	Number of litter items
	hectares	days	items
Coburg	50*	27*	10901*
Melbourne	600,000	365	1,800,000,000
	Urban catchment area	Rainfall (mm)	Number of litter items
Coburg	50*	57*	10901*
Melbourne	600,000	650	1,500,000,000

* measured data

McKay & Marshall (1993) estimate 4 to 5 million items per year of floating litter in Melbourne's waterways. Their study used: efficiency ratings for floating booms (determined with floating tagged litter items); volumes collected by the floating booms; and an estimate of the number of items per cubic metre; to estimate the annual number of items in Melbourne's waterways. From analysing collected material in the CDS device it was concluded that floating litter items represent only 20% of total litter load (Section 6.1). Therefore the estimate of 4 to 5 million items annually for Melbourne's *floating* litter becomes 20 to 25 million items for a *total* litter load.

Results from this study estimate between 1,000 and 3,000 million items of litter travel in Melbourne's stormwater systems annually (Table 6.2). The large difference between the two estimates (orders of magnitude) could be because of the detail of this study (ie. the minimum size of material counted) or the inappropriate nature of this extrapolation. Material counted during this study included items down to five millimetres in size, including individual cigarette butts, bus tickets and packing styrene pieces. An estimate of 5,000 items of litter per cubic metre from actual counted data in this study is much higher than the estimated 190 items per cubic meter used by McKay & Marshall (1993) and highlights the difference in the definition of the size of a litter item between the two studies. Extrapolating Coburg results for the whole of greater Melbourne could potentially influence the accuracy of the estimate as the characteristics of Coburg are unlikely to be consistent with the rest of Melbourne. The experimental sample used to derive this estimate was obtained from one month of monitoring. It is likely that seasonal factors would influence the actual numbers transported during different times of the year. Despite these potential sources of error the estimate is still much larger than McKay and Marshall's (1993) value.

Of the 10,901 items, the most numerous items were: cigarette butts (2500), pieces of paper (2400), plastic food wrappers (1200), paper food containers (1150) and plastic cigarette wrappers (950) and are plotted in Figure 6.9. An interesting observation was the high percentage of cigarette related items (40%).

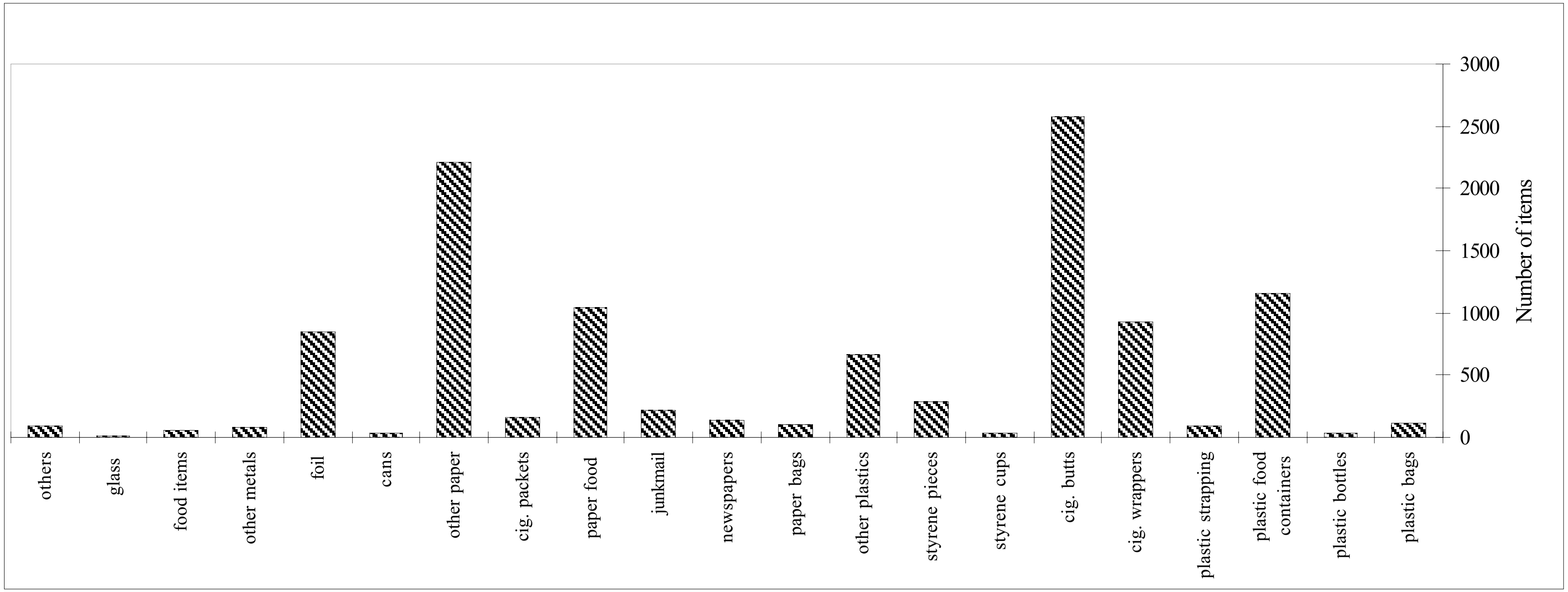


Figure 6.9 An item count of litter collected in SEPTs after 27 days

6.5 NUTRIENT CONTRIBUTION OF GROSS POLLUTANTS

Trees in urban areas can shed large quantities of leaves. The fallen leaves are potential contributors of nutrients as they break down in catchments and in urban waterways. This section focuses only on organic matter (mainly leaf litter) in urban stormwater and whether removing leaf litter from stormwater can significantly reduce nutrient loads in urban waterways.

There is some information in the literature on the nutrient composition of leaf litter and the proportion of this that can leach into water. However, the nutrient impact also depends on the amount of leaves in the stormwater, and there is practically no data on this. This section provides estimates of the amount of nutrients that can leach from stormwater leaf litter using data from the 10 clean-outs performed on the CDS device (Chapter 5). This estimate is then compared with typical nutrient loads in urban stormwater, and some implications on the management of leaf litter in urban waterways are discussed.

6.5.1 Nutrients in Leaf Litter

Prasad et al.'s (1980) analyses of autumn leaf litter from five deciduous tree species in metropolitan Toronto, Canada, indicate that the total phosphorus (TP) and total nitrogen (TN) compositions range from 0.07 to 0.26% and 0.7 to 1.2% respectively (expressed as percentage of dry weight of leaves). Dorney (1986) reported TP composition of leaf litter ranging from 0.06 to 0.44% for residential street trees in Milwaukee and Shorewood, USA. Dorney also acknowledged that TP in the urban street leaves are similar to TP of trees of similar species in natural ecosystems. Attivil and Leeper (1990) report TP and TN compositions of up to 0.1% and 1.2% respectively in leaf litter in Australian forests.

Prasad et al.'s (1980) experiments indicate that 0.006 to 0.07% and 0.05 to 0.24% of dry leaf weight of TP and TN respectively can leach into deionised water. Their experiments also suggest that 48 hours is adequate to leach out most of the soluble substances. Dorney (1986), soaking leaves in distilled water for two hours, reported leaching of TP of 0.004 and 0.026% of dry leaf weight. Cowan and Lee (1973), soaking oak and poplar tree leaves from Madison, USA, for 1.5 hours in distilled water, reported leaching of TP of 0.005 to 0.023%. Riley and Abood (1995) applied different treatments to a rubbish sample from a shopping centre in Sydney, Australia (soaking the sample in aerated and non-aerated stormwater and deionised water) and recorded concentrations of several water quality parameters over 262 days. Assuming that all recorded TP and TN came from leaf litter, their data indicate that approximately 0.003 and 0.05% of dry leaf weight of TP and TN respectively leached into deionised water.

In summary, there is general agreement in the values reported by the various studies. The samples in the North American studies consist mainly of leaf litter from deciduous trees, while urban areas in Australia generally have a mixture of evergreen and deciduous trees. The TP in leaf litter is about 0.05 to 0.45% of dry leaf weight, while the TN is about 0.7 to 1.2% of dry leaf weight. About 5 to 20% of the nutrient in leaf litter can leach into stormwater.

6.5.2 Potential nutrient contribution of leaf litter

After each clean-out of the CDS device the collected pollutants were then taken to a laboratory and sorted into various classifications (for example, plastic, paper, metal and organic material). The bulk of the material was organic matter, and observations during the sorting suggest that more than 90% of this was leaf litter (leaves and twigs). Samples of the organic material were then tested for TP and TN contents at a NATA (National Assessment and Testing Association) registered laboratory for each clean-out.

Table 6.3 shows the dry mass of litter and organic material, the TP and TN compositions of the organic material, and the runoff for the periods between cleans. The TP and TN compositions in the organic material are similar to the nutrient compositions of leaf litter reported in the literature (see Section

6.5.1). The total TP and TN in the organic material in the stormwater, calculated as the nutrient composition multiplied by the total organic material, are shown in the last two columns of Table 6.3.

Table 6.3 Results from nutrient testing of trapped organic gross pollutants

Clean date	**runoff (mm)**	**Organic mass**	**TP conc. for dry organics**	**TN conc. for dry organics**	**TP load from organics**	**TN load from organics**
	mm	kg (dry)	g/kg	g/kg	g	g
13-May-96	5.1	40.0	0.8	7	32.0	280
22-May-96	1.3	13.4	0.9	14	11.7	188
24-May-96	0.6	2.4	0.9	13	2.2	31
21-Jun-96	2.5	19.3	2.8	19	54.0	367
27-Jun-96	21.0	64.7	2.0	22	129.4	1423
4-Jul-96	5.8	61.3	1.1	10	67.4	613
10-Jul-96	1.6	11.2	1.0	10	11.2	112
18-Jul-96	2.7	17.1	1.0	12	17.1	205
24-Jul-96	2.1	9.4	1.1	13	10.3	122
2-Aug-96	12.9	44.0	1.4	16	61.6	704
Total	55.6	283			397	4045

The table indicates that almost 80% of the stormwater gross pollutant consist of organic material (which is mainly leaf litter). It also indicates that the total TP and TN in the organic material over the three-month period were approximately 0.4 and 4.0 kg respectively. With a total runoff volume of 57 mm, the TP and TN in the stormwater organic material can also be expressed as an average of 0.01 mg/L and 0.14 mg/L respectively. Of these, approximately 5 to 20% can potentially leach into the stormwater (see Section 6.5.1).

Water quality testing of stormwater samples taken from the same catchment indicated that TP concentrations of stormwater were generally between 0.3 and 0.6 mg/L (although concentrations as high as 3 mg/L were found) and TN concentrations were between 1.5 and 4 mg/L (concentrations as high as 6 mg/L were recorded) (see Section 4.7.4). These concentrations are within the large range of values reported in the literature for fully developed urban areas in Australia and other parts of the world (Athayde *et al.*, 1983; Chiew *et al.*, 1997; and Duncan, 1997).

The above values indicate that the potential nutrient contribution of stormwater leaf litter in this catchment is about two orders of magnitude smaller than the nutrient loads measured from water samples in the stormwater. The catchment has a mixture of evergreen and deciduous trees, and is typical of many inner-city suburbs in south-east Australia. The monitoring was carried out in late autumn and early winter, and it is likely that the gross pollutant characteristics would be different at other times of the year. Nevertheless, even allowing for the seasonal differences, and the variability in tree species and gross pollutant characteristics between catchments, the values reported here indicate that leaf litter in stormwater contributes little to the total stormwater nutrient load.

6.5.3 Management Implications

Despite a large amount of organic material (larger than 5 mm) being transported by stormwater, it contributes little to the total stormwater nutrient load. As such, removing leaf litter from waterways would not significantly reduce nutrient loads reaching receiving waters. However, because of their large volume, leaf litter and plant matter may need to be considered when designing litter trapping devices, and where they could cause blockages or smother aquatic habitat.

Another implication relates to the monitoring of stormwater nutrient loads. Although conventional methods use sampling bottles that do not admit large material, they provide an accurate estimate of nutrient concentrations because stormwater gross pollutants are not a significant source of nutrients.

7. PERFORMANCE OF CDS DEVICE

The performance of the CDS device is assessed in terms of its trapping efficiency for gross pollutants (defined in Section 3.1), its influence on the water quality parameters in the stormwater, the hydraulic characteristics of the unit (afflux, capacity and head losses), and the required maintenance for long term operation.

The field trials suggest that the CDS unit is an efficient gross pollutant trap. During 12 months of monitoring practically all material greater than the minimum aperture size of the separation screen (4.7 mm) was retained in the separation chamber and the hydraulic impedance of the unit appears to be quite low compared to other trapping techniques. Two cleaning techniques were assessed and a large diameter vacuum was best suited to the Coburg installation requiring a 3-monthly cleaning frequency.

7.1 TRAPPING EFFICIENCY

Two acoustic flow meters (which measure water depth and velocity data) were used to monitor discharge, one located 8m upstream of the CDS unit and one 7m downstream (see Figure 5.2). These probes provided estimates of discharge rate and volume and allowed investigation of the afflux and hydraulic losses caused by the system. Pressure sensors were also installed across the top of the overflow weir to collect depth data. The depth data provided estimates of the capacity of the device and the proportion of discharge volume which bypassed the treatment chamber via the overflow weir.

There is only one feasible route for material to pass the CDS device as described in Section 5.4.1. It occurs when flows over-top the diversion weir and bypass the CDS trap carrying pollutants downstream and therefore passing the trap. During times when the diversion weir is not over-topped, the only pathway for material is through the CDS screen, and given that gross pollutants are defined as material retained by a 5 millimetre screen this is not possible. Therefore measuring the amount of discharge going over the weir is critical for determining the CDS efficiency and instrumentation was located with this in mind.

When the diversion weir is over-topped the significance of any material passing the trap was estimated from the amount of discharge that surcharged the diversion weir compared to the volume that passed through the device. Although this gave no indication of the amount of gross pollutants that were transported downstream, it provided an insight to the discharge proportion that bypassed the unit. It was not feasible to locate a gross pollutant sampler (as used in Chapter 4) downstream of the device because of limited access points.

The instrumentation indicated that less than 1% of stormwater flowed over the weir during 12 months of monitoring as overflows only occur during the highest discharges. In estimating the amount of material passing over the weir it is assumed that the amount is proportional to the discharge that flows over the weir (ie. assuming the water overflowing the weir has an event mean concentration of gross pollutants). In addition, as material captured cannot return back to the stormwater system, it is reasonable to expect 100% capture rate of material larger than the separation screen size that enters the separation chamber. Therefore, the trapping efficiency of the CDS device was estimated to be approximately 99% efficient during the 12 months of monitoring.

The trapping efficiency for material less than the mesh size is unclear although laboratory studies by Wong et al. (1995) have indicated a high percentage (near 95%) of captured sediment of sizes down to 50% of the separation screen aperture size. The field data from the Coburg study indicated that 90% of the sediment collected from the unit was less than the mesh size as illustrated in the size grading presented in Figure 7.1. This suggests that the CDS unit traps finer sediments than the separation screen, however the quantity that pass the unit are unknown. Results of water quality testing of samples collected upstream and downstream of the device suggest that the CDS device retains some suspended sediments during the early part of a runoff event (see the next section).

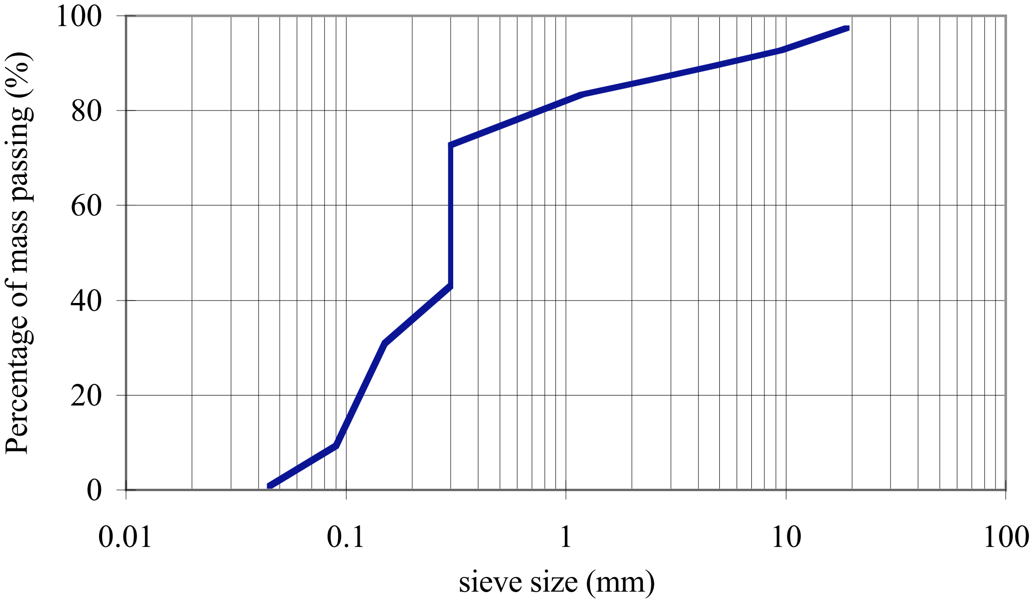


Figure 7.1 Size gradings for sediments collected from the CDS sump

7.2 WATER QUALITY RESULTS

Water samples from seven storm events have been collected and analysed from upstream and downstream of the CDS unit. In addition, low-flow water samples were collected from upstream and downstream of the CDS unit and from within the CDS unit sump over a 12 month period. The samples were then analysed in the laboratory to determine concentrations of TN, TP and TSS. This information, along with discharge data for a substantial water quality data set for an urban catchment can provide insights into the water quality effects of a CDS unit. Data collected upstream of the trap also has the potential for use in pollutant modelling studies, improving the understanding of urban stormwater runoff quality.

As described in Section 5.4.1 the stormwater samples were tested using a Merck Photometer (Merck, undated) in a laboratory at the University of Melbourne. To check the validity of the results from the Merck unit, duplicates were sent to a NATA certified laboratory (Water EcoScience, Victoria) and the results of the two analyses are compared in Figure 7.2. The results indicate that the Merck device appears to be accurate compared with certified laboratory results, within the variations expected in sub-sampling stormwater samples for analysis.

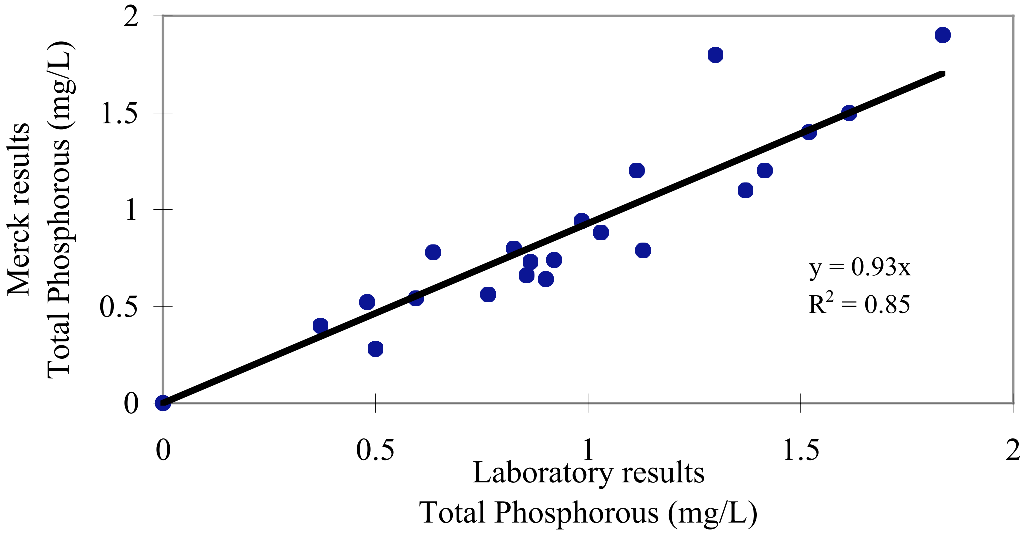


Figure 7.2 Plot of stormwater TP concentrations comparing results using a Merck Photometer (see Section 5.4.1) and a certified laboratory

Storm Event Water Quality:

Analyses of seven storm events show that the maximum concentrations of TN were around 7 mg/L but concentrations were generally between 1.0 to 3.5 mg/L, TP concentrations generally range between 0.2 to 0.6 mg/L with the highest recorded concentration 2.5 mg/L and TSS concentrations generally did not exceed 150 mg/L, however a maximum of 600 mg/L was recorded. All results show a trend of higher concentrations recorded in the early parts of the storm and decreasing with its duration. Two typical storm events are presented in Figures 7.3 and 7.4 and Appendix B contains the other five storm events.

Figures 7.3 and 7.4 indicate that the CDS unit influences downstream water quality during the early stages of storm event runoff by reducing the amounts of TSS, TN and TP. Results from the seven events appear to suggest that inflows with TSS exceeding 200 mg/L are effectively reduced to a baseline level of between 150 mg/L and 200 mg/L. Both upstream and downstream samples show similar trends for TSS concentrations, that is, the highest concentrations occur early in the event and decrease with the duration of the storm.

The same trend is apparent for TN and TP and could be related to the sediments being retained by the CDS unit. Analysis of sediment removed from within the sump showed that 90 % was smaller than the mesh size indicating that some sediment retention is performed by the CDS unit (Figure 7.1). This is consistent with the reduction in TSS early in the storm events when the inflows have the highest concentrations of sediments. When values of TSS are less than 150mg/L there appears to be little influence by the CDS and therefore less variation in upstream and downstream concentrations (shown in Figures 7.3 & 7.4 and Appendix B).

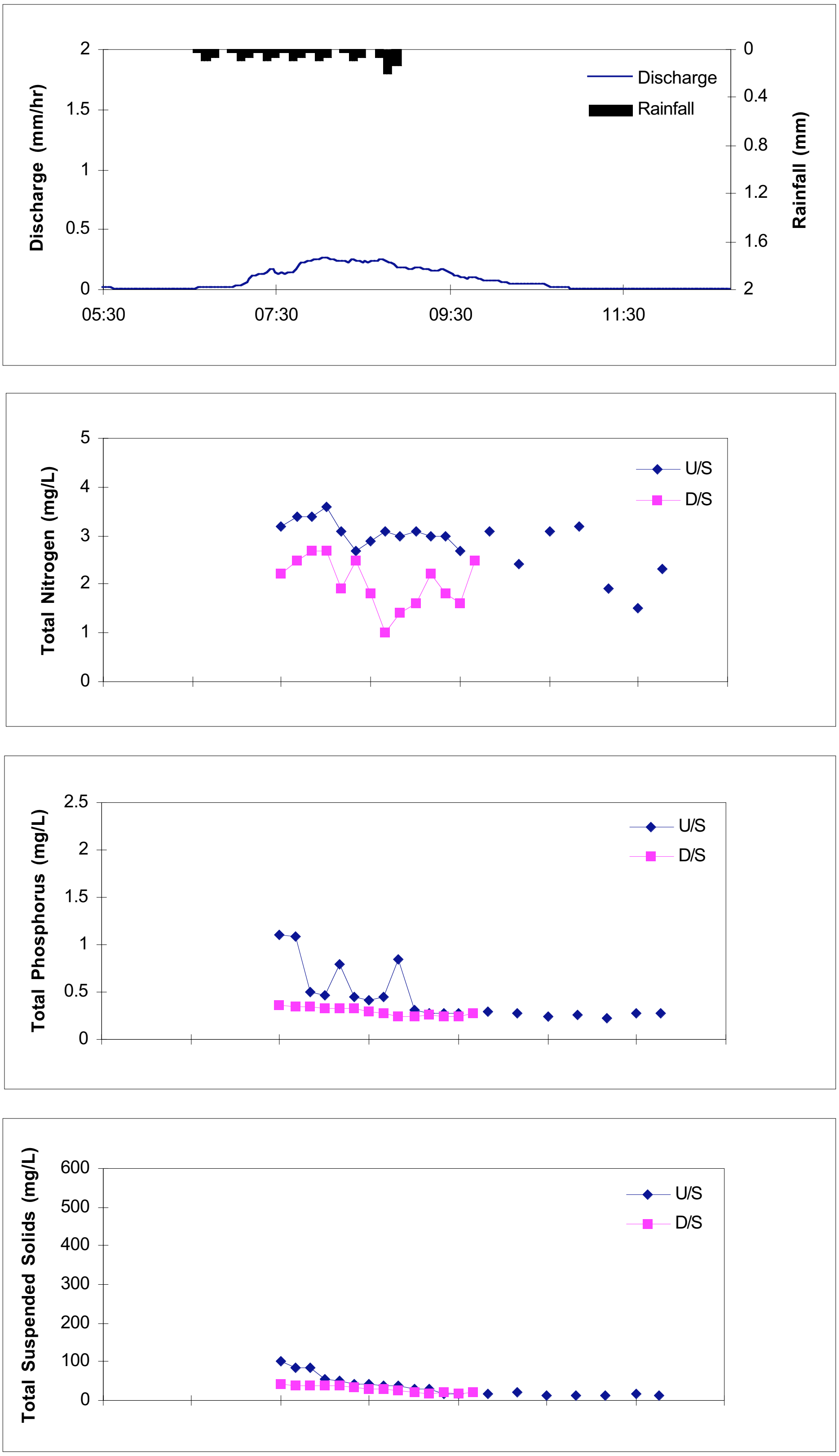


Figure 7.3 Rainfall, discharge and upstream/downstream water quality concentrations on 3 May 1997

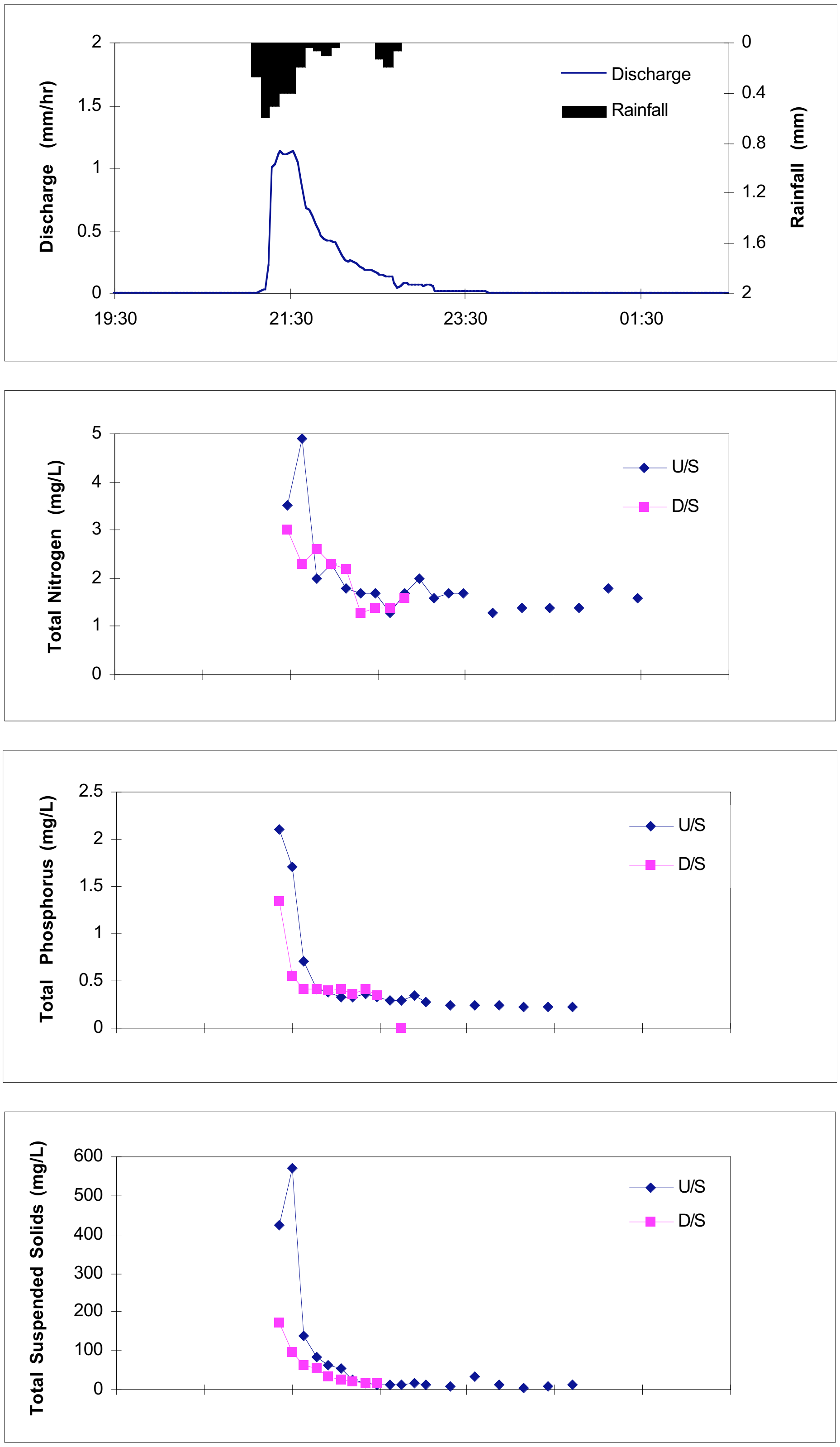


Figure 7.4 Rainfall, discharge and upstream/downstream water quality concentrations on 5-6 June 1997

Dry Weather Water Quality:

A summary of testing results for the low-flow water samples is presented in Table 7.1. To illustrate the influence of the CDS trap in dry weather flows upstream water quality concentrations are plotted against downstream (Figure 7.5).

Table 7.1 Summary of low-flow water quality testing

Date	TESTED FOR TOTAL PHOSPHORUS TP mg/L					TESTED FOR TOTAL NITROGEN TN mg/L					TESTED FOR TOTAL SUSPENDED SOLIDS TSS mg/L				
	U/S	**D/S**	**1m**	**2.5m**	**Sump**	**U/S**	**D/S**	**1m**	**2.5m**	**Sump**	**U/S**	**D/S**	**1m**	**2.5m**	**Sump**
12-May-96	0.7	0.3				2.3	1.2								
13-May-96	0.3	0.8	0.4		0.4	2.1	1.2	1.2		1.3	04	07	03		
22-May-96	0.5	0.5	0.5		0.5	1.4	1.2	<1.0		2	02	07	13		04
17-Jun-96	1.2	1.3	1.4		1.2	1.5	2	2.3		2.1	49	50			
17-Jun-96	1.2	1.3	1.4		1.4	2.4	2.3	1.8		2.1	53	54			
21-Jun-96	0.9	4.5	1.2		1.6	1.3	5	1.4		2.2	202		22		16
03-Jul-96	1.7	2.1	2		1.7	1.5	2.8	2		2.6	07	22	07		05
10-Jul-96	12	3.2	2.1		2.5	5.8	2.8	1.8		2.2	81	48	06		07
18-Jul-96	5		2.3		2.7	1.8	2.3	1.6		1.8	16	24	22		21
24-Jul-96	0.8	1.2	1.4		1.4	1.6	1.7	1.5		1.5	23	31			83
28-Jan-97	1.4	1.1	1.2	1.2	1.2	3.5	2.4	3.3	3.2	3.4	06	12	09	13	32
12-Feb-97	1.5	1.1	1.2	0.8	1	3.8	3.8	3.5	3.1	3.6	29	14	19	10	38
20-Feb-97	1.2	1.5	0.5	1.2	1.6	3.7	3.6	3.2	5.7	6.2	67	18	09	32	268
25-Feb-97	0.6	1.5	0.7	0.5	0.6	3.2	3.2	3.3	3	6.7	17	14	100	56	437
07-Mar-97	0.8	0.6	0.7	0.7	1.1	3.4	3.7	4.6	4.4	7	04	09	87	80	91
14-Mar-97	1.3	0.7	1.2	1	2.5	3.5	3.1	4.2	5.4	5.8	05	04	24	32	606
21-Mar-97	0.9	0.8	1.1	3.2	1.5	2.8	2.9	3.2	3.3	8.1	12	11	28	72	143
07-Apr-97	0.7	0.4	1.1	1	1.5	3.1	3	3.2	5.3	7.7	03	15	07	19	27
11-Apr-97	1.1	0.8	1.1	1.2	1.6	2.8	2.3	3.6	3.2	3.5	11	03	20	69	88
02-May-97	0.9	1.1	1.4	1.4	1.5	2	2.1	2.8	3.8	4.2	07	25	49	291	167
23-May-97	1.8	1.2	1.3	3.4	3.5	2.8	2.1	2.9	9.1	9.1	10	55	88	552	513

The results presented in Figure 7.5 indicate that the CDS appears to have little impact on low-flow water quality. This trend was consistent over a range of concentrations for all except a few outlying points (ie. the points which would deviate from a 1:1 line in Figure 7.5). Upstream and downstream water sample concentrations for TP generally range between 0.3 and 2.0 mg/L with the highest recorded concentration at 4.5 mg/L, TN values are within a larger range of between 1.5 and 4.0 mg/L with two outlying concentrations of 5 mg/L for downstream and 5.8 mg/L for upstream. TSS concentrations are generally low and compared to storm event results show more variability in comparison to TP and TN. These results indicate that the CDS unit has little affect on TN, TP and TSS during low-flow conditions.

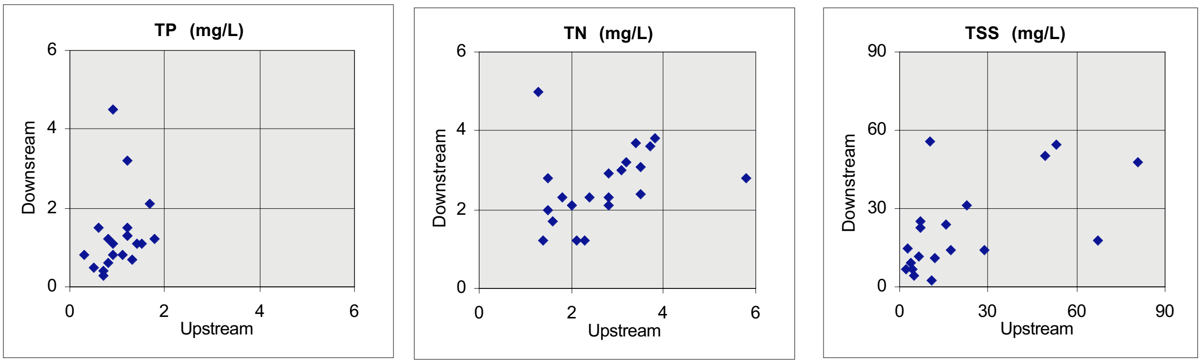


Figure 7.5 Plots of low-flow U/S and D/S water quality parameters.

Water samples taken from within the CDS sump (from depths 1.5m, 2.5m and at the bottom of the sump) provide insights into the breakdown of pollutants as they are retained over long periods of time (up to three months between clean-outs). The results show that concentrations of pollutants found in the sump were highest in the deepest parts (2.5m and bottom) indicating breakdown of material at the bottom and limited mixing in the collection chamber during dry weather.

The samples collected at the top of the collection chamber showed similar concentrations to those taken from upstream and downstream of the unit. This would suggest that water passes through the device without significant mixing with the more concentrated water deep in the sump during dry weather flow conditions.

7.3 HYDRAULIC CHARACTERISTICS OF CDS UNIT

The hydraulic performance of the CDS device is assessed in terms of the afflux (the rise in upstream water level) caused by the presence of the unit, the discharge capacity of the unit (defined as the maximum discharge passing through the collection chamber without water passing over the by-pass weir) and the head-losses caused by the device.

An example of data collected by the monitoring instruments is presented in Figure 7.6. The plot shows the upstream, downstream and weir depths for a large event that flowed over the by-pass weir. It indicates a large difference between upstream and downstream depths during high discharges, and especially when the by-pass weir was flowing. This suggests the CDS device causes increased upstream water levels.

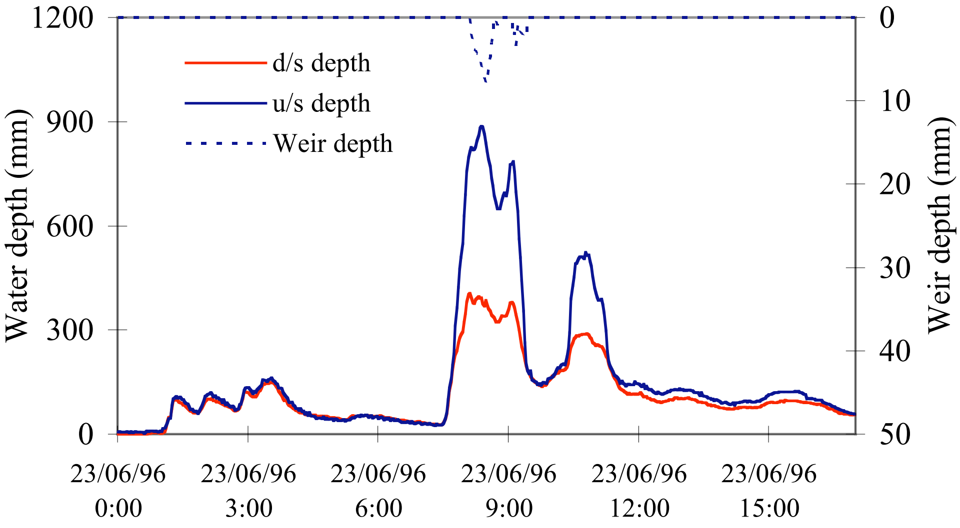


Figure 7.6 Plot of water depths for upstream, downstream and across the weir of the CDS unit during a large event

The presence of the CDS unit causes water to pond upstream of the diversion weir. The magnitude of the water level rise caused by the presence of the CDS unit (afflux) is estimated here by assuming that the downstream water depth is representative of the water level at the upstream location if the trap were not installed. Therefore, the afflux caused by the trap is estimated by calculating the difference between the upstream and the downstream water depths recorded by the monitoring instruments. The afflux caused is calculated over a range of discharges and these values are presented in Figure 7.7. The relationship indicates that the CDS device causes an increase in the upstream water levels and that the rise increases with the discharge. The increase in water depth could act to reduce the capacity of the drainage system upstream of the CDS unit, but there were insufficient data on events of significant by-pass flow conditions to assess the degree in which the capacity of the drainage system upstream is reduced.

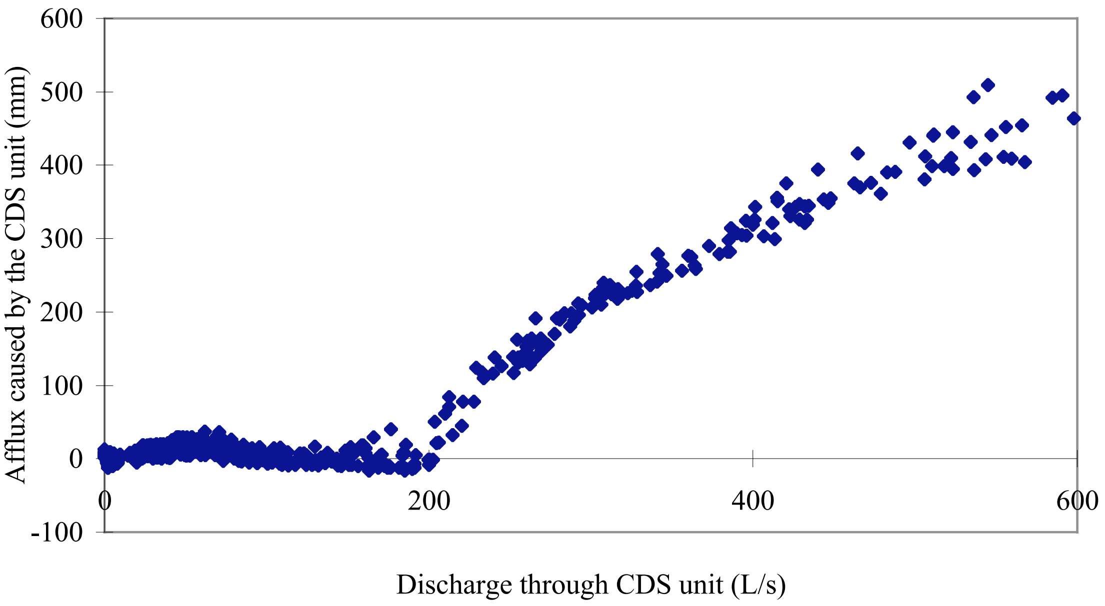


Figure 7.7 Estimated upstream water level rise caused by the presence of the CDS device (during a large event on 23-6-96)

The capacity of the CDS unit is estimated by noting the discharge at the downstream *Starflow* instrument at the moment the by-pass weir begins to flow. The downstream *Starflow* unit is used to estimate discharge because it is not affected by the disturbance caused by the CDS device (unlike the upstream *Starflow* instrument). The pressure transducers (that measure water depth) placed on the top of the diversion weir were used to determine the time when discharge commenced over the by-pass weir (ie. when depths were greater than zero).

The capacity of the CDS unit was estimated by considering three large runoff events. During two of these events water flowed over the by-pass weir, while the third event had a high discharge rate, but was insufficient to cause water flow over the by-pass weir.

During two of the runoff events water flowed over the by-pass weir and therefore, by definition, exceeded the capacity of the unit. Therefore, the capacity of the CDS system was estimated to be less than the maximum discharge rate from these events (598 L/s and 568 L/s respectively). The capacity of the unit is equal to or larger than the maximum discharge rate during the third event, as the flow did not pass over the by-pass weir (530 L/s). Hence, the capacity of the unit is estimated to be between 530 L/s and 570 L/s. There is no indication which is closer to the true capacity of the unit and therefore, the capacity is estimated to be 550 L/s for the Coburg installation.

Channel-mean velocity and centre depth data are derived from the *Starflow* instruments, located some distance upstream and downstream of the unit (Figure 5.2). These values are used in the one dimensional energy equation (Equation 7.1) to estimate the difference in total hydraulic head between upstream and downstream. The difference between the upstream and downstream values includes the friction losses caused by the drain between the two instruments as well as the losses caused by the CDS unit. Assuming the friction loss is equal to the bed slope, an estimate of the loss caused by the CDS unit can be made. This was done for a number of discharges and the resultant losses caused by the CDS unit are presented in Figure 7.8.

$$H = d + \frac{v^2}{2g} + z \qquad \text{(Equation 7.1)}$$

H = total head

v = channel mean velocity
d = channel centre depth
z = elevation from datum
g = gravitational constant (9.8 m/s^2)
all in SI units

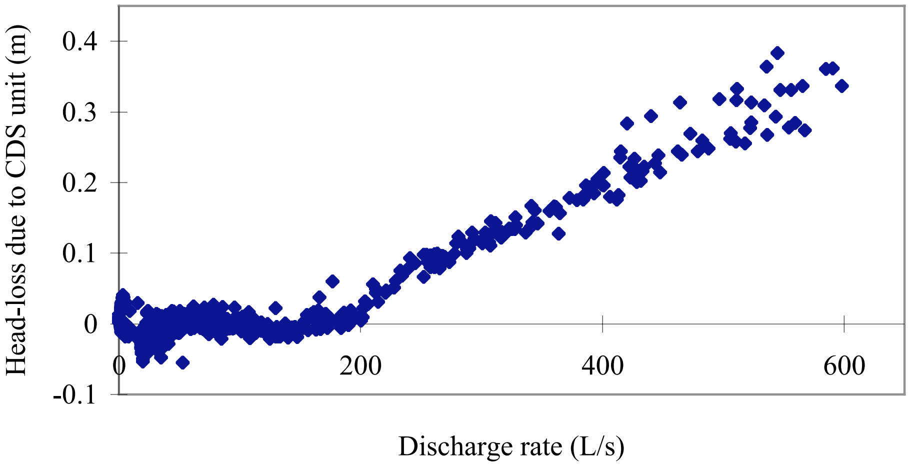


Figure 7.8 Estimated head losses caused by the CDS trap (during a large event on 23-6-96)

Figure 7.8 shows that the head-loss values attributed to the CDS unit increase with discharge. The maximum energy loss caused by the device was approximately 0.4 metres and occurred at the commencement of bypass flow (approximately 550 L/s). Higher head losses are possible under by-pass conditions.

The head loss coefficient is in the order of 1.3 which is less than a typical junction pit. The small losses make the CDS system suitable in a range of urban locations including low-lying areas, and is the only trapping system, with a high capture rate, to achieve this.

7.4 MAINTENANCE OF CDS SYSTEM

The Coburg CDS unit was cleaned manually for the first six months of the field trials for the purpose of examining the contents in detail. After this period two alternative long term cleaning methods were examined. Firstly, the contents of the CDS were educted by a large diameter (150 mm) high powered vacuum and secondly, a basket was fitted into the sump of the separation chamber and material that settled into the sump was removed by lifting the sump-basket onto a disposal truck.

Eduction cleaning method:

The eduction process (vacuuming material out of the sump) took four hours to remove all of the collected pollutants and yielded approximately 4 tonnes of wet material. This cleaning method left the CDS unit empty of water and pollutants and therefore an inspection of the unit ensured that no material remained in the chamber (Photographs 7.1).

Photograph 7.1 Cleaning the CDS unit with a large vacuum device

Sump-basket cleaning method:

With the site located in a roadway the covers over the separation chamber were required to be very strong and this limited the span of the opening to the CDS unit (see Photograph 5.6). This meant the opening at road level was smaller than the full width of the separation screen and therefore the basket could only be installed to the width of the sump (the size of the opening - 1800 mm, which is located in the centre of the chamber), not to the edge of the separation screen (3000 mm diameter). Consequently, material could deposit around the outside of the sump and not be removed when the sump-basket is raised. The proportion that remained behind after removing the sump-basket was investigated during cleaning. By pumping the water from the chamber (in the same way as described in Section 5.4) after the basket had been removed, the remaining material could then be manually removed. The wet mass recovered was then compared to the mass removed in the basket.

Photograph 7.2 Removing the sump-basket from the CDS unit

The sump-basket recovered 0.8 tonnes of wet material from the CDS unit. After pumping the water from the sump and manually removing the remaining material a further 1.1 tonnes of wet material (58% of the total mass of collected material) was removed. The large amount of material that was left behind after the sump-basket was removed appeared to have settled around the edge of the sump basket and failed to slide into the sump.

Comparison of two methods at Coburg:

In summary, comparison of the two methods for cleaning the CDS unit in Coburg suggests the suction method to be the preferred option. In fact, the suction method appears to be the only feasible method to remove all of the collected pollutants without manual handling at the Coburg unit (which has the disadvantage of the covers over the separation chamber not spanning the full width of the chamber).

The suction method has the advantages of:

minimal road disturbances (only required to remove two lids, Photograph 7.1);
no manual handling of material; and
only one machine and two people are required.

However, the suction truck is a specialised piece of equipment and may not be available for a wide range of installations. An estimated costs for the cleaning process at the Coburg unit after three months without cleaning is $1000 per clean (excluding dumping costs).

The main limitation of the Coburg site for the sump-basket installation is the size of the opening above the separation chamber through which the sump-basket is raised. Observations in Coburg suggest that the sump-basket misses considerable pollutants when it is raised. Limitations with this method listed here relate directly to the Coburg CDS unit because of the small covers (which are not typical for CDS units not positioned on roads). Should a sump-basket span the full width of the separation chamber an improved removal rate would be expected. Costs for cleaning the Coburg unit are estimated to be more expensive than the eduction method ($1200-1500). The method requires two large pieces of equipment (20 tonne crane and a disposal truck) which adds to the complexity of organising a clean-out.

The main limitations with the sump-basket cleaning method in Coburg were:

large disturbance with road closure during basket removal;
long set-up time to removed nine lids and two cross beams (a crane is required);
large crane is required to remove the potentially heavy basket (20 tonne crane used in the trial);
requirement of manually placing floating material into the collection basket (with pool scoop);
unable to inspect remaining material after cleaning (as the chamber remains full of water); and
a large amount of material is left behind after the sump-basket is removed.

8. PERFORMANCE OF SEPTS

The performance of SEPTs was assessed in terms of their trapping efficiency for gross pollutants and the distribution of the loads caught by individual traps.

SEPTs can trap significant quantities of gross pollutants. They are cheap, simple to install and can be used to target specific areas because they can be installed on individual drainage entrances. Although they cannot remove all gross pollutants from the drainage network, the monitoring here indicates they can capture up to 85% of the litter load and up to 75% of the total gross pollutant load entering the drainage system, if placed on all public road entrances.

Regular maintenance to clean traps implies that putting traps everywhere (ie. 100% coverage of road entrances) is unlikely to be feasible. It is therefore imperative to choose the entrances that contribute the most loads to the drainage system when only a proportion of the total can be selected. Results indicated that it is possible to put traps on about half of road entrances and capture about two thirds of the litter load and half of the total load. Comparing the loads caught by those same traps in three subsequent storms suggested that it was the same traps that continued to catch the majority of the load. In addition, the monitoring indicates that side entry pits and side entry pits with grates are the entrances that should be targeted. The results also reveal that commercial areas not only have the most pits per area but each commercial pit contributes more litter than any other land-use type and should therefore be targeted.

8.1 INTRODUCTION

Altogether 192 SEPTs were installed in the 50 hectare catchment. These were installed to cover all publicly owned entrances to the drainage system and included three different types: grates, side entry pits, and side entry pits with grates. The catchment areas draining into the entrances were classified to have either residential, commercial, or light-industrial land-uses. The numbers of different entrances and catchment types are shown in Table 8.1 and Photographs 8.1 to 8.3 show examples of the different entrance types. For each clean-out all 192 baskets and the CDS trap were cleaned during the same day (see Section 5.4.2 for cleaning methods).

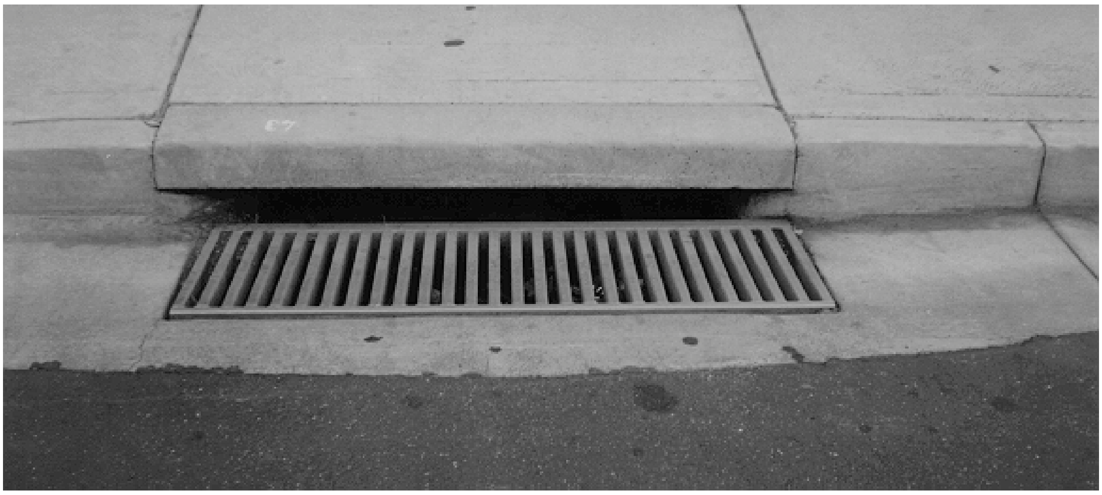
Table 8.1 Numbers of entrances from each land-use type in the Coburg catchment

Drain entrance types	Commercial	Residential	Light-industrial	Total
Grates	19	23	1	43 (22*)
Side entry pits (SEP)	42	48	0	90 (47*)
Side entry pits with grates (SEP/G)	25	32	2	59 (31*)
Total	86 (45*)	103 (53*)	3 (2*)	192 (100*)

* percentage

Photograph 8.1 A typical grate entrance in the experimental catchment

Photograph 8.2 A typical side entry pit in the experimental catchment



Photograph 8.3 A typical side entry pit with grate in the experimental catchment

Initial investigations of council stormwater plans revealed approximately 100 entrances in the experimental catchment, but a detailed field inspection yielded approximately double this (192). This highlighted the importance of detailed field inspections for assessing the feasibility of a SEPT system. The field inspection also revealed many inlets to the drainage system that were at locations other than road entrances. These were typically from direct inputs to the drainage system from commercial building roof drainage or from multi-dwelling buildings (see Photograph 8.4). These entrances can be up to 200 mm in diameter and could therefore deliver gross pollutants to the drainage system that bypass SEPTs.

Photograph 8.4 A Coburg entrance to the drainage system that bypasses the SEPTs

8.2 TRAPPING EFFICIENCY

The trapping efficiency is defined as the proportion of dry mass of gross pollutants retained by the SEPTs compared to the total amount of gross pollutants flowing through the drainage system. The CDS device was found to have a very high capture rate and therefore is an excellent monitoring device for material that escapes SEPTs. Therefore the trapping efficiencies of the SEPTs in Coburg were estimated by comparing the dry mass collected by the SEPTs with the sum of this mass and the mass of material collected in the CDS device, over the same period.

On four occasions the SEPTs and the CDS device were cleaned together. However, for the second and third clean-outs, the CDS trap had a small hole in the mesh screen and some gross pollutants may have passed downstream. For this reason, efficiency estimates for SEPTs for the second and third cleans are an 'at best' estimate for trapping efficiency. The trapping efficiency of all the SEPTs combined (ie. 100% coverage of road entrances) for the four clean-outs are presented in Table 8.2.

Table 8.2 Trapping efficiency results for the SEPTs

Clean date	**Days between cleans**	**rainfall**	**runoff**	**Total dry mass (CDS + SEPT)**	**% caught by SEPTs**	**% caught by SEPTs**	**% caught by SEPTs**
		mm	mm	dry kg	human derived	organics	total load
29-Aug-96	27	57	18	111	78	59	66
30-Sep-96	32	60	24	366	83*	72*	75*
15-Oct-96	15	15	7	206	85*	69*	71*
15-Nov-96	31	31	17	285	73	59	62

*upper limit estimate due to small hole in CDS device

It is not clear if the individual trap inefficiencies account for lost material through the SEPT system (reaching the CDS device) or it is the other untrapped entrances. Observations made while cleaning the traps suggested that both occur, as material often blinded the baskets pores, suggesting overflows from the baskets, but the proportion of loss this caused compared to the loss caused by untrapped entrances is unknown.

It is also interesting to note that the percentage of organic matter caught is less than the percentage of litter capture. This may suggest that material does pass the SEPTs by untrapped entrances because only vegetation is readily available on roofs (from trees) and generally only small amounts of litter can reach roofs and therefore, the direct inputs into the drainage system would deliver much more organic material than the litter. Hence, the untrapped entrances are of little concern for litter reduction strategies.

8.3 DISTRIBUTION OF TRAPPED MATERIAL

With so many road entrances to the drainage system in urban areas and regular maintenance required, it is likely that SEPTs will not be placed on all entrances. Therefore, it is imperative to locate SEPTs in positions that yield the most load capture. To illustrate how the loads captured by the SEPTs vary a plot of the cumulative percentage of trapped load against the cumulative percentage of traps is shown in Figure 8.1. The plot shows the proportion of the total load that can be caught with the minimum number of traps assuming the traps are positioned in locations that capture the most loads. To help locate traps in the positions that capture the most, their attributes are compared against the trapped loads for the four clean-outs in Coburg in the following section.

Traps in different locations capture different amounts of litter and organic material, therefore, the rank order of traps influences the distribution curve for the caught loads. Figure 8.1 shows results from the first clean-out, with the traps ordered according to the most litter load caught. The plot also shows the percentage capture of the total load (ie. including organic material) for the traps *in the same order*. The traps ordered from highest to lowest litter load capture represents the best-case scenario for choosing locations for SEPTs (ie. the installer chose pits that contribute the most load to install the traps in first). Figure 8.1 shows that it is possible to put traps on 40-50% of the pits and capture about 65-70% of the litter load and 45-55% of the total load.

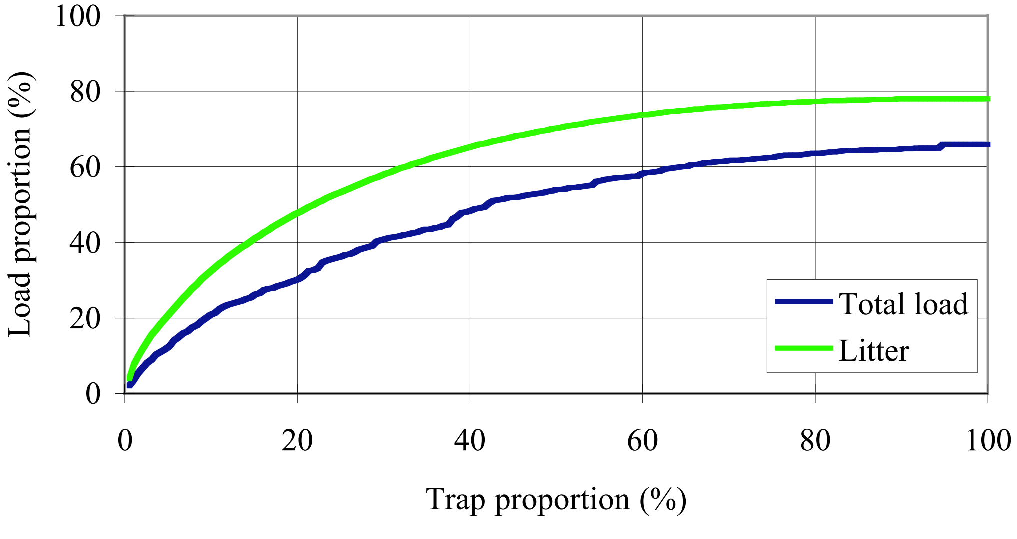


Figure 8.1 Distribution of trapped material for clean-out 1 (ranked by litter loads)

Figure 8.2 shows results from the same clean-out but uses the total load data to rank the traps from most to least caught (and corresponding litter loads). In order to maximise capture for one element of gross pollutants (litter or total load in this case) the other must be compromised. It is therefore important to recognise which is the more important gross pollutant, litter or debris, and optimise the use of SEPTs accordingly.

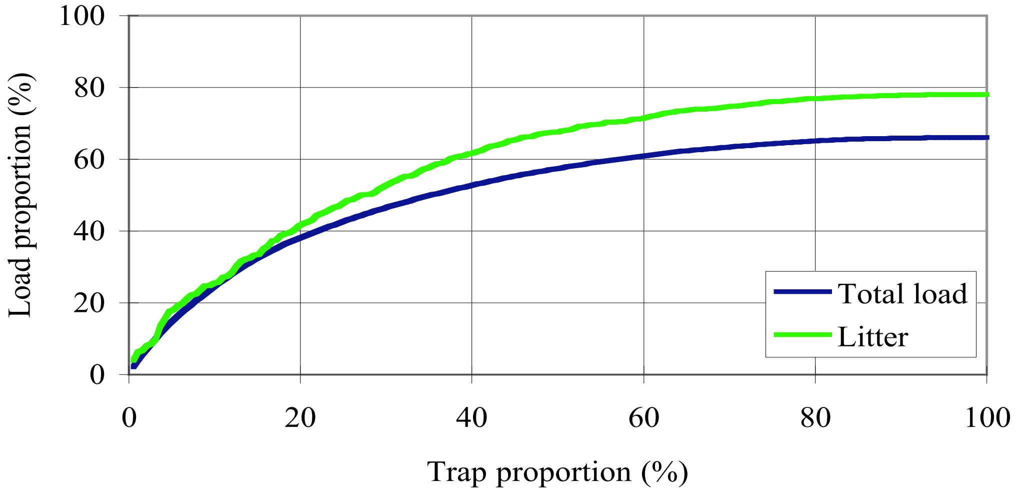


Figure 8.2 Distribution of trapped material for the clean-out 1 (ordered by total load)

It is equally important for designs of trapping systems that the same traps continue to trap the highest loads. The next three figures (8.3 to 8.5) show the load proportions for the three subsequent clean-outs using the same trap order as for Figure 8.1 (ie. by captured litter loads in clean-out 1).

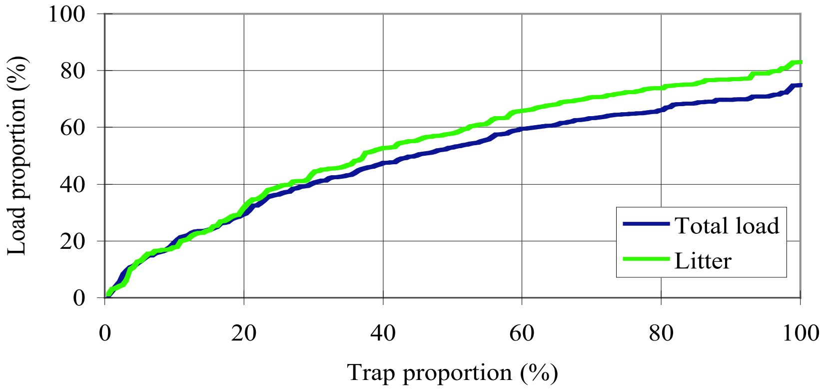


Figure 8.3 Distribution of trapped load in clean-out 2 (order by litter in clean-out 1)

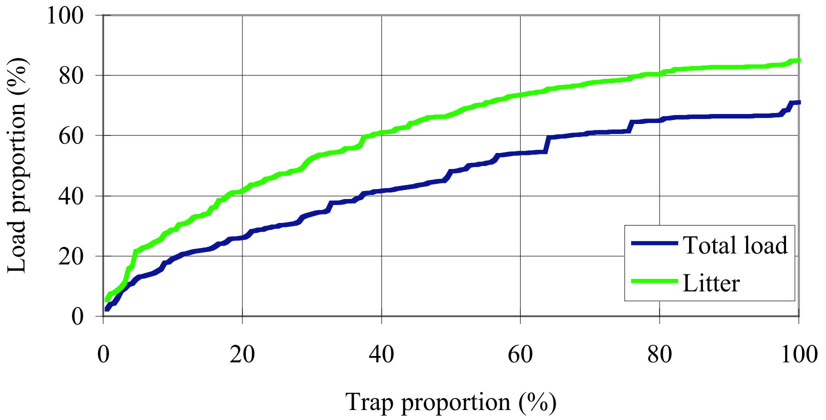


Figure 8.4 Distribution of trapped load in clean-out 3 (order by litter in clean-out 1)

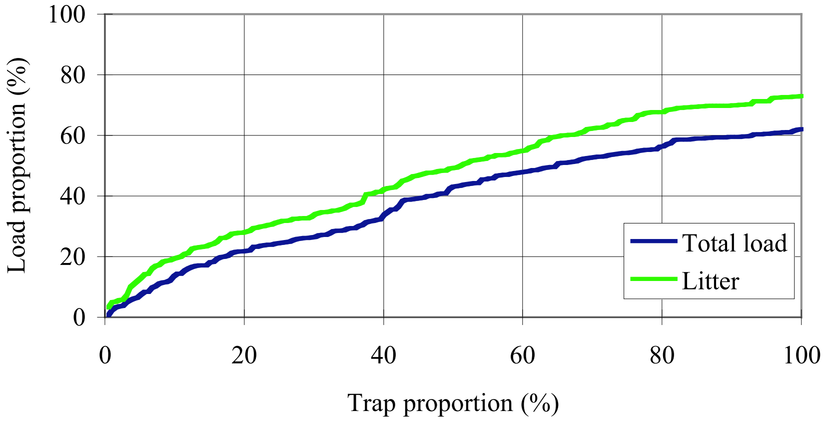


Figure 8.5 Distribution of trapped load in clean-out 4 (order by litter in clean-out 1)

The plots (Figures 8.3 to 8.5) show that despite some reduction in the capture rate, the same pits generally are the ones that capture the most loads. This is important for considering where to locate future installations of SEPTs.

8.4 POLLUTANT ORIGINS

To identify the characteristics of the pits that capture most of the loads the pit characteristics were compared to the captured materials. The analysis allows types of pollutants and catchment attributes to be compared. The results presented in Tables 8.3 to 8.5 reveal that side entry pit entrances contributed approximately double the load compared to grated entrances, and also that areas with commercial activity and residential areas with large catchments contributed the largest amounts of litter.

The loads are compared to the land-use type in the catchment, the gutter length upstream of the pit and the type of entrance in the following analysis.

The most litter items entered the drainage network from commercial areas, presumably due to the high level of activity in the catchments (especially for food, drink and cigarette items). Organic loads of material were relatively uniform from the different land-uses, and may be attributed to near uniform coverage of vegetation in the catchment and the influence of wind. Analysis of different entrances in the experimental catchment revealed that side entry pits deliver more gross pollutants to the drainage system than grates and therefore should be targeted during clean-up programs.

In addition, the gutter-length upstream of all entrances was measured as a surrogate for catchment area, to investigate any relationship between catchment area and the load caught by each SEPT. Urban catchment areas at small scales are very difficult to determine because of the complex network of drainage pipes and altered surface drainage paths. It is common in urban areas for drainage to go against the natural (pre-urbanisation) drainage path. Gutter-lengths are feasible to measure and give an indication of the relative size of the areas draining to different drain entrances.

Comparisons between the gutter length draining into each pit and the total gross pollutant load captured show no relationship between gutter-length and the load caught. A plot of gutter length and the load caught is shown in Figure 8.6 and each catchment types is shown with different markers. Figure 8.6 shows the scatter of the data and in addition highlights the relatively small loads caught by grates.

Table 8.3 Percentage of LITTER load trapped for various entrance types and land-use types

		GRATES					SIDE ENTRY PITS					SIDE ENTRY PITS V		
		n = 22.4%					n = 46.9%					n = 30.7%		
	n (%)	Clean 1	Clean 2	Clean 3	Clean 4	**Ave.**	Clean 1	Clean 2	Clean 3	Clean 4	**Ave.**	Clean 1	Clean 2	Clean 3
Commercial	44.8	5.7	5.5	5.2	5.5	**5.5**	22.5	29.4	28.3	18.6	**24.7**	24.7	21.1	23.4
Residential	53.6	0.8	1.0	1.6	1.1	**1.1**	26.3	23.3	25.4	29.7	**26.2**	18.0	17.0	14.7
Industrial	1.6	0.6	0.4	0.1	0.2	**0.3**	0.0	0.0	0.0	0.0	**0.0**	1.5	2.3	1.4
All areas	100.0	7.1	6.9	6.9	6.8	**6.9**	48.8	52.8	53.7	48.3	**50.9**	44.1	40.4	39.5

Table 8.4 Percentage of ORGANIC load trapped for various entrance types and land-use types

		GRATES					SIDE ENTRY PITS					SIDE ENTRY PITS V		
		n = 22.4%					n = 46.9%					n = 30.7%		
	n (%)	Clean 1	Clean 2	Clean 3	Clean 4	**Ave.**	Clean 1	Clean 2	Clean 3	Clean 4	**Ave.**	Clean 1	Clean 2	Clean 3
Commercial	44.8	6.8	9.1	7.6	8.2	**7.9**	15.6	19.9	12.1	7.7	**13.8**	11.7	9.4	16.4
Residential	53.6	3.7	3.2	6.8	2.9	**4.1**	44.7	41.9	47.1	48.6	**45.6**	16.6	14.7	9.5
Industrial	1.6	0.3	0.7	0.1	0.5	**0.4**	0.0	0.0	0.0	0.0	**0.0**	0.5	1.1	0.5
All areas	100.0	10.8	13.0	14.5	11.6	**12.5**	60.3	61.8	59.2	56.3	**59.4**	28.9	25.2	26.3

Table 8.5 Percentage of TOTAL load trapped for various entrance types and land-use types

		GRATES					SIDE ENTRY PITS					SIDE ENTRY PITS V		
		n = 22.4%					n = 46.9%					n = 30.7%		
	n (%)	Clean 1	Clean 2	Clean 3	Clean 4	**Ave.**	Clean 1	Clean 2	Clean 3	Clean 4	**Ave.**	Clean 1	Clean 2	Clean 3
Commercial	44.8	6.4	8.3	7.1	7.6	**7.3**	18.5	22.2	15.3	10.1	**16.5**	17.0	12.1	17.8
Residential	53.6	2.5	2.7	5.8	2.5	**3.4**	37.1	37.5	42.8	44.5	**40.5**	17.2	15.2	10.5
Industrial	1.6	0.4	0.6	0.1	0.4	**0.4**	0.0	0.0	0.0	0.0	**0.0**	0.9	1.4	0.6
All areas	100.0	9.3	11.5	13.0	10.5	**11.1**	55.6	59.7	58.1	54.6	**57.0**	35.1	28.8	28.9

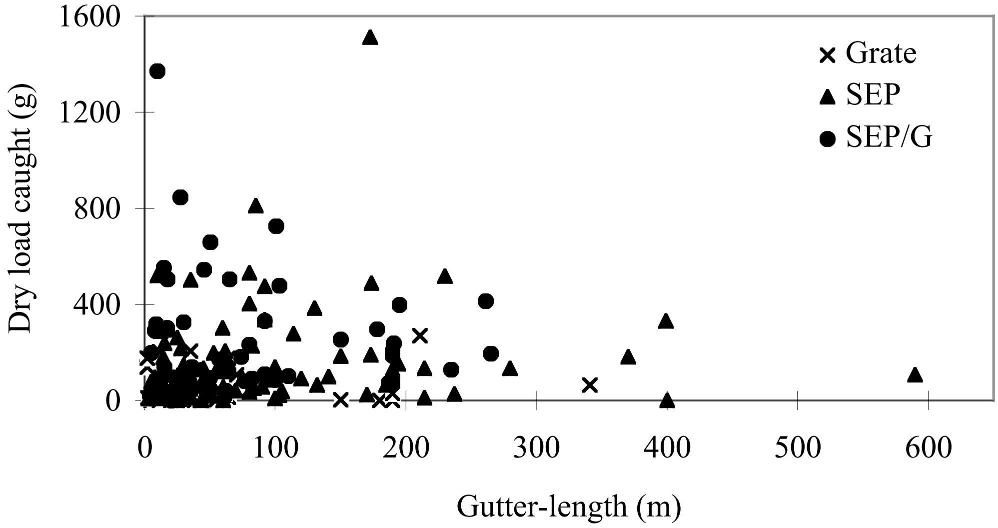


Figure 8.6 Captured gross pollutant load for the first SEPT clean-out plotted against gutter length draining into each pit

8.5 MAINTENANCE OF SEPTS

During the field trials the SEPTs were cleaned manually on all but one occasion. Manual cleaning was performed so that the contents of each basket could be kept separate from other baskets and allow analysis of the contents of each basket in the laboratory. This is not the recommended method for cleaning (see Section 3.1.2). On one occasion the traps were cleaned using the standard method which is to educt the contents of the baskets with a street sweeping truck vacuum (Photograph 3.3.). The cleaning process took approximately 3 hours for two people and one street cleaner to complete (192 baskets).

There is considerable experience with maintaining SEPTs by Banyule City Council who use the vacuum method for all of their traps and they estimate the cleaning to costs between $5 and $10 per trap per clean (Colin Rose, pers. comm.).