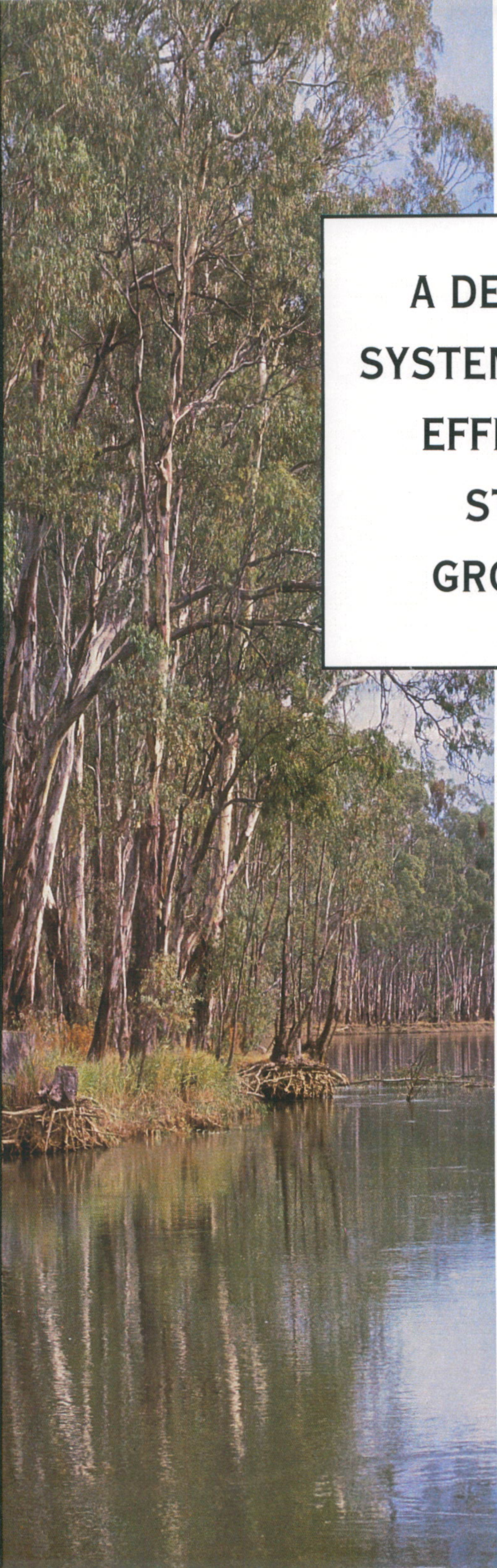

A DECISION-SUPPORT-SYSTEM FOR DETERMINING EFFECTIVE TRAPPING STRATEGIES FOR GROSS POLLUTANTS

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PREFACE

This is one of three reports that describe the gross pollutant research study undertaken by the Cooperative Research Centre for Catchment Hydrology. The study is part of Project C2 (Design and Management Procedures for Urban Waterways and Detention Basins) in the CRC's Urban Hydrology Program.

The objectives of the study are to understand the quantities and characteristics of gross pollutants moving through the stormwater system, and to review and assess gross pollutant trapping techniques. A feature of this study is the extensive field monitoring which involved a range of parties, including federal, state and local agencies, community groups and two private companies.

An industry report which provides a general description of gross pollutant characteristics and trapping devices has been published. A related technical report outlines the study in much more detail. This report describes the development of a decision support system that is based on the results from the study. The decision support system provides a method for comparing different approaches for trapping gross pollutants.

Tom McMahon
Program Leader, Urban Hydrology
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ABSTRACT

There is increasing public concern about the large amount of gross pollutants, such as litter and debris, observed in urban waterways and receiving waters. These pollutants are unattractive, disturb the physical habitat, degrade the waters, are linked to marine animal deaths and reduce amenity values.

A number of approaches are used to reduce the problem: public awareness and education programs, penalties for littering, the provision of collection bins and extensive street cleaning. Despite these efforts it is clear that significant amounts of material enter the urban drainage system. Traps can be installed to collect gross pollutants and can be located at street channel entry pits, within main drains and in slow moving receiving waters. However, it is rarely feasible to provide sufficient trapping to collect all the pollutants in the urban drainage system.

This report describes a *decision-support-system* (DSS) that can be used to assist Authorities select an appropriate strategy for trapping gross pollutants from a particular urban area. The DSS takes into account the urban drainage layout, trapping locations, the predominant land-use type and funding limitations in assessing the benefits and costs of a proposed strategy. The DSS is established using essentially results from a CRC gross pollutant field monitoring study, as well as a review of litter trapping devices commonly used in Australia.

ACKNOWLEDGMENTS

This project involved extensive field-based experiments and contributions from many people resulted in this report. The authors wish to acknowledge the generous support in time and resources from the following organisations:

- Melbourne Water Corporation,
- Moreland City Council,
- Merri Creek Management Committee,
- CDS Technologies (formerly Pollutec),
- Banyule City Council,
- Bureau of Meteorology,
- Commonwealth Environmental Protection Authority, and
- Streamline Australia.

Much of the field work was dirty, smelly and tedious and special thanks goes to Sharyn Ross, Ian Finlay and Brendan Salmon of the University of Melbourne; Ian O'Callaghan, Jaz LeCouteur and Paul Murfitt (all from the Merri Creek Management Committee) for their endurance under difficult circumstances. In addition, the authors wish to thank other staff and postgraduates from the University of Melbourne who helped with much of the field monitoring. Dr Charles Essery (Australian Water Technologies) and Dr Tony Wong (Monash University) contributed technical advice and encouragement for the project and the authors wish to sincerely thank them for their input.

This project would not have been possible without the cooperation and support of different agencies while initiating the project. Many thanks to Nick Ronan and Graham Rooney (Melbourne Water), Fred Harington and Les Horvath (Moreland City Council), Paul Blanche, Stephen Crompton and Charles Humphries (CDS Technologies) and Colin Rose and Simon Thomas (Banyule City Council) for their enthusiasm for and commitment to the project. Thanks also to Robyn Sim (Sydney Water) and Doug Vallance (Parks Victoria) for contributing valuable data for the project.

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INTRODUCTION

Despite education, awareness and street cleaning programs, large amounts of gross pollutants (litter and debris greater than 5 mm in size) are reaching and degrading receiving waters. In fact, urban areas contribute approximately 30 kilograms per hectare per year of dry gross pollutants to the stormwater system. The majority of the pollutants are organic (mainly leaves and twigs) and the remainder mainly paper and plastic food and drink items. For Melbourne this is equivalent to about 200,000 to 300,000 cubic metres of gross pollutants and one to two billion items of litter annually. The large amount of material reaching the drainage system suggests that new or improved approaches are required to prevent gross pollutants reaching and degrading receiving waters.

Reduction campaigns for gross pollutants can be divided into two categories, non-structural and structural. Non-structural measures are means of reducing the quantity of pollutants available for wash-off, primarily by changing the attitudes (and actions) of the community. Structural measures are constructed in-transit treatments that separate and contain pollutants. Despite the presence of non-structural programs, significant quantities of gross pollutants reach receiving waters and improved or alternative approaches for reducing their impacts are required. Trapping systems provide a structural method for reducing the quantities of gross pollutants that reach receiving waters and are the focus of this study. Although little information is available concerning their performance they are becoming increasingly used in Australia.

This reports describes a decision-support-system (DSS) that aids catchment managers in choosing appropriate trapping systems to remove gross pollutants from urban waterways. This report builds on field-based experiments that investigated the quantities of gross pollutants emanating from different land-use types and the performance of two gross pollutant trapping techniques, as well as a review of current trapping technologies. A complementary report (Allison et al., 1997b) describes this work in more detail.

An Authority implementing a trapping strategy for gross pollutant removal from an urban catchment will wish to maximise the quantity removed within budgetary limitations. It is unlikely that these limitations will allow traps to be placed on all catchments in a drainage system. The planner must decide what minimum number of traps should be used and which areas of the catchment should be trapped, bearing in mind the drainage system layout, the predominant land-use type and the climate characteristics. The task is a daunting one. The decision support system (DSS) described in this report assists this task and allows relative strategies to be evaluated.

This report develops a decision-support-system that is designed to aid catchment managers choose appropriate trapping strategies for gross pollutants. The DSS estimates the pollutant loads from different land-use catchments and the costs and performance of selected trapping systems.

There are two parts to this report.

1. A user manual for using the decision-support-system which is included on a computer disk at the back of this report.
2. The remainder of the report discusses the development of the DSS (input data, assumptions and computations).

The DSS was developed using field work results (described in Allison et al., 1997b) and other Australian data. To run the DSS daily rainfall and information about the areas of different land-use types draining to all trapping systems are required. The DSS uses the input data to generate daily gross pollutant loads, and to estimate the annual capture of gross pollutants and costs for particular combinations of trapping systems.

There are two primary characteristics that determine a trapping system's performance: the trapping efficiency and the maintenance requirements. A trap with a low trapping efficiency means that significant gross pollutants are passing the trap and reaching downstream waters. Difficult or expensive maintenance procedures will lead to a decline in the trap's cleaning frequency. A poorly maintained trap will be inefficient at trapping gross pollutants (McKay & Marshall, 1993) and also may potentially become a source of contamination as collected materials break down (DLWC, 1996). Therefore, the maintenance program of any trapping system should be an important consideration when choosing between systems.

The DSS considers six trapping systems for three types of trapping locations: Side Entry Pit Traps (SEPTs) at street entry pits; trash racks, Litter Control Devices (LCD), Continuous Deflective Separation (CDS) devices and Gross Pollutant Traps (GPTs) within main drains; and Floating Debris Traps (FDTs) in slow moving receiving waters. These trapping systems were selected either because they are likely to perform well or because they are commonly used in Australia and have some performance data. The DSS allows comparisons of single trap systems as well as multiple trap systems that can be located in various land-use areas. The input and output of the model allow the user to either minimise the cost for a desired gross pollutant capture rate or aid the choice of gross pollutant trapping systems for a given budgetary constraint.

The DSS takes into account the predominant land-use types and funding limitations in assessing the benefits and costs of the proposed system. It uses recommended cleaning frequencies (that vary for different traps) to estimate costs, and outputs are intended to show relative differences between systems, not absolute costs. This is because of the variability of the input data and assumptions made during the computations. The DSS also improves the users' awareness of the trapping systems available in Australia.

The structure of the DSS allows new information about the trapping performance or cost of any gross pollutant trapping system to be incorporated as data become available. New systems can also be added as field performance data become available.

USER MANUAL FOR THE GROSS POLLUTANT TRAPPING DSS

(The DSS is contained on disk in a pocket at the end of this report)

The user must (everything the user can change is in red italics):

1. in the *rainfall data sheet*;
   enter one complete year of rainfall data (the default is Coburg 1996 data);

2. in the *input & output sheet*;
   enter the catchment areas for the gross pollutant traps and also areas where traps will not be installed, and the characteristics of the following traps: SEPTs, LCDs and FDTs.

The user may:

3. enter an adjustment factor which reduces or increases the gross pollutant loads that enter the stormwater system due to different management practices in their catchment compared to the Coburg data which are used for the calculations here;

4. change the cost and efficiency values of the trapping devices in the *cost & efficiency sheet*, (this option is useful as more data on trap performances become available).

[The data in the *rainfall data sheet* are from Coburg in 1996. The current values in red italics in the *input & output sheet* are for a case study, described in Section 5]

USER MANUAL FOR THE GROSS POLLUTANT TRAPPING DSS

Calculations

- The DSS calculates litter and total gross pollutant loads that enter the stormwater system based on the analyses of the data collected in Coburg (see Section 4).
- If a value other than 100% is entered in (3) above, the loads calculated by the DSS will be adjusted by that percentage factor.
- The traps chosen by the user in (2) above for the different land-use areas and the costs and efficiency information available for the traps (Section 2 and the *cost & efficiency sheet*) are used to calculate the gross pollutant loads that will be trapped.

Results

- All the main outputs are summarised in the *input & output sheet*.

If the user wishes to see more detailed information,

- a summary of the costs of individual trapping devices (if more than one trap is used) can be found at the bottom of the *cost & efficiency sheet*; and
- the daily gross pollutant loads that enter the stormwater system and the daily litter loads and total loads trapped by the devices are shown in the *litter load* and *total load sheets*.

The remainder of this document describes the structure, input data, assumptions and computations used in the DSS. This is followed with a case study to illustrate a procedure for determining an effective trapping strategy for a 150 hectare urban catchment. Finally, some notes on updating the data used in the DSS are presented.

ABBREVIATIONS

CDS	- Continuous Deflective Separation
DSS	- Decision Support System
EAC	- Equivalent Annual Cost
FDT	- Floating Debris Trap
GPT	- Gross Pollutant Trap
LCD	- Litter Control Device
MMBW	- Melbourne and Metropolitan Board of Works
NPC	- Net Present Cost
SEPT	- Side Entry Pit Trap
SPCC	- State Pollution Control Commission, NSW

LIST OF FIGURES & TABLES

1. DSS STRUCTURE

The structure of the DSS is presented in Figure 1, showing the steps involved from the model inputs to the range of outputs.

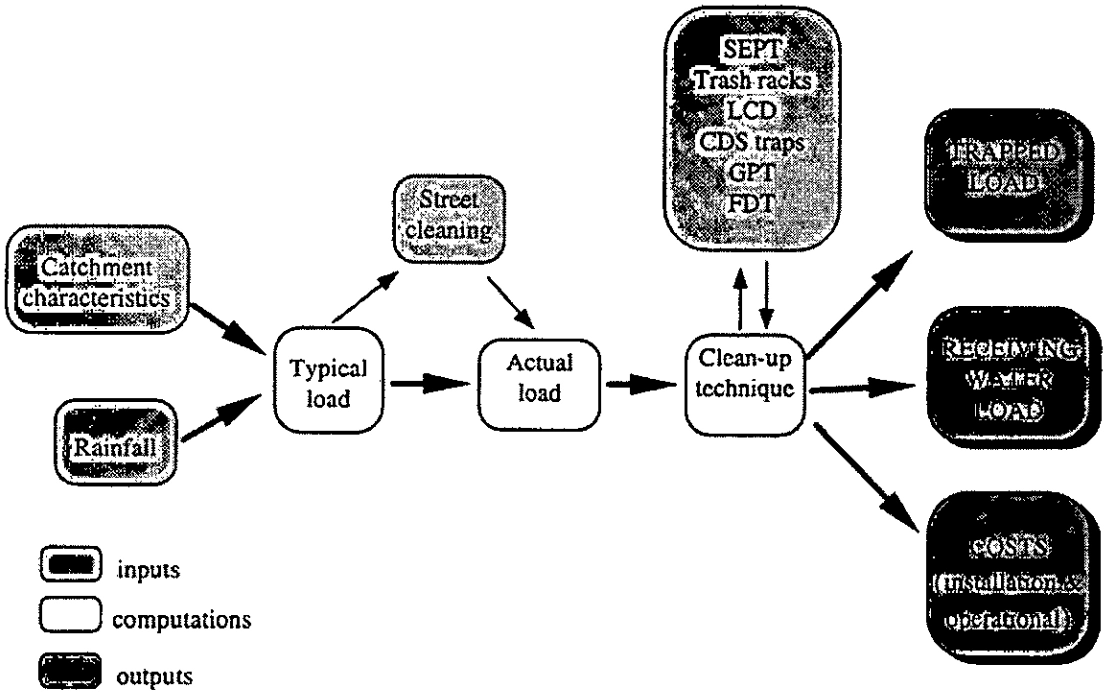


Figure 1 Structure of the DSS showing the steps involved in the computations

1.1 INPUTS

The DSS requires information about the land-uses of the study areas that drain to all trapping systems, and daily rainfall data. The user has the option of considering different combinations of trapping systems by changing trap locations and inputting the areas draining to each trap from different land-use areas (either commercial, residential or light-industrial). The DSS then calculates the loads that each trap captures and misses. Different land-use areas produce different quantities of gross pollutants and therefore have different load characteristics, this is discussed in detail in Section 4. Daily rainfall data are required for one year. The default has daily rainfall data for a rain gauge in Coburg in 1996.

Costs for installation and maintenance of different trapping systems are calculated on a per hectare basis, summarised in Table 10 in Section 2. In the DSS, street cleaning practices are assumed to be the same as in Coburg, unless the user indicates otherwise. Coburg, the location for the field experiments, from which the load relationships are drawn, has typical street cleaning practices for a Melbourne suburb. There, fortnightly street sweeping in residential areas occurs, five days a week in commercial areas and seven days a week in busy commercial areas. No street flushing is performed. There is a lack of Australian data relating to the influence of street cleaning on the gross pollutant loads in stormwater drains. As more information becomes available, the effects of changed street cleaning practices can be accounted for in the DSS. If the user considers street cleaning practices to have a different influence on gross pollutant loads than those in Coburg, a percentage increase or reduction in the gross pollutant load can be entered (ie. default = 100% but it can be increased or decreased according to the user's perceptions).

1.2 OUTPUTS

Outputs from the DSS are intended to give an indication of the differences between the performances of alternative trapping strategies rather than absolute values of their worth. To help managers compare different techniques the DSS presents the following outputs:

- the total load carried by the stormwater system (litter and total load (litter and vegetation) in kg and m^3);
- the load captured (litter and total load in kg, m^3 and percentage);
- the estimated construction cost;
- the estimated cost of maintenance and cleaning each year (using recommended cleaning frequencies); and
- an estimate of the number of traps required.

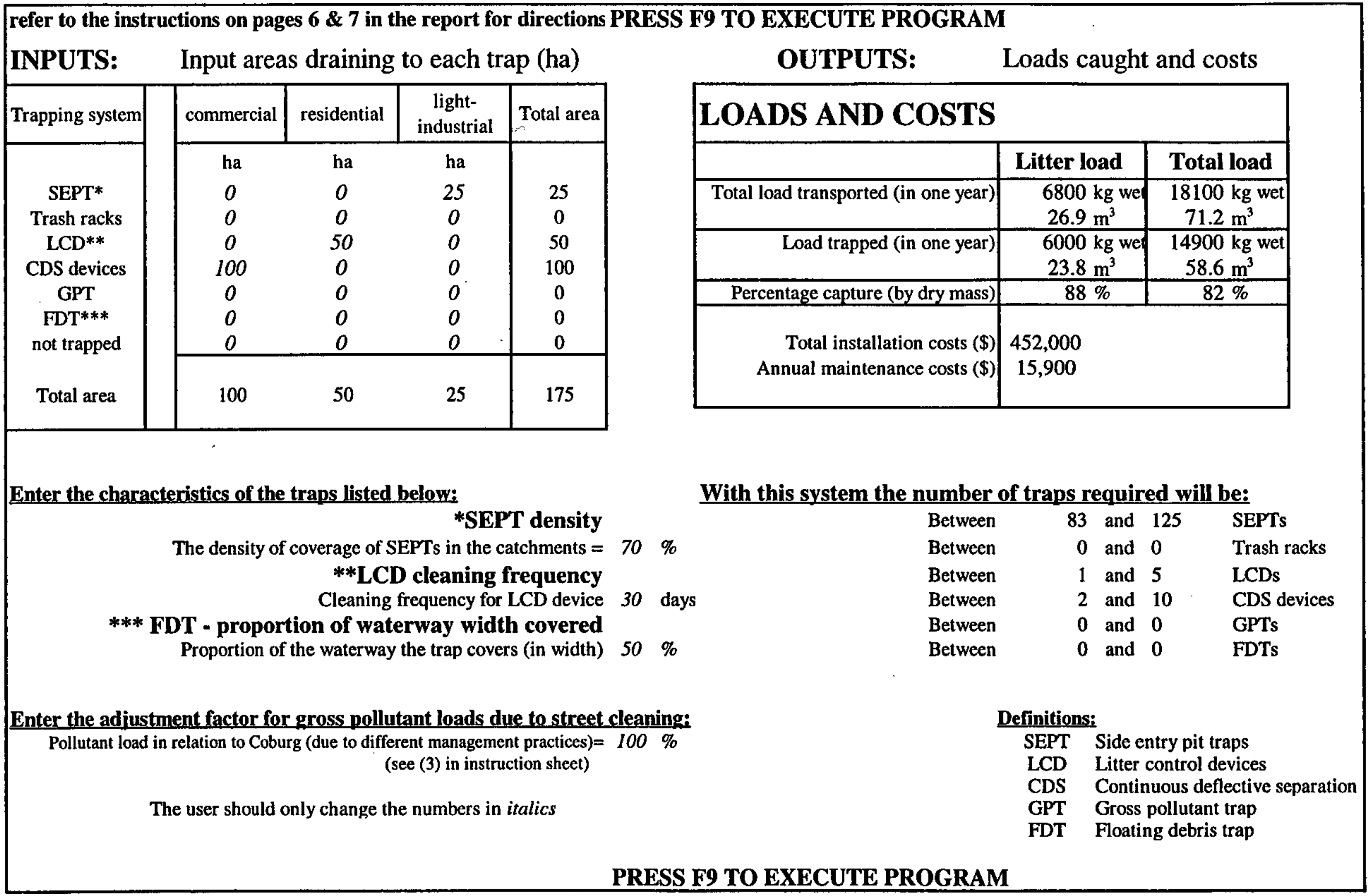
By experimenting with different trapping systems (or combinations of them) in different land-use catchments, the user can quickly establish the best combination of traps suited to their particular catchment. Costs that are presented are not exact. They are averaged over as many data as possible from around Australia and presented as output from the DSS to give an indication of the magnitude of costs. These tend to be biased against the traps with smaller catchments because of the high cost of roads and ancillary works as Phillips (1992) explained for the case of GPTs. However, as long as feasible catchments sizes are entered by the user, reasonable comparisons are possible.

Maintenance costs are presented separately because of their importance to the long term performance of any gross pollutant trapping system. The output gives an indication of the annual maintenance costs (mainly cleaning costs) and the user can determine the best option by comparing the installation costs with the maintenance costs in an economic evaluation of the proposed strategy. These costs vary by an order of magnitude between the traps used in the DSS (for both installation and maintenance) and outputs provide a range of outcomes, which could suit the different budgetary situations of each user.

1.3 EXAMPLES OF INPUT AND OUTPUT

Figure 2 presents an *input/output page* of the DSS for an arbitrary example. It indicates the user's inputs (in italics) and the model outputs of: costs, efficiencies, loads, and the number of traps required for each trapping system. The example presented in Figure 2 is for an area of 100 hectares of commercial, 50 hectares of residential and 25 hectares of light-industrial land-use with SEPTs, LCDs and CDS devices used. The figure also indicates how to input the influence of street cleaning, the density of SEPTs, the cleaning frequency for LCDs and the percentage of a waterway a FDT spans.

Figure 3 presents the *cost and efficiency page* from the DSS for the same example shown in Figure 2. It summarises the values and relationships used in the DSS for calculating the cost and efficiency of each trapping system. Section 2 describes how these values and relationships are derived. Figure 3 also shows the simplicity of entering new data (by simply replacing the numbers in the efficiency and cost table) for any of the systems, as more information becomes available.



refer to the instructions on pages 6 & 7 in the report for directions PRESS F9 TO EXECUTE PROGRAM

INPUTS: Input areas draining to each trap (ha)

Trapping system	commercial	residential	light-industrial	Total area
	ha	ha	ha	
SEPT*	*0*	*0*	*25*	25
Trash racks	*0*	*0*	*0*	0
LCD**	*0*	*50*	*0*	50
CDS devices	*100*	*0*	*0*	100
GPT	*0*	*0*	*0*	0
FDT***	*0*	*0*	*0*	0
not trapped	*0*	*0*	*0*	0
Total area	100	50	25	175

OUTPUTS: Loads caught and costs

LOADS AND COSTS

	Litter load	**Total load**
Total load transported (in one year)	6800 kg we 26.9 m^3	18100 kg wet 71.2 m^3
Load trapped (in one year)	6000 kg we 23.8 m^3	14900 kg wet 58.6 m^3
Percentage capture (by dry mass)	88 %	82 %
Total installation costs ($)	452,000	
Annual maintenance costs ($)	15,900	

Enter the characteristics of the traps listed below:

***SEPT density**

The density of coverage of SEPTs in the catchments = *70* %

****LCD cleaning frequency**

Cleaning frequency for LCD device *30* days

***** FDT - proportion of waterway width covered**

Proportion of the waterway the trap covers (in width) *50* %

With this system the number of traps required will be:

Between	83	and	125	SEPTs
Between	0	and	0	Trash racks
Between	1	and	5	LCDs
Between	2	and	10	CDS devices
Between	0	and	0	GPTs
Between	0	and	0	FDTs

Enter the adjustment factor for gross pollutant loads due to street cleaning:

Pollutant load in relation to Coburg (due to different management practices)= *100* %

(see (3) in instruction sheet)

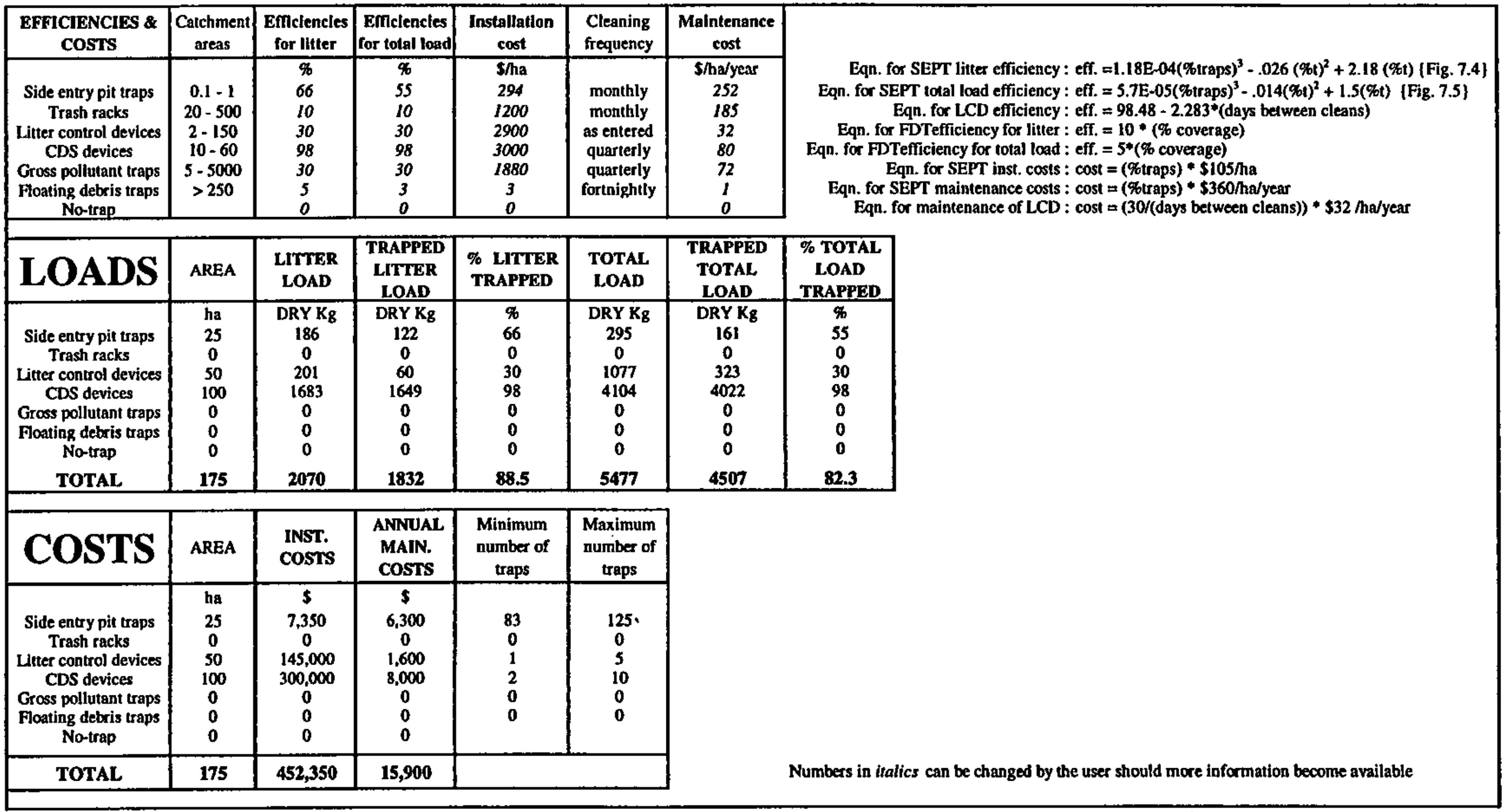
The user should only change the numbers in *italics*

Definitions:

SEPT	Side entry pit traps
LCD	Litter control devices
CDS	Continuous deflective separation
GPT	Gross pollutant trap
FDT	Floating debris trap

PRESS F9 TO EXECUTE PROGRAM

Figure 2 An example of the *input/output page* of the DSS



EFFICIENCIES & COSTS	Catchment areas	Efficiencies for litter	Efficiencies for total load	Installation cost	Cleaning frequency	Maintenance cost
		%	%	$/ha		$/ha/year
Side entry pit traps	0.1 - 1	*66*	*55*	*294*	monthly	*252*
Trash racks	20 - 500	*10*	*10*	*1200*	monthly	*185*
Litter control devices	2 - 150	*30*	*30*	*2900*	as entered	*32*
CDS devices	10 - 60	*98*	*98*	*3000*	quarterly	*80*
Gross pollutant traps	5 - 5000	*30*	*30*	*1880*	quarterly	*72*
Floating debris traps	> 250	*5*	*3*	*3*	fortnightly	*1*
No-trap		*0*	*0*	*0*		*0*

Eqn. for SEPT litter efficiency : eff. =1.18E-04(%traps)^3 - .026 (%t)^2 + 2.18 (%t) {Fig. 7.4}
Eqn. for SEPT total load efficiency : eff. = 5.7E-05(%traps)^3 - .014(%t)^2 + 1.5(%t) {Fig. 7.5}
Eqn. for LCD efficiency : eff. = 98.48 - 2.283*(days between cleans)
Eqn. for FDTefficiency for litter : eff. = 10 * (% coverage)
Eqn. for FDTefficiency for total load : eff. = 5*(% coverage)
Eqn. for SEPT inst. costs : cost = (%traps) * $105/ha
Eqn. for SEPT maintenance costs : cost = (%traps) * $360/ha/year
Eqn. for maintenance of LCD : cost = (30/(days between cleans)) * $32 /ha/year

LOADS	AREA	LITTER LOAD	TRAPPED LITTER LOAD	% LITTER TRAPPED	TOTAL LOAD	TRAPPED TOTAL LOAD	% TOTAL LOAD TRAPPED
	ha	DRY Kg	DRY Kg	%	DRY Kg	DRY Kg	%
Side entry pit traps	25	186	122	66	295	161	55
Trash racks	0	0	0	0	0	0	0
Litter control devices	50	201	60	30	1077	323	30
CDS devices	100	1683	1649	98	4104	4022	98
Gross pollutant traps	0	0	0	0	0	0	0
Floating debris traps	0	0	0	0	0	0	0
No-trap	0	0	0	0	0	0	0
TOTAL	**175**	**2070**	**1832**	**88.5**	**5477**	**4507**	**82.3**

COSTS	AREA	INST. COSTS	ANNUAL MAIN. COSTS	Minimum number of traps	Maximum number of traps
	ha	$	$		
Side entry pit traps	25	7,350	6,300	83	125
Trash racks	0	0	0	0	0
Litter control devices	50	145,000	1,600	1	5
CDS devices	100	300,000	8,000	2	10
Gross pollutant traps	0	0	0	0	0
Floating debris traps	0	0	0	0	0
No-trap	0	0	0		
TOTAL	**175**	**452,350**	**15,900**		

Numbers in *italics* can be changed by the user should more information become available

Figure 3 An example of the *cost and efficiency page* of the DSS using the input from Figure 2

2. TRAPPING EFFICIENCY AND COST DATA

The trapping efficiencies for each trapping system are calculated from either field experiments as part of this study (CDS devices and SEPTs) or from other Australian data. Detailed descriptions of the different trapping techniques are presented by Allison et al. (1997b).

There are seven individual treatments which are considered in the DSS, namely street cleaning, SEPTs, trash racks, LCDs, CDS devices, GPTs and FDTs. Efficiencies and costs are calculated using data averaged for each type of trapping system (ie. even though there may be different brands, eg. for SEPT there are three brands - Pitclear, Dencal and Banyule City Council - it is assumed that all brands of the same trapping system have the same efficiency and costs). The costs of each trapping system (for installation and maintenance) are presented as average costs per hectare of catchment. This approach is a simplification of the measured data and is discussed with the assumptions for the DSS in Section 3.

The computations in this section use mass as the variable to determine trapping performance (ie. how much mass is retained or passes a trap). Dry mass is considered to be the best measure of the amount of gross pollutants in stormwater. Volume loads and item counts can vary with the density, moisture content or the material size of a gross pollutant sample. Outputs from the DSS convert the dry masses into volume and wet mass so that an appreciation of the scale of cleaning and disposal requirements is possible. Data that are not reported as dry mass in the literature are converted to dry mass using relationships derived as mass to volume ratios derived from the Coburg field study.

The trapping systems that are used were selected either because they are likely to perform well or because they are commonly used in Australia and have some performance data. Some systems discussed in Allison et al. (1997b), (ie. baffled pit traps, evolving traps and overseas devices) were excluded because of a lack of performance data. As more performance data become available for these traps it would be possible to add any of these systems to the DSS.

When comparing the cost of different gross pollutant traps it should be recognised that GPTs and CDS devices (and to a lesser extend LCDs) offer other benefits such as sediment removal. This may account for a significant proportion of the installation and maintenance costs. However, the focus of this study is on gross pollutants (material that is retained by a 5 mm mesh screen) and the DSS only takes these into account for the efficiency or cost calculations.

2.1 STREET CLEANING

Australian data about the influence of street sweeping on gross pollutant movements in the urban drainage network are scarce. For the purposes of the DSS it is assumed that typical Australian street cleaning practices are employed, (ie. the same practices as Coburg) and the loads are calculated in light of those practices. If the user estimates street cleaning practices to be significantly different from those described for Coburg (Section 1.1) the quantity of material that reaches the stormwater system can be increased or decreased as appropriate, by varying the street cleaning input parameter.

2.2 SIDE ENTRY PIT TRAPS (SEPT)

SEPTs are baskets that are placed in the entrance to drains from road gutters. The baskets are fitted below the invert of the gutter, inside drainage pits (Figure 4). Stormwater passes through the baskets to the drain and material larger than the basket mesh size (5-20 mm) is retained. Material remains in the basket until a maintenance crew removes the material either manually (Pitclear Industries, 1994; and Dencal Industries, 1995) or using a large diameter vacuum device (ie. an eductor, Banyule City Council, 1996). The traps are intended to be cleaned every four to six weeks.

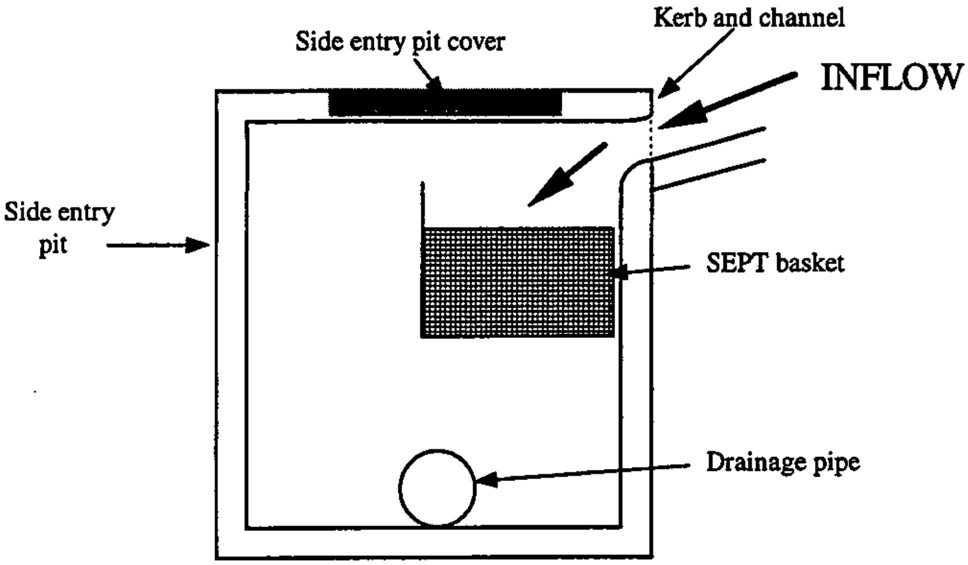


Figure 4 Side Entry Pit Trap - side elevation (after Davies, 1995)

The traps are installed with a gap at the rear of the pit to prevent flooding at the drain entrance. When the basket pores are blocked or during high flows, water is discharged over the rear of the basket. Items smaller than the pore size can also be retained due to the collected material partly blocking the basket pores.

Trapping efficiency data for SEPTs are derived from the results of the field experiments performed by the CRC (described in Allison et al., 1997b). The overall trapping performance of SEPTs is influenced by the proportion of the entrances that are covered with traps and their individual trapping efficiencies.

In the Coburg experiment all of the public road entrances were installed with SEPTs to investigate the trapping efficiencies for different densities of traps. Knowing the loads caught by individual traps, it is possible to simulate the trapping efficiency for situations that have less than 100% of the drain entrances installed with SEPTs. However, to do this, information is required about which of the entrances will not be installed with traps. For the purposes of the DSS, it is assumed that the managers of a particular drainage system can identify the entrances that are likely to produce the most gross pollutants, and place the SEPTs on them. These positions are likely to be side entry pit entrances in either commercial areas or residential entrances with large catchments (Allison et al., 1997). It is considered likely that local authorities have a good sense of the high gross pollutant producing areas from experience with drain blockages and from street cleaning.

Efficiency data for SEPTs depend on the proportion of entrances fitted with SEPTs (determined by the user as an input) and are determined from Figures 5 or 6 for litter or total load respectively. The efficiencies for 100% coverage were taken from the first and last clean-outs of the SEPTs as part of the field work. Results for the second and third clean-outs were affected by a small hole in the CDS unit (Section 2.5) and so the values of the SEPT efficiency may have been overestimated. However, the relative trapped loads for situations when less than 100% of entrances are fitted with SEPTs are calculated using distribution data from all four clean-outs (Figures 5 and 6). The trapping efficiencies determined for all of the clean-outs are adjusted to have the same equivalent 100% trap density trapping efficiency as the average of clean-outs 1 and 4. The cumulative percentage of loads are plotted for the four clean-outs in Figures 5 and 6 for litter and total load respectively. A line is fitted to these points and represents the percentage coverage against the trapped percentage of litter or total load used in the DSS.

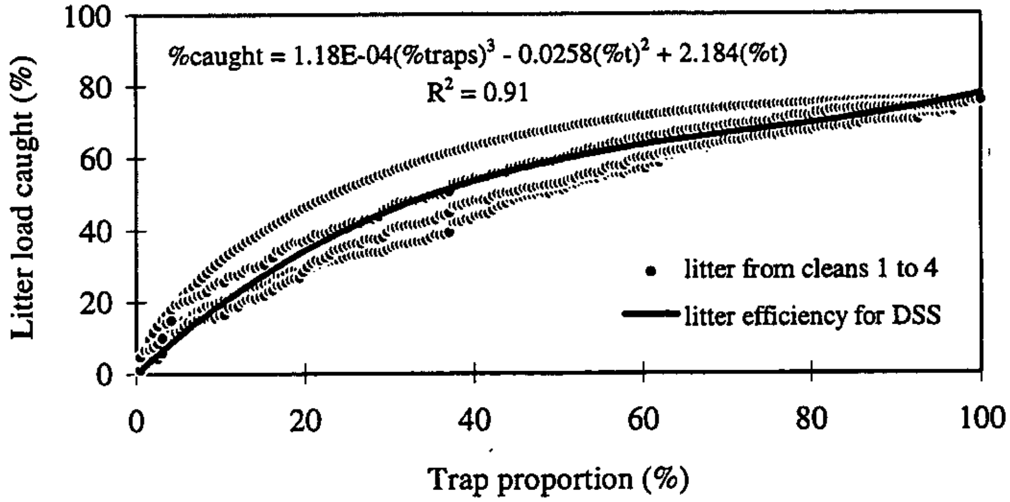


Figure 5 Efficiency curves for litter loads with various proportions of SEPTs installed

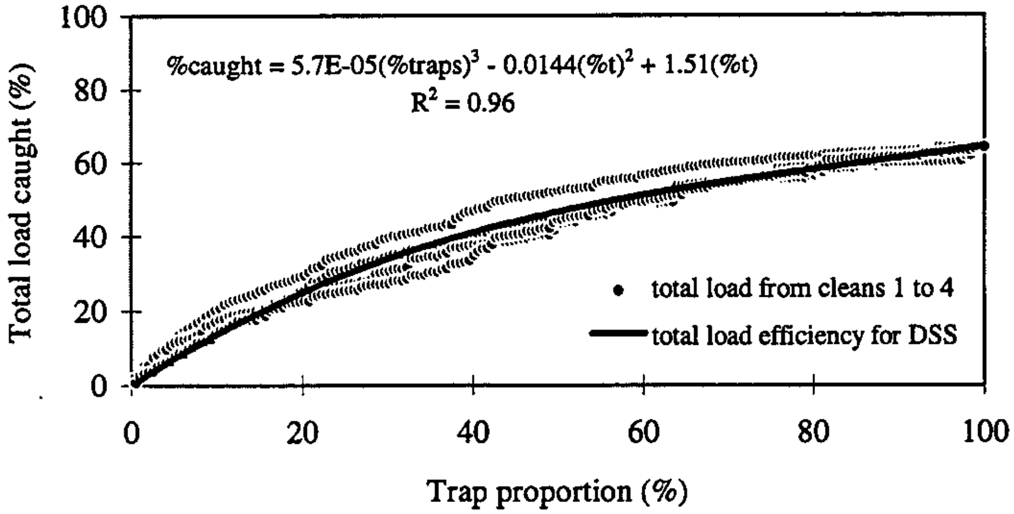


Figure 6 Efficiency curves for total gross pollutant load with various proportions of SEPTs installed

SEPTs cost between $60 and $150 to install per trap (Colin Rose, pers. comm., Banyule City Council). Overall costs per hectare depend on the density of traps installed in a catchment. This is determined by the user selecting the proportion of trap coverage. 100% coverage of drainage entrances is assumed to be 4 traps per hectare. This value was determined from the field experiments and costs are therefore: @ $105 for each SEPT, $420 per hectare. The cost to maintain traps has been estimated at $5-10 per pit per clean (Colin Rose, pers. comm., Banyule City Council). Assuming $7.50 per clean and monthly cleaning, for 100% coverage of SEPTs the cleaning costs are $360 per hectare per year. These costs are proportioned linearly according to the percentage of coverage the user selects as input to the DSS.

2.3 TRASH RACKS

Trash racks are installed in storm drainage channels to intercept floating and submerged objects (such as plastic bags). They generally consist of either vertical or horizontal steel bars (typically spaced 40-100 mm apart) and are manually cleaned. Trash racks provide a physical barrier that water must past through and material larger than the bar spacing is retained. As material builds up behind the trash rack finer material also accumulates (Nielsen & Carleton, 1989).

Trash rack performance data were derived from a tagged litter study undertaken in Melbourne (McKay & Marshall, 1993). The study released tagged items upstream of trash racks and booms and determined the trapping efficiencies from the number of items recovered from in and downstream of the traps. McKay & Marshall only investigated floating items. For the purposes of this DSS, the trapping efficiencies that are quoted for trash racks by McKay & Marshall (1993) are assumed to relate to all gross pollutants (floating and submerged). This assumption is on the premise that trash racks are designed to trap floating, submerged and bed load gross pollutants and without any evidence to suggest that the trapping performance is different for either floating or submerged items, it is assumed they are the same (and the same argument for litter items and total load, ie. they are assumed to be the same).

The performances quoted by McKay & Marshall (1993) suggest that the trapping efficiencies of trash racks vary from 5% to 14%, and 10% is used in the DSS. This low efficiency value is mainly due to blockage and overflow problems during high flows (as described by Nielsen and Carleton, 1989; Beecham and Sablatnig, 1994; and DLWC, 1996).

The costs of trash racks are derived from Sydney data (Robyn Sim, pers. comm., Sydney Water). The installation and maintenance costs are averaged from three trash racks. The costs used in the DSS are $1200 per hectare to install and an annual maintenance cost of $185 per hectare, see Table 1. There have been other Australian trash rack data collected on the quantity of trapped material (eg. QUT, 1996), but no other cost data were located by the author after an extensive search and hence the Sydney data are used in the DSS.

Table 1 Costs of trash racks in Sydney (after Robyn Sim, pers. comm.)

Location	Catchment area	Installation Cost	Installation cost / hectare	Maintenance	Main/hectare year
	(ha)	($)	($/ha)	($/year)	($/ha/year)
Cup and Saucer Creek	500	215,000	430	22,000	44
Mackey Park	90	272,000	3,022	70,000	778
Orissa Street	55	305,000	5,545	28,000	509
TOTAL (all traps)	645	792,000	1,228	120,000	186

2.4 LITTER CONTROL DEVICES (LCDs)

North Sydney City Council developed a stormwater litter trap in response to publicity surrounding a clean-up campaign (Cooper, 1992) and by 1995 they had constructed nine devices (Brownlee, 1995). The traps are located in pits in the drainage network (catchment areas range from 2 to 145 hectares) and consist of steel frames that support metal baskets (approximately one cubic metre), see Figure 7.

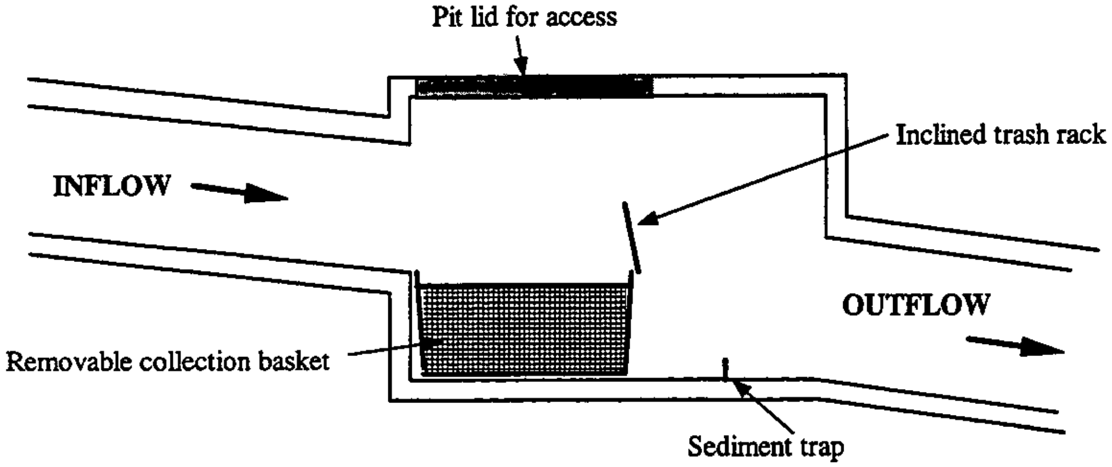


Figure 7 Litter control device (after Brownlee, 1995)

The baskets sit below the invert of the inlet pipe and water drops into the baskets (that have 30 mm diameter pressed holes in the sides) and flows out through the holes in the baskets. Large material (greater than 30 mm pore size) is retained in the basket and, as it builds up reduces the pore sizes offered to the incoming flow (Hocking, 1996) allowing smaller material to be caught. The traps require approximately one metre drop in the channel bed from inlet to outlet to accommodate the basket (Hocking, 1996). This limits their applicability in low lying areas.

Hocking (1996) suggests a capture rate of up to 80% for LCDs in North Sydney City Council from a monitoring study. This value appears to be too high because of changed hydraulic conditions and increased trap cleaning frequency during the monitoring period. Monitoring screens with 10 millimetre apertures were placed across the outlet pipe downstream from the LCD. Material that collected on the monitoring screens quickly blocked the screen and retarded outflow, thus causing ponding upstream of the monitoring screen and flooding of the LCD collection basket.

The changed flow conditions during the monitoring period limits the reliability of the efficiency data from the study. Hocking (1996) also notes that only a small amount of material was found in the baskets after large rainfall events. Monitoring as part of the present study, indicated that large events transport large quantities of gross pollutants. This would suggest that material escaped the LCD during high flows and consequently only small quantities of gross pollutants remained after large flow events.

Monitoring of the LCD on a weekly cleaning cycle yielded approximately three times more gross pollutants than previous monitoring (of the same trap) using a monthly cleaning frequency (Hocking, 1996). This suggests that pollutants may escape LCDs if not maintained as regularly as in the monitoring program (weekly) and that the monitoring overestimated the pollutant capture for the device compared to normal operational conditions (when they were cleaned monthly).

For the DSS a monthly cleaning regime is assumed (as recommended by Brownlee, 1995), and therefore, the efficiency that Hocking (1996) reported (of 80%) needs to be reduced to be comparable with a monthly cleaning cycle. With three times more material collected during weekly compared to monthly cleaning (Hocking, 1996) it would be expected that the efficiency of the system with monthly cleaning would be approximately three times lower (ie. 28% - say 30%). In the DSS, the cleaning regime (and hence the trapping efficiency) can be changed by the user (which also increases maintenance costs). For example, fortnightly cleaning is estimated to be 43% efficient and have double the costs of the monthly cleaning cycle, and weekly cleaning is 80% efficient.

The installation costs for the LCDs are estimated from the nine units built in North Sydney City Council, see Table 2 and Brownlee (1995). The average installation costs are $2900 per hectare and for maintenance the annual costs are estimated to be $32 per hectare with monthly cleaning (and $140 per hectare for weekly cleaning).

Table 2 Costs of LCDs from Sydney data (after Brownlee, 1995)

Location	Catchment area	Installation Cost	Installation cost / hectare	Maintenance	Maintenance /hectare/year
	ha	$	$/ha	$/year	$/ha/year
Willoughby Street	8.9	100,000	11,211		
Walker Street	16.8	120,000	7,160		
Smoothey Park	16.5	120,000	7,282		
Waverton Park	30.0	120,000	3,999		
Crows Nest Road	25.3	120,000	4,749		
Ellamang Street	1.7	50,000	29,240		
Honda Road	40.2	100,000	2,488		
Grafton Street	144.7	130,000	898		
Hayes Street	38.4	80,000	2,083		
TOTAL(all traps)	323	940,000	2,915	10,400	32

2.5 CONTINUOUS DEFLECTIVE SEPARATION (CDS)

The CDS mechanism of solid separation is by diverting the incoming flow and associated pollutants away from the main flow stream of the pipe or waterway into a pollutant separation and containment chamber. Solids within the separation chamber are kept in continuous motion and are prevented from "blocking" the screen. This is achieved by a hydraulic design that ensures the tangential force exerted on an object by the circular flow action is significantly higher than the friction caused by the centrifugal force associated with the rotating flow in the circular chamber. Floating objects are kept in continuous motion on the water surface while the heavier pollutants settle into a containment sump.

CDS devices capture 100% of gross pollutants (as defined as material retained by a 5 mm mesh screen) from the discharge that passes through the chamber. The overall gross pollutant trapping efficiency is therefore affected by the quantity of flow that passes through the separation chamber compared with how much by-passes the chamber at higher flows via the overflow weir (and carries gross pollutants with it). During field monitoring and from the analysis of Wong et al. (1996) it is estimated that 98% of the discharge flows through the separation chamber on an annual basis (and 2% goes over the by-pass weir) if the diversion weir is set to divert a 0.5 ARI. Since the diversion weir only operates at times of high flow (by design) and this is not the time of the highest concentration (see Allison and Chiew, 1995), it is assumed that the concentrations are close to mean event concentrations therefore the proportion of gross pollutants that by-pass the chamber is proportional to the quantity of discharge that by-passes the chamber over the by-pass weir. With this assumption and the typical design size, the trapping efficiency of the CDS device is estimated to be 98% for both litter and total load.

Costs for CDS devices are based on current purchase prices. A three metre diameter unit is estimated to cost $100,000 to construct as a base price (ie. not including additional costs for items such as rock excavation or difficult access; Paul Blanche & Stephen Crompton, pers. comm., CDS Technologies). The unit monitored as part of this study is a three metre diameter unit and services a catchment area of 50 hectares, costing approximately $230,000 (Graham Rooney, pers. comm., Melbourne Water). However, there were many extra costs associated with construction, including realignment of power, water, telephone and gas lines; and the location was in a roadway requiring the covers to withstand large trucks passing over them. These additional costs are not considered typical for most installations.

As the cost data for all other systems in the DSS include the construction constraints of each site, and the only available cost data are for the Coburg CDS unit (which had more than typical costs because of the location), the cost of the Coburg CDS unit cannot be used to compare with other typical costs used in the DSS. Therefore, for the purposes of the DSS, a construction costs of $150,000 (equivalent to $3,000 per hectare) is assumed for a unit the same size as the Coburg CDS unit. This cost is between the 'base' cost and the 'actual' cost of the Coburg unit. This value is assumed for typical construction costs and would include some extra costs for site constraints, but not as much as the Coburg installation. This value can be easily updated in the DSS as more information becomes available. The size and capacity of constructed CDS devices are listed in Table 3 and shows that for a three metre diameter unit (as installed in Coburg) a 50 hectare catchment is typical.

Maintenance costs for CDS devices are also relatively unknown. From the field work in Coburg, as part of this study, a 3-monthly cleaning cycle is estimated to be adequate and from experience in Coburg (Section 6.2.4) an estimate for cleaning costs is $1000 per clean. Therefore, in the DSS, the annual maintenance costs for the CDS devices is estimated to be $80 per hectare. These costs can be easily updated in the DSS as more information becomes available.

Table 3 List of constructed CDS units, the size of the units and catchment areas (after Blanche & Crompton, pers. comm.)

Location	Collection chamber diameter	Catchment area
State	m	ha
NSW	1.5	3.6
TAS	1.5	24
NSW	2	16.5
NSW	2	12.4
SA	2	27
SA	2	58
NSW	3	47
NSW	3	50
QLD	3	58
VIC*	3	50
NSW	3	51

* Coburg CDS unit

2.6 GROSS POLLUTANTS TRAPS (GPT)

GPTs are in-transit pollution traps intended to remove litter, debris and coarse sediments. GPTs have evolved from sedimentation basins (see Perrens (1992) and Queck et al. (1991) for descriptions of sedimentation basins). They generally consist of a large concrete lined wet basin upstream of a weir and a trash rack is located above the weir (Willing and Partners, 1992; and see Figure 8). Maintenance involves dewatering the wet basin and using a backhoe to remove sediments (Willing and Partners, 1992). GPTs are primarily designed for trapping coarse sediments from stormwater. These criteria have governed their shape and size (Willing and Partners, 1992).

The philosophy behind GPTs is to decrease flow velocities sufficiently, so that coarse sediments settle to the bottom. This is achieved by increasing the width and depth of the channel in the GPT basin. The trash rack on the downstream end of the basin (usually constructed of vertical steel bars) is intended to collect floating and submerged debris in the same way as conventional trash racks.

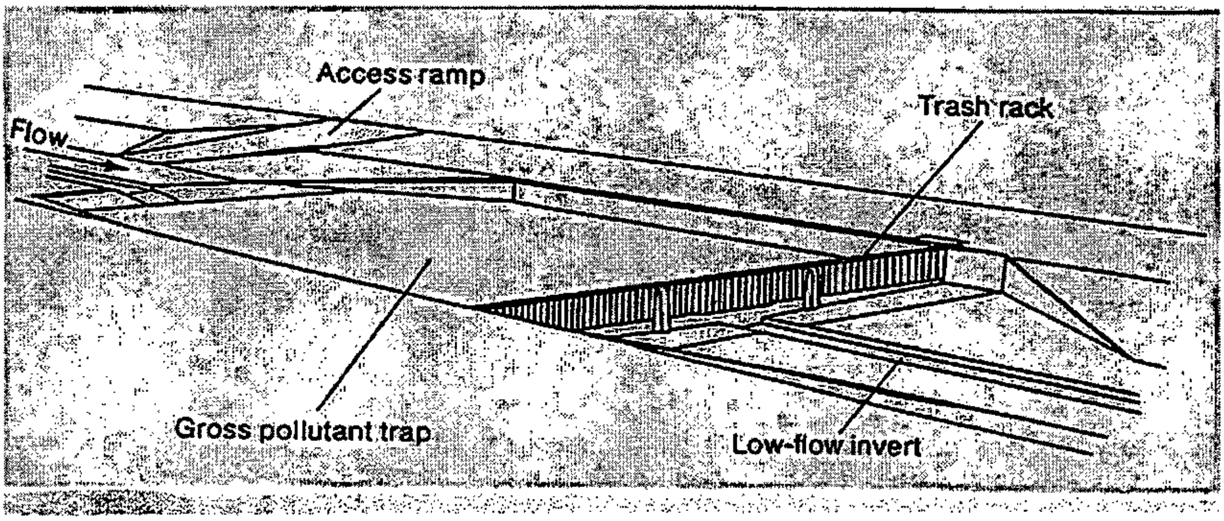


Figure 8 Gross Pollutant Trap (after Willing and Partners, 1988)

Gross pollutant traps use the same principle as trash racks to capture gross pollutants. However, the stormwater channels entering GPTs are widened for the sedimentation basin and therefore the trash rack (located on the downstream end of the basin) provides more trash rack area for a given stormwater channel width than a conventional trash rack (constructed in the channel). A GPT is typically at least three times wider than the channel width (but may vary because GPTs are sized according to sediment retention not trash rack size, Willing & Partners, 1992). For this DSS the trapping efficiency used for GPTs is three times that for trash racks, ie. 30%, assuming that the channel is widened to three times that of the inlet channel (and consequently so too is the trash rack area).

GPT costs are estimated from Sydney data despite the large number of GPTs in Canberra. Installation costs for the Canberra traps were not available to the author. The costs for installation and maintenance of the Sydney GPTs are shown in Table 4 (Robyn Sim, pers. comm., Sydney Water) and show that the average cost for a GPT is $1880 per hectare and $72 per hectare to maintain annually averaged for the six traps.

Table 4 Costs of Sydney GPTs (after Robyn Sim, pers. comm.)

Location	Catchment area	Installation cost	Installation cost / hectare	Maintenance	Maintenance /hectare/year
	ha	$	$/ha	$/year	$/ha/year
Bondi/Roscoe	46.0	800,000	17,391	18,964	412
Bondi//Lamrock	46.0	800,000	17,391	18,964	412
Botany	890.0	1,200,000	1,348	15,977	18
Orissa Street	55.0	450,000	8,182	19,971	363
Roslyn Gardens	14.0	55,000	3,929	12,613	901
Wolli Creek	1128.0	800,000	709	70,621	63
TOTAL(all traps)	2179	4,105,000	1,884	157,110	72

2.7 FLOATING DEBRIS TRAPS (FDT)

Floating debris traps or litter booms are constructed by stringing partly submerged floating booms across waterways. The boom, originally designed as an oil slick retention device, collects floating objects as they collide with it (MMBW et al., 1989). The performance of any boom is greatly influenced by the flow conditions of the waterway (McKay & Marshall, 1993; Melbourne Water, 1995; and DLWC, 1996). Litter booms are best suited for very slow moving waters and perform best with floating objects such as plastic bottles and polystyrene (SPCC, 1989).

More recently, Floating Debris Traps (FDTs; Bandalong Engineering, 1995) have evolved from booms and have an enhanced retention of captured material and an improved cleaning method. The traps use floating polyethylene boom arms with fitted skirts to deflect floating debris through a flap gate into a storage compartment (Figure 9). The flap gate is intended to prevent collected floatables escaping with changed wind or tidal conditions. A sliding gate on the downstream end of the trap provides an improved cleaning method. As the gate is raised material flows out of the trap and into a collection basket that is located downstream of the trap during cleaning. Once full, the cleaning basket is lifted onto a specially designed barge (fitted with a crane to lift the basket).

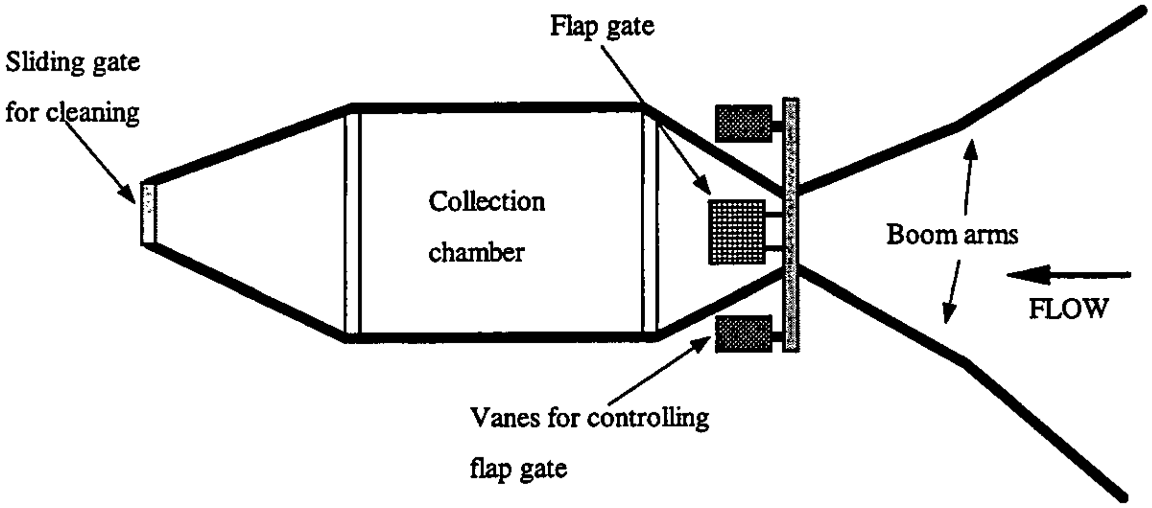


Figure 9 Plan view of Bandalong floating debris trap

The location of FDTs is critical to their performance because the traps can rarely span the full width of a waterway as they are restricted by waterway traffic or the size of the waterway. In addition to inefficiencies caused by not spanning the full width of a waterway the results of monitoring, as part of this study, revealed that only 20% to 25% of litter items float (and less than 10% for organic material), and therefore only these proportions are available to be trapped by floating traps. Furthermore, during high flows material is forced over or under the floating booms as described by Nielsen and Carleton (1989), Gamtron (1992) and Horton et al. (1995).

McKay & Marshall (1993) report efficiencies for *floating material* of 12% to 50%. The highest efficiency reported was for a boom that spanned the full width of a waterway (Merri Creek) and the lowest value (12%) for the trap located on the widest waterway (the Yarra River at Chapel Street). For the purposes of the DSS, the efficiency for a FDT is proportional to the percentage of the waterway width it spans. A 100% coverage (ie. full width) is assumed to have a 50% efficiency for *floating* material (as the Merri Creek boom in McKay & Marshall (1993) suggests). Floating items are considered to be 20% of the litter load (see Allison et al., 1997b). Therefore the overall efficiency for a FDT spanning the full width of a waterway is 20% of 50%, namely 10%.

The efficiency is assumed to reduce with the proportion of the waterway that is spanned by the FDT. For example, a trap that covers 60% of the waterway width will have an efficiency of 60% of a FDT that spans the full width, namely 6% for litter capture (including suspended and sinkable materials).

For total gross pollutant load, the efficiency is further reduced because of the smaller proportion of vegetation that floats compared to that which sinks or is neutrally buoyant. The total load is a combination of litter and vegetation (but mainly vegetation). The proportion of the total load that floats is assumed to be 10% (from results in Allison et al., 1997b). Therefore, the efficiency for a FDT which spans the full width of a waterway is assumed to be 50% (the efficiency for floating material) of 10% (the proportion which floats), hence the overall trapping efficiency for total load is 5% (when spanning full width of a waterway). Again the efficiency is assumed to be proportionally less according to the percentage of the width of the waterway that the trap spans.

The catchment areas (and hence average costs per hectare) of floating debris traps are difficult to estimate because they are generally located in slow moving waters that typically have very large catchment areas. In addition, they are used in clusters along river reaches (for example, on the lower Yarra River in Melbourne). Estimates of the unit-costs for each trap are between $15,000 and $20,000 (Tony Welsh, pers. comm., Bandalong Engineering).

Catchment areas are calculated by dividing the total urban catchment area of the lower Yarra River by the number of FDTs used along the reach of waterway. The urban catchment area upstream of the traps is estimated to be 60,000 hectares from catchment plans. With ten traps in this reach of the Yarra River the individual trap catchments are assumed to be 6,000 hectares. Therefore, the installation costs are assumed to be $3 per hectare.

The cost of maintaining floating debris traps is also estimated from Melbourne Parks and Waterways data (Doug Vallance, pers. comm., Melbourne Parks & Waterways). Monthly maintenance costs (averaged over one year for five traps) are $5,940 per trap and again assuming a catchment area of 6,000 hectares per trap, $1 per hectare per year would be the monthly cleaning cost. The annual maintenance costs for FDTs used in Melbourne are presented in Table 5.

Table 5 Maintenance costs for FDTs in the Yarra River, Melbourne (after Vallance, pers. comm.)

Maintenance costs per month for floating debris traps on the Yarra River

Location	Aug-94	Sep-94	Oct-94	Nov-94	Dec-94	Jan-95	Feb-95	Mar-95	Apr-95	May-95	Jun-95	Jul-95	Totals
	$	$	$	$	$	$	$	$	$	$	$	$	$
Leonda		513	522	576	504	306	450	1548	1008	972	504	288	7191
Grange Road	306	36	315	414	315	144	378	234	360	1206	936	630	5274
Mary Street						1152	72	90	387	198	252	72	2223
Prahran M.D.	666	531	306	522	315	252	378	1026	306	198	162		4662
Morall Bridge	158								72		270	54	554
Miscellaneous costs*	709	904	834	904	904	974	1044	1554	1184	764	0	0	9775
TOTALS	1839	1984	1977	2416	2038	2828	2322	4452	3317	3338	2124	1044	29679

Average costs per trap per year = $29,679 / 5 = $5,940 per trap per year

*miscellaneous costs are for all traps combined and include barge hire etc.

2.8 SUMMARY OF DSS EFFICIENCY DATA AND ASSUMPTIONS

In Table 6 the efficiency values used in the DSS for the trapping systems are presented and the key assumptions that are made in deriving the values are listed.

Table 6 Summary of efficiency data used in DSS and assumptions made to derive them

Device	**Catchment areas**	**Efficiencies for litter**	**Efficiencies for total load**	**Assumptions**
		%	%	
Side entry pit traps	0.1 - 1	76*	64*	Efficiency depends on distribution and density - at best 100% coverage and reduces with less coverage , as per Figures 7.6 & 7.7
Trash racks	20 - 500	10	10	Estimated to be 10% for both litter and total on the basis of McKay & Marshall (1993)
Litter control devices	2 - 150	30**	30**	Estimated from Hocking (1996) but default assumes monthly cleaning and a reduction in efficiency because of this
CDS devices	10 - 60	98	98	Trapping efficiency proportional to volume of runoff through separation chamber as all gross pollutants retained by chamber
Gross pollutant traps	5 - 5000	30	30	Same as trash racks but increase with of channel by at least 3, therefore assumed to be 3 times more efficient
Floating debris traps	> 250	10***	5***	FDT efficiencies depend on the proportion of the waterway they span, and only trap floatables (which are 20% of litter load; 10% of total gross

*assuming 100% saturation of SEPTs

**cleaning frequencies can change efficiencies either weekly (82%) or fortnightly (41%)

*** assuming FDT spans full width of waterway

3. ASSUMPTIONS IN THE DSS

Comparing alternative trapping systems when data have been derived from different collection techniques and locations requires assumptions to be made. Data for the DSS have been derived from field work as part of this study and from other Australian data. The assumptions made to allow comparisons are:

- that dry mass is used to measure gross pollutant loads (not volume or items counts);
- that land-use type and rainfall are the primary influences on gross pollutant loads;
- that the data used to derive gross pollutant loads are typical of urban areas for which the DSS will be used;
- that all load and cost data are expressed in terms of the area (ha) of the catchment; and
- that suitable and feasible construction sites are available for all locations of traps that the user wishes to be considered.

In addition, individual trap efficiency assumptions are described in the previous section.

Dry mass is considered to be the most appropriate measure of gross pollutants because it ensures that the moisture content of material does not influence the measured load. Gross pollutants are generally trapped and collected in different ways (some traps retain pollutants dry and some wet) and therefore the moisture content of the gross pollutants will vary from trap to trap and influence the mass of wet material greatly. By measuring the dry mass in each instance a more accurate measure of the quantity of material is presented.

Using a mass relationship to determine the effectiveness of trapping systems is biased against some litter items that have very low densities but contribute to waterway degradation (eg. polystyrene pieces and plastic bags) and the potential impacts of these materials need to be recognised. The DSS presents the litter component of the gross pollutant load separately which allows the user to focus on the litter retention capabilities of any trapping system, in addition to the total load performance.

In the report by Allison et al. (1997b) a number of variables are plotted against the loads monitored in the experimental catchment (65% residential, 30% commercial and 5% light-industrial). From these analyses rainfall and runoff appeared to be the best indicators of gross pollutant loads, however, rainfall was chosen for the DSS because it is more readily available than runoff.

The DSS is based on field experiments carried out in Coburg, as part of this study (except for cost and efficiency data for four traps). To use the DSS elsewhere, it is assumed that the areas to be investigated are similar to Coburg. The user can enter variations in land-use areas and any influence of street cleaning. However, within each land-use type (residential, commercial and light-industrial) it is assumed that gross pollutant generation and transport mechanisms are similar to those found within the Coburg areas.

Data for the loads of material and the costs of traps are averaged over catchment area. Therefore, the loads and costs are relative to the catchment areas that the user inputs. There are minimum sizes for some of the trapping systems and consequently the user must be aware of these in order for the averaged values to be multiplied by the catchment area to represent meaningful values. To help the user, ranges of acceptable catchment sizes for each trap are presented in the *cost and efficiency page* of the DSS. A 'no-trap' option is also offered for locations where it is not feasible to construct traps.

To obtain generic trap efficiencies for each type of trapping system (as described in Section 4.2), assumptions from the results of performance testing in the Australian literature need to be made and these are described in Section 2 and summarised in Section 2.8. The user enters the catchment areas for each trap and it is assumed that there are feasible locations for trap installations.

A constant value of trapping efficiency and cost per hectare is assumed in the DSS regardless of the catchment area. This simplification is made because of the lack of efficiency data for traps of different sizes. A trap installed in a smaller catchment would cost more per hectare and have a higher trapping efficiency than another trap of the same type and size, installed in a larger catchment. However, the exact catchment sizes and the number of traps required for a catchment area would not be known by the user at the start of analysis. The position of the traps will depend on the catchment layout and the feasibility of construction. A unit-cost (per hectare) for each trapping system is assumed in the DSS as it provides a general description of the trapping system. Data which are used in the DSS were obtained from studies of trapping systems with different catchment sizes. The unit-cost simplification compensates for the higher unit-cost and trapping efficiency associated with smaller catchments, and the lower unit-cost and trapping efficiency associated with larger catchments for the same type and size of traps.

There are many assumptions used to derive the costs here. The data are intended to give an indication of relative performances and costs between very different types of trapping systems. Further investigation into the costs and feasibility of the traps would be required before the possibility of construction can be determined.

4. COMPUTATIONS IN THE DSS

A flow chart of the computations performed by the DSS is presented in Figure 10 and the following sections describe each step.

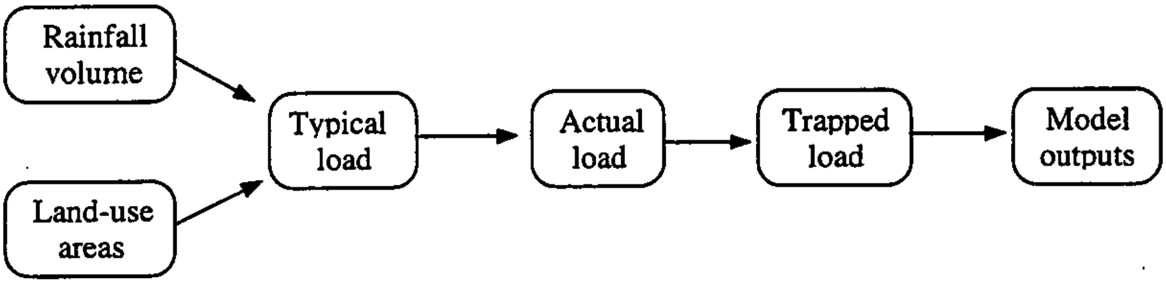


Figure 10 Flow chart of calculations performed by the DSS

Gross pollutant loads are calculated for the total load and the litter component of the load separately. This enables the users to adopt whichever criterion is most important for their particular catchment (either litter or total load). From rainfall and land-use type data the typical loads are estimated; the typical load is then adjusted for street cleaning practices and results in a "actual-load". The actual-load is then used, along with the trapping efficiencies, to calculate the quantities of material that are retained by each trapping system. Finally, the costs (installation and maintenance) for the chosen system(s) and the annual wet mass and volume are calculated from the catchment areas draining into each trap.

4.1 RAINFALL AND LAND-USE TYPE TO TYPICAL LOADS

Data for generating gross pollutant loads are derived from the field monitoring of the CDS device (described in Allison et al., 1997b). The CDS device provides an excellent monitoring tool for estimating the quantity of gross pollutants transported in stormwater systems because of its high capture rate. However, these data were collected during only three months of winter monitoring. Loads of gross pollutants may vary during other seasons (because of changes in storm characteristics, nature and amounts of vegetative material or pedestrian habits) and therefore additional monitoring of gross pollutant loads (beyond the scope of this study) would strengthen this component of the DSS.

Analyses of the loads collected from the CDS device during monitoring show that both rainfall and runoff display a strong correlation to load. For the purposes of this DSS, rainfall is taken as the explanatory variable for gross pollutant loads because rainfall data are more widely available than runoff data.

Data collected over the three months of monitoring are used to derive the equations for estimating gross pollutant loads (Figures 11 and 12). These data are used because they are the best data available in which the amount of gross pollutants travelling through a stormwater system was measured in a 50 hectare urban catchment (see Allison et al., 1997b). 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. With increasing data, rainfall may not appear to be the best indicator of gross pollutant loads and an alternative variable could easily be implemented in the DSS.

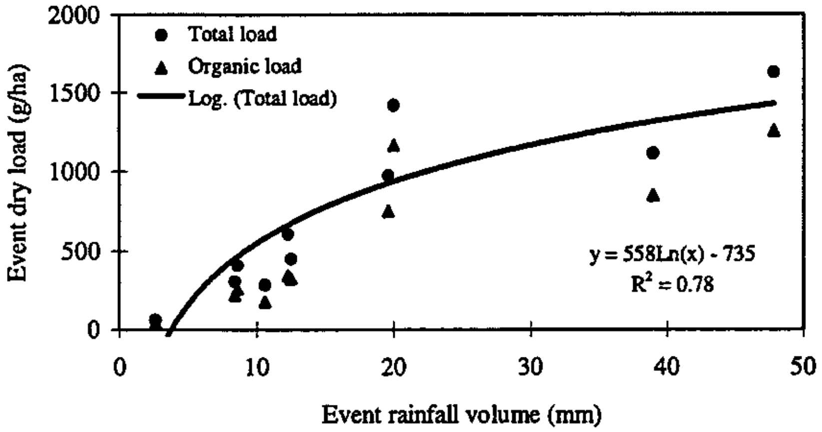


Figure 11 Rainfall against total and organic loads for the ten clean-outs

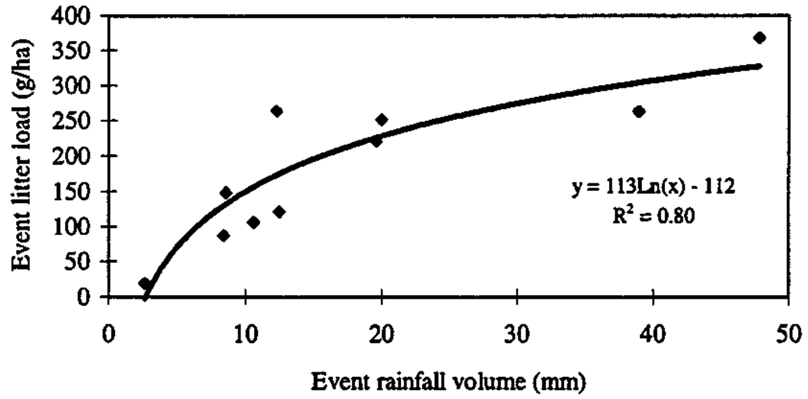


Figure 12 Rainfall against litter loads for the ten clean-outs

The loads monitored in the CDS device were derived from a mixed land-use catchment (residential 65%, commercial 30% and light-industrial 5%) and the relative inputs from each land-use type are unknown. Previous monitoring, as part of this study, in the same area investigated the influence of land-use type on gross pollutant loads. The data presented in Allison et al. (1997b) are from only two storm events and conclusions from this information should be treated with caution. Relationships are derived here (Table 7 and 8) to present a procedure for incorporating land-use type into the determination of gross pollutant loads. The different catchments - residential, mixed commercial/ residential and light-industrial - are used to determine loads for residential, commercial and light-industrial areas, (ie. the mixed area is broken into residential and commercial areas).

Once the load values for each land-use area are determined they are compared to the weighted average of all of the areas combined. This ratio represents the relative loads for each land-use area (for both litter and total load, Tables 7 and 8) compared to the average of all the areas combined. The results show similar values of this ratio for both storms for all cases except light-industrial areas where the small catchment area contributed to errors because of the effect of one large item caught by a basket on one occasion.

Table 7 Average loads for each land-use type and the proportion to the weighted average load for the whole area for a storm on 27-1-95

LANDUSE	AREA	LITTER LOAD		TOTAL LOAD	
	ha	g/ha	value / weighted average	g/ha	value / weighted average
Commercial	9.5	164	2.0	423	1.3
Residential	26.5	43	0.5	292	0.9
Light-industrial	2.5	162	2.0	242	0.8
Weighted average	38.5	81	1.0	321	1.0

Table 8 Average loads for each land-use type and the proportion to the weighted average load for the whole area for a storm on 31-5-95

LANDUSE	AREA	LITTER LOAD		TOTAL LOAD	
	ha	g/ha	value / weighted average	g/ha	value / weighted average
Commercial	9.5	598	2.5	747	1.9
Residential	26.5	127	0.5	308	0.8
Light-industrial	2.5	20	0.1	63	0.2
Weighted average	38.5	236	1.0	400	1.0

The relative loads for each land-use area are averaged over the two monitored storms for the DSS and these data are presented in Table 9. These relationships are used to adjust the loads monitored in the CDS device (from mixed land-uses) to represent loads for individual land-use types. The relationships for load against rainfall for different land-use types are presented in Figures 13 and 14. The relative loads for different catchment areas are shown in Table 9, the ratios are: commercial 2.2 for litter and 1.6 for total gross pollutants, residential areas (.54 and .84) and light-industrial areas (1.0 and .46).

Table 9 Averaged ratios of litter and total gross pollutant loads derived from different land-use types compared to the average for all areas combined

LANDUSE	AREA	LITTER LOAD	TOTAL LOAD
	ha	value / weighted average	value / weighted average
Commercial	9.5	2.3	1.6
Residential	26.5	0.5	0.8
Light-industrial	2.5	1.0	0.5

To form the relationships between rainfall and loads for each land-use type (Figures 13 and 14) two sets of data have been used: data collected from sampling single land-use catchments and data collected relating to the loads captured from a mixed land-use catchment (the CDS device catchment). It is fortunate that the sum of the individual land-use catchments monitored as part of the single land-use monitoring, have similar ratios of areas of land-use type to the catchment monitored as part of the load-monitoring (the CDS device catchment).

The sum of the catchments monitored have the following land-use categories: residential (69%), commercial (25%) and light-industrial (6%). The land-use types in the catchment draining to the CDS device are estimated to be residential (65%), commercial (30%) and light-industrial (5%). It is assumed for the purposes of the DSS that these areas are not greatly different and the loads expected from the CDS catchment would be similar to those from the sum of the individual land-use catchments monitored on a per hectare basis (ie. the ratio of land-uses for these areas are the same). This assumption allows simulated litter load and total gross pollutant load magnitudes (determined from CDS monitoring) to be related to single land-use types (using Table 9). These relationships are used in the DSS to compute the loads of gross pollutants for different land-use areas and are presented in Figures 13 and 14.

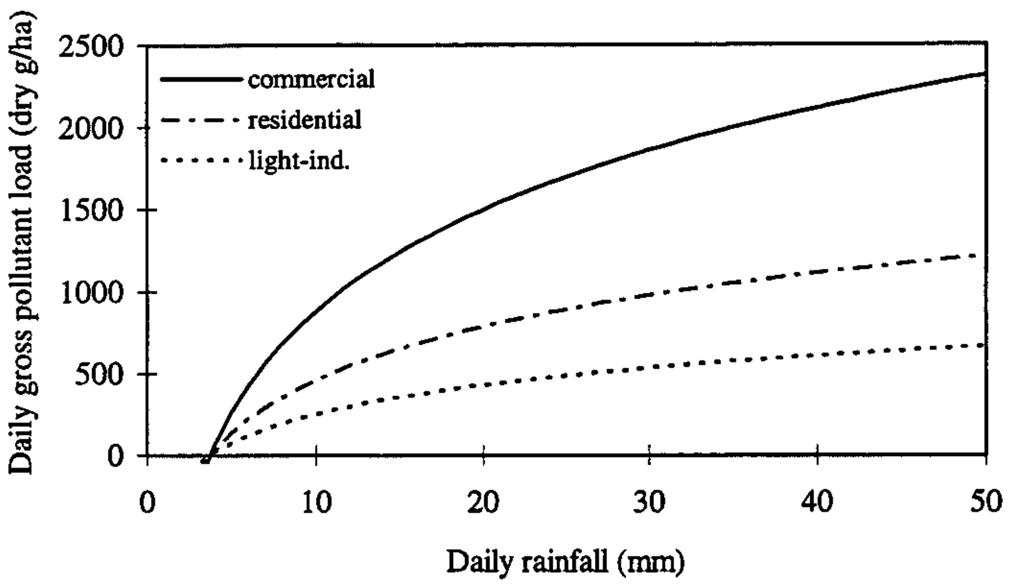


Figure 13 Total gross pollutant load relationships for different land-use areas (as used in the DSS)

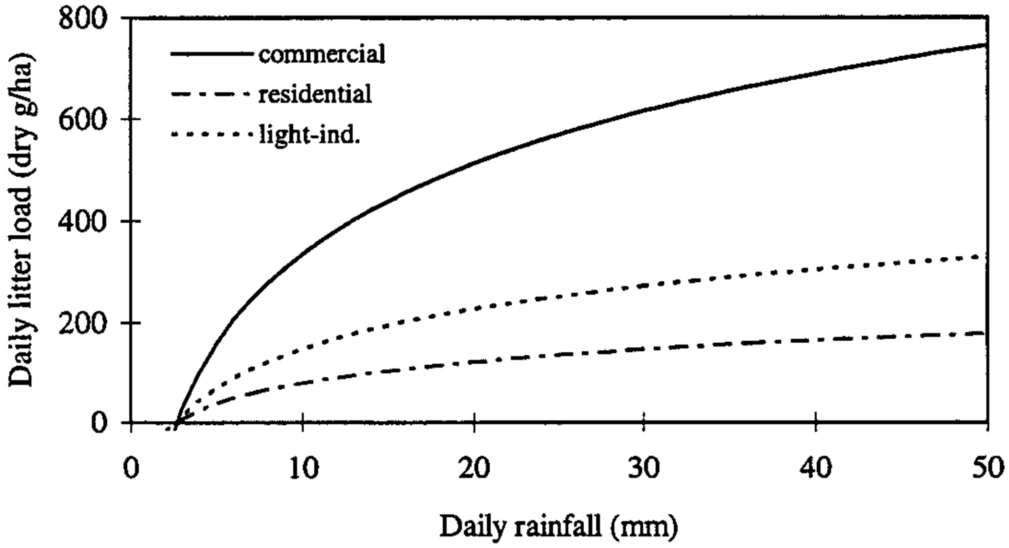


Figure 14 Litter load relationships for different land-use areas (as used in the DSS)

4.2 TYPICAL LOAD TO ACTUAL LOAD

In the DSS, street cleaning only affects results if the practices in the catchments entered by the user are considered to be different to the typical practices undertaken in Coburg (Section 1.1). In Coburg, street sweepers operate fortnightly in residential areas, five days a week in commercial areas and daily in busy commercial areas. No street flushing is performed. Because there is a lack of Australian data on the quantities of gross pollutants removed by street cleaning, a factor is used to adjust the loads in the DSS. The factor adjusts the actual load relative to the practices in Coburg. The factor will need to be reassessed as more information becomes available about the effectiveness of street cleaning programs on gross pollutant loads.

When the user believes cleaning regimes are considerably different from those in Coburg, they can enter a percentage increase or decrease in the load reaching the stormwater system as part of the input to the DSS.

4.3 ACTUAL LOAD TO TRAPPED LOAD

Loads (calculated with rainfall and land-use area information) are multiplied by the trapping efficiencies to yield a total dry mass retained and dry mass of material passing downstream of each trap. These dry loads are then converted into the model outputs as the next section will describe.

The individual trapping efficiencies for the six traps used in developing the DSS vary for litter and total load in the cases of SEPTs and FDTs. The trapping efficiencies of the other systems (presented in Table 6) are assumed to be the same for litter loads and total gross pollutant loads because there is no evidence to indicate otherwise.

Table 10 Costs and efficiencies (averaged over a number of traps) for each trapping system considered in the DSS, derived in Section 2

Device	Operational catchment areas	Efficiencies for litter	Efficiencies for total load	Installation cost	Cleaning frequency	Maintenance cost
	ha	%	%	$/ha[4]		$/ha.year[4]
Side entry pit traps	0.1 - 1	76[1]	64[1]	420[1]	monthly	360[1]
Trash racks	20 - 500	10	10	1200	monthly	185
Litter control devices	2 - 150	30[2]	30[2]	2900	monthly[2]	32[2]
CDS devices	10 - 60	98	98	3000	quarterly	80
Gross pollutant traps	5 - 5000	30	30	1880	quarterly	72
Floating debris traps	> 250	10[3]	5[3]	3	fortnightly	1

[1] assuming 100% saturation of SEPTs
[2] cleaning frequencies can change to either weekly ($140/ha/year) or fortnightly ($64/ha/year)
[3] assuming FDT spans full width of waterway
[4] 1997 A$

4.4 MODEL OUTPUT CALCULATIONS

Using relationships averaged from ten clean-outs of the CDS trap, dry mass is converted into wet mass and volume of gross pollutants (Table 11 shows the conversions used in the DSS). This gives the user an idea of the magnitude of disposal requirements and potential receiving water impacts. An example of the output from the DSS is shown in Figure 2.

Table 11 Conversions of dry masses to wet masses and wet volumes (after Table 6.1)

Clean date	**Volume**	**Total wet mass**	**Total dry mass**	**Total dry mass**	**Wet : dry**	**Wet density**
	m3	kg	g/ha	kg		kg per m3
13-May-96	0.4	176	972	49	3.6	450
22-May-96	0.3	62	408	20	3.1	240
24-May-96	0.1	14	62	3	4.4	170
21-Jun-96	0.3	95	608	30	3.1	280
27-Jun-96	1.0	253	1621	81	3.1	260
4-Jul-96	0.8	239	1417	71	3.4	280
10-Jul-96	0.3	51	307	15	3.3	160
18-Jul-96	0.3	77	447	22	3.5	240
24-Jul-96	0.3	55	283	14	3.9	170
2-Aug-96	0.7	163	1109	55	2.9	220
Total	4.6	1184	7233	362	3.3	260
Conversions used	**0.013**	**3.3**		**1**		

The costs per hectare of various combinations of traps are calculated from the areas contributing to each trap system (irrespective of land-use type) and the average installation and maintenance costs are shown in Table 10.

Table 10 shows that trap installations costs (excluding FDTs) vary from $420 to $3000 per hectare and annual maintenance costs vary from $32 to $360 per hectare of catchment for different trap types. The maintenance costs do not include the cost of dumping material. Maintenance costs are separated from the installation costs because of the importance of maintenance to the long-term success of any gross pollutant trapping system.

The DSS calculates the costs for maintaining different combinations of trapping systems by assuming standard cleaning frequencies (as Table 10 shows). The user can change the cleaning frequency for LCDs and the percentage coverage of SEPTs which affects the maintenance costs (and overall trapping efficiencies). Default cleaning frequencies in the DSS are the values shown in Table 10.

5. CASE STUDY FOR REDUCING GROSS POLLUTANT DISCHARGES

In this section the DSS is used to compare the costs and efficiencies of different trapping strategies in a real catchment. The analysis considers the site constraints and the system layout in determining the feasibility of each system. The drainage layout influences the position of possible traps and the land-use types draining to them, and therefore the feasibility of some systems. A 150 hectare area in Coburg, Melbourne is adopted as the case study catchment.

5.1 CASE STUDY METHODOLOGY

During the analysis, the DSS is used to:

1. apply each trapping system (in the DSS) to the whole catchment and apply an economic evaluation of the results to determine the respective trapping efficiencies and equivalent annual costs;

2. using these results, choose four combinations of trapping systems that appear to be the most suitable for the case study catchment;

3. compare the equivalent annual cost of the four combinations of trapping systems, for a range of litter trapping efficiencies;

4. plot litter trapping efficiency against cost (equivalent annual cost); and

5. use this plot to determine the best trapping strategy for the catchment.

5.2 CATCHMENT DESCRIPTION

The catchment area is 150 hectares (shown in Figure 15) of primarily residential land-use (96 hectares) but with some commercial (38 hectares), light-industrial (8 hectares) and park-land (8 hectares) areas. The drainage layout is shown in Figure 15 and determines where traps can be built and also the land-use areas that drain to the traps. The characteristics of the area and management practices are described in Section 1.1 (as it is the same area used for the gross pollutant monitoring). This catchment was chosen because land-use areas and drainage layout information were already established. It is also the same area from which the DSS was derived and therefore no adjustments for street cleaning or rainfall to the DSS were required.

Figure 15 Diagram of case study area showing possible locations of the trapping systems

5.3 ECONOMIC COMPARISONS

Ultimately the choice between different trapping strategies will depend on an economic evaluation of each potential strategy. One approach to compare the costs of different engineering systems is to use a net present worth analysis to evaluate each system (Dandy & Warner, 1989).

To do this the total project costs (net present costs (NPC)) are determined in present day dollars and then divided by the duration of the project. The costs of each strategy are presented as capital and annual maintenance costs from the DSS and therefore can be used to determine total NPC in 1997 dollars by adding up all installation costs and the annual maintenance costs. The equivalent annual costs (EAC) are then calculated by dividing the NPC by the life-span of the project.

5.4 CASE STUDY ASSUMPTIONS

For the analysis in the case study a 30 year project life is assumed. All trapping systems are assumed to have 30 year life spans, except for SEPTs that are estimated to last 15 years with the plastic materials used in construction (ie. SEPTs require replacement after 15 years and therefore require two installations). The park-land area is conservatively assumed to have the same gross pollutant characteristics as the residential area (but is likely to produce fewer gross pollutants).

5.5 SINGLE TRAPPING SYSTEMS APPLIED TO THE WHOLE CATCHMENT

The DSS is used to determine the cost and trapping efficiency of each trapping system applied to the whole catchment. This gives an indication of the loads of gross pollutants that move through the stormwater system and of the differences in costs and performances of the systems applied in the Coburg catchment (assuming all the systems can be installed).

Output from simulations of the individual traps over the whole catchment area (shown in Table 12) indicates that 3.7 tonnes (15 m^3) of litter and 13 tonnes (51 m^3) of total gross pollutants travel through the stormwater system annually. The output also indicates that CDS devices are the most efficient trapping system, but cost the most to install. Using EAC, the cheapest option is a LCD system with a 30 day cleaning cycle, but this has a low trapping efficiency, and therefore is unlikely to be adopted. SEPTs are the cheapest to install and retain a significant proportion of the gross pollutants but have considerable cleaning requirements. LCDs can also retain significant amounts of gross pollutants with weekly cleaning but are also expensive to install and maintain.

Table 12 DSS output for single-trap systems applied to the whole case study area (150 ha)

system	$ install	$ maintain per year	Equivalent annual cost	Litter load	Total load	% litter caught	% total caught
	$000's	$000's	$000's	wet tonnes	wet tonnes	%	%
SEPT (100%)	63 + 63*	54	58.2	3.7	12.8	76	64
SEPT (60%)	38 + 38*	32	34.5	3.7	12.8	63	51
Trash racks	180	28	34.0	3.7	12.8	10	10
LCD (30 days)	435	5	19.5	3.7	12.8	30	30
LCD (7 days)	435	21	35.5	3.7	12.8	82	82
CDS	450	12	27.0	3.7	12.8	98	98
GPT	282	11	20.4	3.7	12.8	30	30
FDT	not applicable in Coburg						

*replacement cost for SEPTs after 15 years

The selection of one of these or any trapping system for a catchment is determined by: the costs and trapping efficiency of the systems, the perceived importance of the downstream waterway, and any social or political pressures. Therefore, as many trapping systems as possible are included in the DSS despite different performance characteristics (eg. trash racks are included in the DSS despite their low efficiency because managers may only get funds to install trash racks, and the DSS can be used to help determine the best location for them).

With each system having unique construction, maintenance and trapping efficiency values it is possible that a combination of different trapping systems, will provide the trapping strategy best suited to the experimental catchment. Four combinations of potential trapping systems are examined in the following section. Note that a 'combination' can include any number of trapping systems (including a single trapping system).

5.6 COMBINATIONS OF TRAPPING SYSTEMS

When choosing between trapping strategies, objectives for gross pollutant removal need to be identified. For this exercise, trapping litter items is adopted as the objective. An objective of 65% litter capture is adopted to select four potential strategies best suited to this case study catchment. The costs are then calculated for incremental increases in the percentage of litter removal for each of the four trapping strategies chosen.

To select locations for different traps, consideration of the drainage system layout and land-use areas is essential. Commercial and light-industrial areas are likely to produce the most litter items (Figure 14) and therefore these are the areas that are targeted. However, it is unlikely that it will be possible for any traps except SEPTs to have single land-use catchments, because of the nature of urban areas. The scale of catchments for each trap also influences the proportion of targeted land-use area (eg. commercial areas) that will be treated. For example, consider the differences in contributing areas for points B and C in Figure 15, the commercial area in the larger catchment (at point C) is 25% of the total area, compared with 63% in the smaller catchment (at point B), even though the two points are close to each other.

The preferred (as defined by the authors) four combinations of traps that capture 65% of the litter are presented in Table 13 as estimated by the DSS. The four strategies used are: SEPTs; LCDs with SEPTs; CDS devices; and CDS devices with SEPTs. The proportion of the entrances that have SEPTs installed in them and the cleaning frequency of LCDs are shown in brackets in Table 13.

Table 13 Output for the case study from four combinations of trapping systems

system	$ install	$ maintain per year	Equivalent annual cost	% litter caught	% total caught
	$000's	$000's	$000's	%	%
SEPT (75%)	45 + 45*	38.3	41.3	65	54
LCD (7 days) / SEPT (85%)	246 + 5.4*	16.0	24.4	65	55
CDS	260	6.9	15.6	65	55
CDS / SEPT (70%)	161 + 13.8*	15.8	21.6	65	53

*replacement cost for SEPTs after 15 years

For a 65% capture rate, Table 13 suggests that a CDS device system will provide the cheapest option over a 30 year period. The equivalent annual cost is estimated to be $15,600.

Selecting trapping combinations requires close consultation of land-use areas and drainage maps. The catchment areas for each combination to reach a 65% litter capture rate are presented in the input/output pages from the DSS, shown in Appendix A. A description of each combination of trapping systems is presented below to indicate the detail of investigation required to determine the values shown in Table 13.

1. The first system (SEPT at 75% density; Table 13) satisfies the 65% litter capture rate and has the lowest initial cost but the highest maintenance cost (and the highest EAC). The system has SEPTs located in all of the catchment except 8 hectares of residential area (details of the simulation are in Appendix A). The traps are installed at a 75% density (ie. three traps per hectare) and are cleaned monthly.

2. The second system uses a combination of LCDs and SEPTs to reach the 65% litter capture target. The LCD would be located near to point F in Figure 15 and the SEPTs (placed at an 85% density) on the remaining commercial and light-industrial areas leaving 52 hectares of residential area untreated (Appendix A). To obtain this capture rate the LCDs require weekly cleaning and the SEPTs monthly cleaning. The frequent cleaning and the large initial cost of the LCD makes this option the second most expensive.

3. The third system considered is a CDS unit strategically placed (near point F in Figure 15) to capture a high proportion of the commercial and light-industrial areas leaving the remaining areas without treatment (ie. 8.5 commercial, 52 residential and 3 light-industrial hectares untreated, Appendix A). Although the system is the most expensive to construct, it is the cheapest to maintain and has the lowest EAC.

4. The final system presented in Table 13 is cheaper to install than the CDS unit alone but costs more to maintain because of the number of SEPTs that are used to reach the 65% litter capture rate and is the second cheapest option. A smaller CDS unit is used than in the previous example (placed between points E and F in Figure 15) along with SEPTs in the rest of the commercial, light-industrial and some of the residential areas (Appendix A).

These four trapping strategies are now used to illustrate how their costs vary for different litter capture rates. Depending on the objectives set by the user, an alternative strategy may prove to be more appropriate, however, these four strategies are used here to demonstrate the methodology for determining any potential point of diminishing return for a particular strategy. Each strategy is applied to the catchment so that an incremental increase of 10% litter trapping efficiency is achieved. The estimated costs are used to determine a relationship between costs and trapping efficiencies for each trapping strategy applied to the case study catchment.

As an example of the procedure used, consider the CDS system alone. Costs are estimated for an incremental increase of 10% litter trapping efficiency (ranging from 10% to 98%). The costs, contributing areas and locations for the CDS devices for each trapping efficiency are shown in Table 14, (Figure 15 shows the theoretical locations of the CDS devices, points A to J). The locations are determined by trial and error, with consideration of the land-use types, drainage layout and the resulting trapping efficiency. Details for the other three strategies are presented in Appendix B.

Table 14 EAC for different litter trapping efficiencies for the CDS system in the case study catchment

Trapping efficiency (%)	Location of CDS traps in Figure 15	AREA TRAPPED			AREA NOT-TRAPPED			INSTALL COST	ANNUAL MAIN. COSTS	EQUIVALENT ANNUAL COST
CDS system		com.	res.	light-ind.	com.	res.	light-ind.			
		ha	ha	ha	ha	ha	ha	$000's	$000's	$000's
10	A	5	7	0	33	97	8	36	1.0	2.2
20	B	12	7	0	26	97	8	57	1.5	3.4
30	C	11	33	3	27	71	5	141	3.8	8.5
40	D	16	38	5	22	66	3	177	4.7	10.6
50	D + E	19	52	5	19	52	3	201	5.4	12.1
60	D + F	26	52	5	12	52	3	249	6.6	14.9
71	G	33	55	5	5	49	3	279	7.4	16.7
80	H	34	70	8	4	34	0	336	9.0	20.2
90	I	36	92	8	3	12	0	407	10.8	24.4
98	J	38	104	8	0	0	0	450	12.0	27.0

The results from these analyses and the other three trapping system combinations are plotted in Figure 16, where the trapping efficiency to cost relationship for each of the four combinations in the experimental catchment is presented.

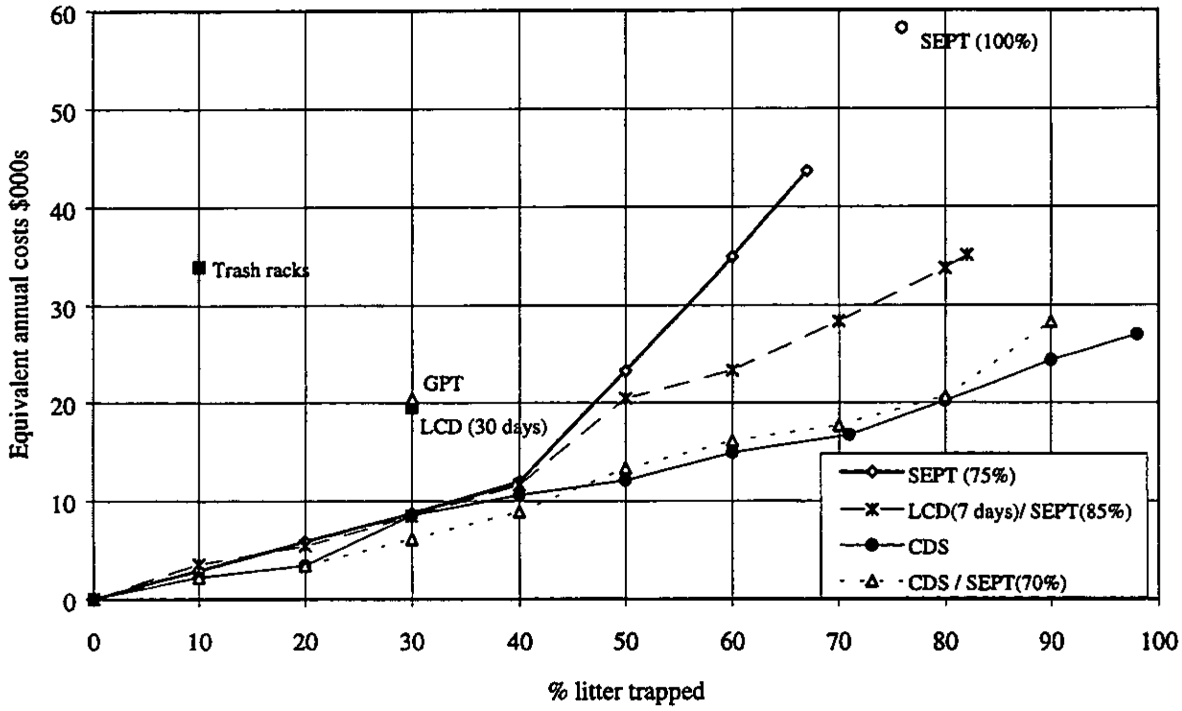


Figure 16 Equivalent annual costs versus the litter trapping potential of four systems examined in the case study catchment

The relationships presented in Figure 16 show how the litter trapping efficiency varies with the equivalent annual cost for each of the four trapping strategies considered. The figure also plots the comparative performance of some of the single trapping systems applied to the case study catchment (trash racks, LCD (30 days), GPTs and SEPT (100%)).

The outputs from the DSS plotted in Figure 16 indicate that a combination of SEPTs and CDS devices are consistently the cheapest option. In addition, the plot shows that trash racks, LCD (30 days) and GPTs are not worthy of consideration for the case study catchment. The plot also indicates that for trapping efficiencies of less than 50% a combination of a CDS / SEPT (70%) strategy appears to be the cheapest option. The figure also indicates that for more than 50% of the litter to be captured either CDS or CDS / SEPT (70%) strategies will provide the cheapest option for catchment managers.

Using these results some general conclusions can be made about the case study catchment. For capture rates of less than 50% of the litter a combination of a CDS / SEPT (70%) could be adopted as the cheapest option.

Should the litter capture rate required be more than 50% either a CDS or a CDS / SEPT (70%) strategy could be adopted as the cheapest options. As there is little difference between the costs of the two strategies it would be likely that a single trapping system would be more appealing to a catchment manager than a combination of trapping systems (for the simplicity of dealing with only one contractor). Thus, it would be likely that a CDS system would be adopted.

Therefore, for less than 50% litter capture a CDS / SEPT (75%) combination is preferable for the case study catchment, and for more than 50% litter capture a CDS strategy would provide the most attractive option to the catchment manger.

5.7 CASE STUDY RESULTS

Using the DSS an annual estimate of 3.7 tonnes (15 m^3) of litter and 13 tonnes (51 m^3) of total gross pollutants travel through the Coburg stormwater system. To reduce the effects of this pollution on the downstream waterways the DSS results suggest that a trapping strategy consisting of CDS devices is the best option should more than 50% of the litter want to be removed. If it is acceptable for less than 50% of the litter to be captured, a combination of SEPTs and a CDS unit is the most attractive option over a 30 year period.

6. SUMMARY

This report describes the development and application of a decision support system (DSS) which can be used by Authorities to determine effective approaches for trapping gross pollutants within a particular urban drainage area. The DSS is designed to provide comparisons between gross pollutant trapping systems. It uses fieldwork results and other Australian performance and cost data for gross pollutant trapping systems.

With the large areas in urban lands it is unlikely all areas will be covered with trapping systems. Therefore, specific areas are likely to be targeted, presumably the ones that produce the most gross pollutants. These areas were found to be commercial areas for litter and total gross pollutant loads. However, most catchments that are feasible for gross pollutant trapping systems (excluding SEPTs) are of a size that contains multiple land-use areas (which depends entirely on the drainage layout) and each land-use area can be entered separately into the DSS.

A case study is used to illustrate the value of the DSS for comparing different trapping systems. A 150 hectare catchment was used for the case study and from the DSS it was estimated that 13 tonnes of gross pollutants travel through the stormwater system annually (and of these 4 tonnes are litter). A CDS system was found to be the best option for trapping more than 50% of the litter load and combination of SEPTs and a CDS unit was the most attractive system for capturing less than 50% of the litter.

REFERENCES

Allison R.A. & Chiew, F.H.S., 1997, *Leaf litter in stormwater: A major source of nutrients?*, Water, 24(1):18

Allison R.A., Rooney, G., Chiew, F.H.S. & McMahon, T.A., 1997, *Field trials of side entry pit traps for urban stormwater pollution control*, in the proc. of the 9th National Local Government Engineering Conference, August, Melbourne, pp 9-13, ISBN0958721602

Allison R.A., Walker, T.A., Chiew, F.H.S., O'Neill, I.C. and McMahon, T.A., 1998, *From Roads to Rivers - Gross Pollutant Removal from Urban Waterways*, CRC for Catchment Hydrology

Allison R.A. and Chiew F.H.S., 1995, *Monitoring of stormwater pollution from various land uses in an urban catchment*, in the Proc. of the 2nd International Symposium on Urban Stormwater Management, Melbourne, pp 511-516, NCP 95/03.

Bandalong Engineering, 1995, *Floating debris trap - product description*, Victoria

Banyule City Council, 1996, *Drainage Pit Litter Trap - product description*, Victoria

Beecham, S.C. & Sablatnig, S.J., 1994, *Hydraulic Modelling of Stormwater Trashracks*, Proc. Int. Con. on Hydraulics in Civil Engineering, NCP 94/1, I.E. Aust., pp. 97-104

Brownlee, R.P., 1995, *Evaluation of Effectiveness and Efficiency of North Sydney Council Litter Control Program*, 2nd Int. Sym. on Urban Stormwater Management, Melbourne Australia, 11-13 July, I.E. Aust., NCP 95/03, Vol. 2, pp. 413-416

Cooper, G., 1992, *Hayes Street Litter Control Trap*, in Proc. Design and Performance of Gross Pollutant Traps and Wet Basins, Warwick Farm, 20 May, I.E. Aust, Sydney Division

Dandy G. C. & Warner R.F., 1989, *Planning and Design of Engineering Systems*, Unwin Hyman Ltd., London, ISBN 0-04-620017-7

Davies, G. 1995, *Litter Control in the Yarra Catchment*, YarraCare Land Management Series, Discussion paper No. 9, 17 pp.

DLWC (Department of Land and Water Conservation, NSW), 1996, DRAFT - *The Manager's Guide to: Sediment, Nutrient and Gross Pollutant Control, First Edition*, Resource Management Division, Sydney

Gamtron P/L, 1992, *Performance Assessment of Four Rubbish Interception Booms*, prepared for Water Board, Southern Region Stormwater Management, Rockdale NSW, 68 pp.

Hocking, J., 1996, *Evaluation of Effectiveness and Efficiency of Smoothey Park Litter Control Device*, Proc, 4th Annual Conference Soil and Water Management for Urban Development, I.E. Aust, NSW

Horton, P.R., Cox R.J. & Wilkinson D.L., 1995, *Stormwater Boom Performance Assessment and Enhancement*, 16th Australian Water and Wastewater Association Federal Convention

McKay, P. & Marshall, M., 1993, *Backyard to bay: tagged litter report*, Melbourne Water, ISBN 0 7306 3518 X, 36 pp.

Mein R.G. and Goyen, A.G., 1988, *Urban Runoff*, Civil Engng. Trans., 30 (4): 225-238

Melack, J.M., 1985, *Interactions of detrital particulates and plankton*, Hydrobiologia, 125: 209-220

Melbourne Water, 1995, *A Guide to Current Technologies for Removing Litter and Sediment from Drains and Waterways*, Waterways and Drainage Group, 41 pp.

MMBW (Melbourne & Metropolitan Board of Works), Environment Protection Authority (Victoria), Merri Creek Parklands, & City of Coburg, 1989, *Litter Control in Urban Waterways*, MMBW Internal Report, Book No. 006915, 40 pp.

Nielsen, J.S. & Carleton, M.G., 1989, *A Study of Trash and Trash Interception Devices on the Cooks River Catchment, Sydney*, in the Proc. of the 13th Australian Water and Wastewater Association Federal Convention, pp. 126-129

Perrens, S.J., 1992, *Design of Sediment Control Structures: Tuggerah Lakes*, Dames and Moore Consulting Report, Ref: 3425/D1785

Phillips B.C., 1992, *A Review of Design Procedures for Gross Pollutant Traps and Water Pollution Control Ponds*, in the Proc. of Design and Performance of GPTs and Wet Basins, I.E. Aust., pp. 1-21

Queck, K.H., Bliss, P.J. & Ball, J.E., 1991, *Effect of Basin Design Features on the Removal Efficiencies of Sedimentation Tanks,* in the Proc. of the 14th Australian Water and Wastewater Association Federal Convention, Vol. 1, pp. 242-247

QUT (Queensland University of Technology), 1996, *Results of an Audit of Litter Captured in Trash Racks Located at Sandy Creek and Cressey Street,* for Brisbane City Council, Department of Works, 23 pp.

SPCC (State Pollution Control Commission), 1989, *Pollution Control Manual for Urban Stormwater,* ISBN 0 7305 0702 5, New South Wales, August, 111 pp.

Willing and Partners Pty. Ltd., Water Resources Division, 1988, *Major and minor Gross Pollutant Traps,* prepared for the National Capital Development Commission, February, Canberra

Willing and Partners Pty. Ltd., Water Resources Division, 1992, *Design Guidelines for Gross Pollutant Traps,* for ACT Planning Authority, Dept. of Environment, Land and Planning, Project No. 3015

Wong, T H F, Wootton, R M & Fabian, D, 1996 , *A Solid Separator using a Continuous Deflective System,* in the Proc. of the 7th Int. Con. on Urban Stormwater Drainage, Hannover, Germany. pp. 881-886

Appendix A

Input/output & *cost/efficiency* pages from the DSS for four combinations of trapping systems for the case study catchment.

(i) SEPT (75%) system

(ii) LCD / SEPT (85%) system

(iii) CDS device system

(iv) CDS device / SEPT (70%) system

refer to the instructions on pages 6 & 7 in the report for directions PRESS F9 TO EXECUTE PROGRAM

INPUTS: Input areas draining to each trap (ha)

Trapping system		commercial	residential	light-industrial	Total area
		ha	ha	ha	
SEPT*		*38*	*96*	*8*	142
Trash racks		*0*	*0*	*0*	0
LCD**		*0*	*0*	*0*	0
CDS devices		*0*	*0*	*0*	0
GPT		*0*	*0*	*0*	0
FDT***		*0*	*0*	*0*	0
not trapped		*0*	*8*	*0*	8
Total area		38	104	8	150

OUTPUTS: Loads caught and costs

LOADS AND COSTS

	Litter load	**Total load**
Total load transported (in one year)	3700 kg wet 14.5 m^3	12900 kg wet 50.6 m^3
Load trapped (in one year)	2400 kg wet 9.5 m^3	6900 kg wet 27.2 m^3
Percentage capture (by dry mass)	65 %	54 %
Total installation costs ($)	45,000	
Annual maintenance costs ($)	38,300	

Enter the characteristics of the traps listed below:

***SEPT density**

The density of coverage of SEPTs in the catchments = *75* %

****LCD cleaning frequency**

Cleaning frequency for LCD device *30* days

***** FDT - proportion of waterway width covered**

Proportion of the waterway the trap covers (in width) *50* %

With this system the number of traps required will be:

Between	473	and	710	SEPTs
Between	0	and	0	Trash racks
Between	0	and	0	LCDs
Between	0	and	0	CDS devices
Between	0	and	0	GPTs
Between	0	and	0	FDTs

Enter the adjustment factor for gross pollutant loads due to street cleaning:

Pollutant load in relation to Coburg (due to different management practices)= *100* %
(see (3) in instruction sheet)

The user should only change the numbers in *italics*

Definitions:

SEPT	Side entry pit traps
LCD	Litter control devices
CDS	Continuous deflective separation
GPT	Gross pollutant trap
FDT	Floating debris trap

PRESS F9 TO EXECUTE PROGRAM

refer to the instructions on pages 6 & 7 in the report for directions PRESS F9 TO EXECUTE PROGRAM

INPUTS: Input areas draining to each trap (ha)

Trapping system		commercial	residential	light-industrial	Total area
		ha	ha	ha	
SEPT*		*12*	*0*	*3*	15
Trash racks		*0*	*0*	*0*	0
LCD**		*26*	*52*	*5*	83
CDS devices		*0*	*0*	*0*	0
GPT		*0*	*0*	*0*	0
FDT***		*0*	*0*	*0*	0
not trapped		*0*	52	*0*	52
Total area		38	104	8	150

OUTPUTS: Loads caught and costs

LOADS AND COSTS

	Litter load	**Total load**
Total load transported (in one year)	3700 kg wet 14.5 m^3	12900 kg wet 50.6 m^3
Load trapped (in one year)	2400 kg wet 9.4 m^3	7100 kg wet 28.2 m^3
Percentage capture (by dry mass)	65 %	56 %
Total installation costs ($) Annual maintenance costs ($)	246,000 16,000	

Enter the characteristics of the traps listed below:

***SEPT density**

The density of coverage of SEPTs in the catchments = *85* %

****LCD cleaning frequency**

Cleaning frequency for LCD device *7* days

***** FDT - proportion of waterway width covered**

Proportion of the waterway the trap covers (in width) *50* %

With this system the number of traps required will be:

Between	50	and	75	SEPTs
Between	0	and	0	Trash racks
Between	1	and	8	LCDs
Between	0	and	0	CDS devices
Between	0	and	0	GPTs
Between	0	and	0	FDTs

Enter the adjustment factor for gross pollutant loads due to street cleaning:

Pollutant load in relation to Coburg (due to different management practices)= *100* %

(see (3) in instruction sheet)

The user should only change the numbers in *italics*

Definitions:

SEPT	Side entry pit traps
LCD	Litter control devices
CDS	Continuous deflective separation
GPT	Gross pollutant trap
FDT	Floating debris trap

PRESS F9 TO EXECUTE PROGRAM

refer to the instructions on pages 6 & 7 in the report for directions PRESS F9 TO EXECUTE PROGRAM

INPUTS: Input areas draining to each trap (ha)

Trapping system	commercial	residential	light-industrial	Total area
	ha	ha	ha	
SEPT*	*0*	*0*	*0*	0
Trash racks	*0*	*0*	*0*	0
LCD**	*0*	*0*	*0*	0
CDS devices	*29.5*	*52*	*5*	86.5
GPT	*0*	*0*	*0*	0
FDT***	*0*	*0*	*0*	0
not trapped	*8.5*	*52*	*3*	63.5
Total area	38	104	8	150

OUTPUTS: Loads caught and costs

LOADS AND COSTS

	Litter load	**Total load**
Total load transported (in one year)	3700 kg wet 14.5 m^3	12900 kg wet 50.6 m^3
Load trapped (in one year)	2400 kg wet 9.5 m^3	7700 kg wet 30.5 m^3
Percentage capture (by dry mass)	65 %	60 %
Total installation costs ($)	260,000	
Annual maintenance costs ($)	6,900	

Enter the characteristics of the traps listed below:

***SEPT density**

The density of coverage of SEPTs in the catchments = *100* %

****LCD cleaning frequency**

Cleaning frequency for LCD device *30* days

***** FDT - proportion of waterway width covered**

Proportion of the waterway the trap covers (in width) *50* %

With this system the number of traps required will be:

Between	0	and	0	SEPTs
Between	0	and	0	Trash racks
Between	0	and	0	LCDs
Between	1	and	9	CDS devices
Between	0	and	0	GPTs
Between	0	and	0	FDTs

Enter the adjustment factor for gross pollutant loads due to street cleaning:

Pollutant load in relation to Coburg (due to different management practices)= *100* %
(see (3) in instruction sheet)

The user should only change the numbers in *italics*

Definitions:

SEPT	Side entry pit traps
LCD	Litter control devices
CDS	Continuous deflective separation
GPT	Gross pollutant trap
FDT	Floating debris trap

PRESS F9 TO EXECUTE PROGRAM

refer to the instructions on pages 6 & 7 in the report for directions **PRESS F9 TO EXECUTE PROGRAM**

INPUTS: Input areas draining to each trap (ha)

Trapping system	commercial	residential	light-industrial	Total area
	ha	ha	ha	
SEPT*	*23*	*20*	*4*	47
Trash racks	*0*	*0*	*0*	0
LCD**	*0*	*0*	*0*	0
CDS devices	*15*	*30*	*4*	49
GPT	*0*	*0*	*0*	0
FDT***	*0*	*0*	*0*	0
not trapped	*0*	*54*	*0*	54
Total area	38	104	8	150

OUTPUTS: Loads caught and costs

LOADS AND COSTS

	Litter load	**Total load**
Total load transported (in one year)	3700 kg we 14.5 m^3	12900 kg wet 50.6 m^3
Load trapped (in one year)	2400 kg we 9.4 m^3	6800 kg wet 26.8 m^3
Percentage capture (by dry mass)	65 %	53 %
Total installation costs ($)	161,000	
Annual maintenance costs ($)	15,800	

Enter the characteristics of the traps listed below:

***SEPT density**

The density of coverage of SEPTs in the catchments = *70* %

****LCD cleaning frequency**

Cleaning frequency for LCD device *30* days

***** FDT - proportion of waterway width covered**

Proportion of the waterway the trap covers (in width) *50* %

With this system the number of traps required will be:

Between	157	and	235	SEPTs
Between	0	and	0	Trash racks
Between	0	and	0	LCDs
Between	1	and	5	CDS devices
Between	0	and	0	GPTs
Between	0	and	0	FDTs

Enter the adjustment factor for gross pollutant loads due to street cleaning:

Pollutant load in relation to Coburg (due to different management practices)= *100* %
(see (3) in instruction sheet)

The user should only change the numbers in *italics*

Definitions:

SEPT	Side entry pit traps
LCD	Litter control devices
CDS	Continuous deflective separation
GPT	Gross pollutant trap
FDT	Floating debris trap

PRESS F9 TO EXECUTE PROGRAM

Appendix B

Locations and costs for three trapping systems applied to the case study catchment for a range of different litter trapping efficiencies.

(I) SEPT (75%) system

(ii) LCD / SEPT (85%) system

(iii) CDS device / SEPT (70%) system

(i) SEPT system at 75% density

Trapping efficiency (%)	AREA TRAPPED			AREA NOT-TRAPPED			INSTALL COST	ANNUAL MAIN. COSTS	EQUIVALENT ANNUAL COST
SEPT system	com.	res.	light-ind.	com.	res.	light-ind.			
	ha	ha	ha	ha	ha	ha	$000's	$000's	$000's
10	10	0	0	28	104	8	3	2.7	2.9
20	20	0	0	18	104	8	6	5.4	5.8
30	30	0	0	8	104	8	9	8.1	8.7
40	38	0	3	0	104	5	13	11.1	12.0
50	38	34	8	0	70	0	25	21.6	23.3
60	38	74	8	0	30	0	38	32.4	34.9
67	38	104	8	0	0	0	47	40.5	43.6

(ii) LCD (7 days) / SEPT (85%) system

Trapping efficiency (%)	Location of LCDs shown in Figure 15	AREA TRAPPED			AREA NOT-TRAPPED			INSTALL COST	ANNUAL MAIN. COSTS	EQUIVALENT ANNUAL COST
LCD/SEPT		com.	res.	light-ind.	com.	res.	light-ind.			
		ha	ha	ha	ha	ha	ha	$000's	$000's	$000's
10	A	7	7	0	31	97	8	36	2.3	3.5
20	B	15	7	0	23	97	8	56	3.5	5.4
30	B	24	7	0	14	97	8	59	6.3	8.4
40	B	34	7	0	4	97	8	63	9.3	11.7
50	D & E	27	52	5	11	52	3	223	12.9	20.4
60	D & E	36	52	5	2	52	3	226	15.6	23.3
70	G	38	55	5	0	49	3	277	18.9	28.4
80	I	38	96	8	0	8	0	397	20.5	33.8
82	J	38	104	8	0	0	0	435	20.6	35.1

(iii) CDS / SEPT (70%) system

Trapping efficiency (%)	Location of CDS traps shown in Figure 15	AREA TRAPPED			AREA NOT-TRAPPED			INSTALL COST	ANNUAL MAIN. COSTS	EQUIVALENT ANNUAL COST
CDS/SEPT		com.	res.	light-ind.	com.	res.	light-ind.			
		ha	ha	ha	ha	ha	ha	$000's	$000's	$000's
10	A	5	7	0	33	97	8	36	1.0	2.2
20	B	12	7	0	26	97	8	57	1.5	3.4
30	B	22	7	0	16	97	8	60	4.0	6.1
40	B	32	7	0	6	97	8	63	6.6	8.9
50	D	26	38	5	12	66	3	180	7.2	13.3
60	D	36	38	5	2	66	3	183	9.8	16.1
70	D + F	36	52	5	2	52	3	252	9.2	17.7
80	G	38	64	8	0	40	0	284	11.0	20.6
90	H	38	96	8	0	8	0	345	16.5	28.3

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