10. The current “best available technologies”

10.1 Introduction

The biggest challenge facing the designer of a litter removal system is that litter can be just about anything - any size, any shape, any density, any hardness. Furthermore, the behaviour of a single item often changes as it moves through the drainage system (see Section 3.4). To make matters worse, the flow rate in channels changes continuously. A structure might work well at a low flow rate, but not at a high flow rate, or vice versa. Once in the drainage system, litter is not easily removed. It is partly for this reason that as much as possible should be done to prevent litter from entering the drainage system in the first place (see Section 3.2).

The ideal trap has, inter alia, the following features (see Section 3.3):

- is economical to construct and operate;
- has no moving parts;
- does not require an external power source;
- has a high removal efficiency;
- is self-cleaning; and
- does not increase flood levels in the vicinity of the structure.

No existing structure satisfies all these requirements perfectly. They are all better in some situations than others. The objective of this section is to summarise and compare the existing technologies to help the designer match the correct technology to the situation.

Some options are summarised in Sections 10.2 - 10.4, and in Appendices A and B. They are briefly compared in Section 10.5. Most of the more successful structures have been patented and are available only from approved suppliers. Mention of a trade name does not indicate that the Water Research Commission or the authors necessarily support the product in question. They are described in this document in an attempt to show designers the sort of features to look out for in litter removal structures, and to indicate some of the better options currently available “off the shelf”. There may of course be other structures, not described in this document, that might remove litter from drainage systems more efficiently and effectively than those described herein.

10.2 Self-cleaning screens

A lot of work has gone into the development of self-cleaning screens. They rely on the control of the flow velocity, the velocity gradient, and gravity to create the self-cleaning action. Three designs show considerable promise:

- The Stormwater Cleaning Systems (SCS) structure (Sections 2.2 and 5.5, and Appendices A.6 and B.6);
- The Baramy Gross Pollutant Trap (BGPT) (Section 5.8, and Appendices A.5 and B.5); and
- The Continuous Deflective Separation (CDS) device (Section 5.10, and Appendices A.4 and B.4).

The **Stormwater Cleaning Systems (SCS) structure** directs flow over a weir and through a steeply declined screen (in the order of -45^{o}). The self-cleaning action arises from a combination of the momentum of the flow and the considerable gravitational force component down the screen. The main advantage of the structure is that it places the litter into a conveniently located self-draining bin ready for easy removal. Its disadvantages are that the maximum upstream Froude number of 0,15 and the maximum overflow rate of 230 litres per second per metre length of weir make it an extremely large structure, whilst the steep angle of declination of the screen inevitably means that there is a considerable drop in water level across the structure - translating into head loss.

The **Baramy device (BGPT)** is similar to the SCS device, but the screen declination is less and consequently the structure relies less on gravity and more on the momentum of the water for its self-cleaning properties. This is achieved by placing the screen directly on the flow path. The performance of the structure is not impacted by high inflow velocities (unlike the SCS structure). Long periods of low flows could, however, potentially cause blockages. It is generally smaller, and therefore potentially cheaper, than the equivalent SCS device, but has a similar head loss. It also places the litter in a conveniently located self-draining bin.

In the **Continuous Deflective Separation (CDS) device**, the flow is also directed across the face of a screen, but in this case, the screen is orientated vertically and gravity plays no role in the self-cleaning mechanism. Instead, a vortex generated within a circular screen keeps water moving rapidly over the surface of the screen and prevents it from blocking. It is the most efficient of the three units both in terms of the low head requirement (approximately 1,3 x the velocity head of the flow in the in-flow conduit), and trap efficiency, but it is an expensive structure to build and maintain because of its complex geometry and great depth.

10.3 In-line screens

In-line screens are the most common form of litter removal device. They usually consist of metal bars raked at some angle between 25^o and 90^o to the invert of the channel (in the direction of flow). They are usually mounted on the floor of the channel or on the top of a low weir wall.

They do not have a good record in South Africa for several reasons:

- They are easily blocked;
- Unless they are carefully located in an area with considerable fall, they represent an upstream flood hazard;
- They are easily damaged (a log moving, say, 3 m/s down a channel can do considerable damage to a screen that is in its path);
- They are often hard to maintain (so are frequently not maintained at all!); and
- They have a relatively limited storage capacity.

Nevertheless, in-line screen can be made to work if they are appropriately designed (see Section 6.). Some of the more successful designs are:

- Side-entry catchpit traps (SECT) (Section 6.2 and Appendices A.1 and B.1);
- Fences or nets straining slow flowing streams (Section 6.3);
- The Canberra Gross Pollutant Trap (GPT) (Section 6.4);
- The North Sydney Litter Control Device (LCD) (Section 6.5 and Appendices A.2 and B.2); and
- The Urban Water Environmental Management (UWEM) concept (Section 6.6 and Appendices A.7 and B.7).

Side-entry catchpit traps (SECTs) offer great potential as a trapping device. They are cheap and easy to construct and install, have a high trapping efficiency, and are a useful catchment management tool as they trap litter close to its source. Their biggest drawbacks are that literally thousands of them are required to cover a whole catchment, and they require an efficient and reliable cleaning programme. Strategically placed, though, they can provide a cost-effective trapping mechanism. Although they require a considerable drop for operation, that drop is usually already provided within the catch-pits.

Fences or nets may be used to **strain slow flowing streams** and thus provide an extremely cheap and effective method of trapping litter providing that they are well located. A particular advantage is that drowned channels frequently imply low velocities and consequently low head losses. Maintenance however is frequently a problem as ideally the channel needs to be drained for the maintenance crew to access the bed-load deposition. This is not usually possible.

The **Canberra type Gross Pollutant Traps (GPTs)** are currently not appropriate for South African conditions unless the prime consideration is sediment removal. The screening principle can be used in conjunction with detention / retention ponds or wetlands, provided that those structures can be drained. GPTs are generally very large, expensive structures that impose a large head loss (1 - 2 m).

The **North Sydney Litter Control Device (LCD)** is easy to maintain, but relatively large and consequently expensive structures will be required to cater for the volume of litter that comes from South African catchments. Other drawbacks are that it can only treat relatively low flows, it has a low trapping efficiency, and it requires a high head (1 - 2 m) for its operation. It may have some application on small commercial or industrial catchments.

In the case of the **Urban Water Environmental Management (UWEM)** approach, head is “generated” by an hydraulically operated sluice gate which forces the flow through rows of suspended screens, under a suspended baffle wall and over a weir. The structure can be drained and the screens lifted for cleaning. The sluice gate opens in the event of a flood to prevent upstream flooding. This is particularly attractive for large canals in areas where gradient is a premium. The fact that the device has a very large screen area makes it possible for the structure to trap enormous volumes of litter.

In every case, the key to the success of an in-line screen is a large screen area. Unless the screen areas are large, head losses will be high and there is a risk of upstream flooding.

10.4 Booms, baffles and ponds

Booms and baffles may be used to deflect and trap litter provided the flow velocities are low enough to:

1. allow desegregation of the litter into bed-load and flotsam; and

2. prevent wash-over / wash-under

and also provided that there is no hydraulic interference between the different structural elements thereby increasing the vorticity of the flow.

This method of trapping is used, inter alia, by:

- The Sydney Harbour Litter Booms (Section 7.2); and
- The In-line Litter Separator (ILLS) (Section 7.4 and Appendices A.3 and B.3).

Litter booms are only capable of removing flotsam - the suspended load and bed-load must be trapped some other way, generally by settling it behind a low weir. The **In-line Litter Separator (ILLS)** shows potential for trapping litter in pipe conduit systems where head is at a premium. Its main disadvantages are that it is a relatively large and therefore expensive structure, and there is always a danger that the rotating boom might get stuck at a crucial moment causing upstream flooding or litter loss.

Detention / retention ponds and wetlands are convenient trapping points because they provide the large flow area that decreases the velocity to levels suitable for booms, baffles and in-line screens (Section 8.).

Work carried out by Furlong, 1995 (Section 4.5) from the University of Cape Town, Burger and Beeslaar, 1996 (Section 4.7) and Compion, 1996 (Section 4.8) all from the University of Stellenbosch, seems to indicate that the practical upper limit for trapping litter behind a weir or suspended screen is a Froude number of about 0,07. This equates to a maximum velocity that varies from about 0,15 m/s for a 500 mm deep channel to about 0,3 m/s for a 2 m deep channel. Once again, this implies large flow areas - from 10 to 20 times that of a typical conduit.

One advantage of using **booms or baffles** is that the structures are simple and there is minimal head loss. The main disadvantages are the difficulty of accessing the large areas for cleaning and maintenance, and the potentially high capital costs of such large structures.

No vortex device suitable for the removal of suspended litter from stormwater has been developed (see Section 9).

10.5 Comparing the structures

The main features of the more promising devices are summarised in Table 10-1. Further information about them, in particular the patent holders or suppliers and typical costs, is to be found in Appendices A and B. Regrettably, very little detailed design information is available as the structures are nearly all protected by patents and design information is jealously guarded by the patent holders.

Device	Typical catchment area (hectares)	Typical cleaning frequency	Head requirement	Maximum efficiency (%)	Comments on performance
SECT	0,1 - 1	Monthly or after every major storm	Low (effectively)	59 - 76 (50 - 100% coverage respectively)	Need to be able to target the catchpits with the highest loads. The efficiency of the unit is strongly affected by the number of untrapped catchpits and the cleaning frequency.
LCD	20 - 150	Monthly or after every major storm	High	25	Inefficient in high flows but collects most material at low to medium flows. Likely to be a relatively expensive option. Relatively easy to clean.
ILLS	5 - 25	Monthly or after every major storm	Low	25	Little data available. Likely to be a relatively expensive option. Moving parts may cause problems.
CDS	10 - 200	4 times a year	Low	99	Very efficient trapping device, but very expensive to install and tedious to clean.
Baramy	10 - 500	4 times a year	High	95	Little prototype data available, but shows considerable promise. Compact. Easy to clean.
SCS	>1	Monthly or after every major storm	High	95	Works well providing the head is available. Easy to clean.
UWEM	>400	After every major storm	Low (effectively - the head is generated by a sluice gate)	90	The concept of generating head in-situ via a hydraulically actuated sluice shows considerable promise for use with other structures eg. Baramy , SCS.
Fences, nets, weirs, booms or baffles used to intercept litter moving down slow-flowing streams	>400	Depends on structure and location. Could vary from weekly to annually.	Low	Varies. Could approach 100% with very low peak velocities.	Efficiency unpredictable - depends on structure and location. Generally the cheapest solution.

Table 10-1 : Summary of litter trapping devices (adapted from Allison, 1997)

In general, **based on the data supplied in Appendix A**, it appears that:

- the Baramy , SCS and UWEM devices have a much higher economic efficiency than the remaining four structures;

- the CDS unit offers a very high removal efficiency, but at a heavy cost. Unit costs may however be brought down if high bypass ratios are used;

- SECTs offer the advantage of being a potential catchment management tool as they show where the bulk of the litter is being generated. They might also be a little cheaper to install and clean in South Africa than the Australian data indicates - owing to the lower cost of labour;

- the ILLS and LCD structures appear on the surface to be costly, but have the advantage they are small and can be installed under streets in confined spaces. The ILLS has the additional advantage that it requires very little head.

- Fences, nets, weirs, booms or baffles may be the most cost effective structures of all, provided a suitable slow-flowing stream (which includes flows through detention / retention ponds and wetlands) is available. A major problem with these devices is cleaning and maintenance. Ideally it should be possible for the channel to be periodically drained for cleaning and maintenance purposes.

Another avenue to explore is a mix of technologies. For example, the hydraulically actuated sluice gate that is used in the UWEM approach could be used to generate the required head to run a Baramy device or a SCS structure.

The final decision of a trapping structure will be site specific. Lack of head may rule out the Baramy and SCS devices. Lack of space may rule out the UWEM approach. The desire for a catchment management tool may favour the choice of SECTs. A requirement for exceptionally high removal efficiency may prompt the installation of a CDS unit. A small catchment may be best served by an ILLS or LCD.

Conditions vary from site to site, but most sites in South Africa would probably be best served by SECTs installed in key catchpits around the CBD, and a Baramy , SCS or UWEM unit installed on the main outlet conduit to the catchment with head provided by a hydraulically actuated sluice if required. Fences or nets will probably be the most cost effective solution in very flat areas where the stormwater is discharging into large bodies of water eg. a lake or the sea.

The recommended selection procedure is described in Section 11. More details on the seven most promising structures are given in Appendix A. A worked example of an hypothetical selection is given in Appendix B.