

A : “Off-the-shelf” devices for the removal of litter

As explained in Section 10.5, very little detailed design information is available on many of the more effective structures as they are nearly all protected by patents, and design information is jealously guarded by the patent holders. The information that was publicly available in 1997 of the suppliers / patent holders and typical costs is supplied below. Some general information on the application, trap efficiency, method of cleaning, advantages and disadvantages of each structure is also given.

Where relevant, the source of the data is indicated in the text. Much of the cost data comes from the suppliers / patent holders and should thus be treated with some caution. Site works (ie. the cost of providing access, re-routing services, or re-establishing road surfaces over the finished structures) have been excluded unless otherwise indicated. **It is the responsibility of the designer to check all data with the suppliers / patent holders prior to the selection of a trapping system. Neither the Water Research Commission nor the authors can be held responsible for any costs that might be incurred through the use of data supplied in this report.**

Since many of the structures are Australian, most of the costs are in Australian dollars (A\$). The exchange rate between Australian dollars and South African Rand (R) varied between A\$1,00 = R3,30 and A\$1,00 = R3,80 over the period September 1996 to September 1997. In view of the fact that labour is much cheaper in South Africa than Australia, an approximate exchange rate of A\$1,00 = R3,00 in 1997 is probably realistic for the purposes of comparison.

Information is supplied on the following devices:

- A.1 Side-entry catchpit traps (SECTs);
- A.2 The North Sydney Litter Control Device (LCD);
- A.3 The In-line Litter Separator (ILLS);
- A.4 The Continuous Deflective Separation (CDS) device;
- A.5 The Baramy® Gross Pollutant Trap (BGPT);
- A.6 The Stormwater Cleaning Systems (SCS) structure: and
- A.7 The Urban Water Environmental Management (UWEM) concept.

It should be noted that neither the Water Research Commission nor the authors are necessarily in favour of any of the products listed here. They are described here in an attempt 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 these.

A.1 Side-entry catchpit traps (SECTs)

1. **Operation** : A suspended basket inside a side-entry catchpit intercepts the litter. See Section 6.2.
2. **Application** : Side-entry catchpits. SECTs can be custom made to suit virtually any side-entry catchpit.
3. **Patent holder** : Various different Australian designers and / or patent holders including the following:
 - Banyule City Council
275 Upper Heidelberg Road
Ivanhoe, Victoria
AUSTRALIA

Phone: [++61] (3) 9490 4222
 - Pitclear Industries
38 McGlynn Avenue
South Morang, Victoria, 3752
AUSTRALIA.
 - Dencal Industries
24 Halcyon Way
Narre Warren South, Victoria, 3805
AUSTRALIA
4. **Installation costs** : A\$60 - 150 per catchpit (Allison, 1997).
5. **Cleaning costs** : A\$5 - 10 per catchpit per clean (Allison, 1997). Typically a catchpit would be cleaned at monthly intervals or after every major storm.
6. **Head requirement** : A minimum of 500 mm (includes the depth of the basket and diameter of the stormwater conduit) - but this is generally already available within the side-entry catchpit.
7. **Size** : Fits within almost all existing side-entry catchpits.

- 8. Trap efficiency :** The basket mesh size varies between 5 and 20 mm. Particles smaller than this are often trapped as a result of the “filter” that starts to form on the basket following deposition. If the baskets are not cleaned often enough, litter will pass over the overflow. According to Allison, 1997 the maximum trap efficiency is about 76%. If not all catchpits are fitted with baskets, the overall efficiency will obviously drop. Allison, 1997 showed that for Coburg, if the engineer correctly selected the catchpits carrying the higher loads, the net efficiency could be predicted from:

$$E = 1,18 \times 10^{-4} \cdot T^3 - 2,58 \times 10^{-2} \cdot T^2 + 2,184 \cdot T \quad (R^2 = 0,91)$$

where

E	=	net trap efficiency (%)
T	=	trap coverage (%)

- 9. Method of cleaning :** By hand or with a vacuum eductor (truck fitted with a suction hose). The basket is then washed with water under high pressure.
- 10. Advantages** (after Melbourne Water Waterways and Drainage Group, 1995) :
- Quick and easy to install.
 - Collection of litter is easily integrated into catchpit maintenance programme.
 - Prevents transfer of kerb-side litter into drains and waterways.
 - Litter trap basket can be easily removed for maintenance purposes.
 - Litter trap basket has been designed to capture debris while still allowing water to pass into the drainage system.
 - Can be used to identify the main sources of litter as part of a catchment management programme.
- 11. Disadvantages** (after Melbourne Water Waterways and Drainage Group, 1995) :
- High cost of acquiring a special vacuum truck for litter collection.
 - The catchpit covers are heavy and need to be removed using safe lifting techniques.
 - A large number of units are required in litter prone areas.
- 12. Comments :** Only cost-effective in high litter producing areas such as in the CBD. Additional traps might be required downstream to catch bypass material. Most effective when used in conjunction with a catchment management programme.

A.2 The North Sydney Litter Control Device (LCD)

1. **Operation :** Conduit flow is dropped through a basket guided, if necessary, by a inclined trash rack on the downstream end of the basket which acts as a deflector plate. The litter is retained in the basket allowing the water to continue downstream. When the basket is full, or the flow rate exceeds the drainage capacity of the basket, surplus water is allowed to overflow the deflector rack. See Section 6.5.
2. **Application :** On conduits up to about 1 500 mm diameter.
3. **Patent holder :** Attention : Mr Ray Brownlee
North Sydney Council
200 Miller Street
North Sydney, New South Wales, 2060
AUSTRALIA

Phone [++61] (2) 9936 8231
Fax [++61] (2) 9936 8203
4. **Installation costs :** The existing data is given in Table A-1:

Location	Cost (A\$)	Catchment Area (Ha)
Willoughby Street	100 000	8,92
Walker Street	120 000	16,76
Smoothey Park	120 000	16,48
Waverton Park	120 000	30,01
Crows Nest Road	120 000	25,27
Ellamang Street	50 000	1,71
Honda Road	100 000	40,20
Grafton Road	130 000	144,74
Hayes Street	80 000	38,40
TOTAL	940 000	322,50

Table A-1 : Capital Costs of Litter Control Devices (Brownlee, 1995)

The average installation cost is A\$2 900 per hectare.

5. **Cleaning costs :** The average cleaning costs are estimated to be in the order of A\$2,67 per hectare per clean (Allison, 1997).
6. **Head requirement :** 650 - 1 000 mm.
7. **Size :** A LCD typically has external dimensions in the order of 3,5 x 3 x 3 m deep.

8. **Trap efficiency :** The baskets are generally constructed from 5 mm thick punched sheet metal with staggered 30 mm diameter holes (Hocking, 1996). Sometimes 20 mm holes are used (Brownlee, 1995). Studies have shown that finer material than this is often bound up in the matrix of coarse material that is soon trapped by the baskets. Trap efficiency is however strongly related to cleaning frequency. Increasing the cleaning frequency from monthly to after every storm (approximately weekly), increased the quantity of litter trapped at the Smoothey Park LCD by 192% (Hocking, 1996). The device is considered to be generally less than 30% efficient with monthly cleaning (Allison, 1997).
9. **Method of cleaning :** The litter is retrieved by lifting the baskets out of the LCD and depositing the litter into the rear of a 6 tonne haulage unit. This takes a two person maintenance crew approximately 35 minutes (Hocking, 1996).
10. **Advantages :**
 - Simple operation.
 - May be installed under road surfaces.
 - Relatively easy to clean.
11. **Disadvantages :**
 - Expensive.
 - Inefficient.
 - Requires a relatively high head for operation.
12. **Comments :** Only likely to find application in high density commercial areas where there is insufficient room to install a more efficient device. Although the LCD is probably the least efficient of the “off the shelf” devices described here, it is considerably better than many other similar devices which are currently on the market. This illustrates the difficulties facing the designers of litter control devices.

A.3 The In-line Litter Separator (ILLS)

1. **Operation :** Conduit flow is deflected by a hinged boom into a rectangular holding pit with a cross-sectional area considerably greater than that of the incoming pipe. The flow is forced underneath a suspended baffle wall, over a weir and then returns to the conduit downstream of the boom. The reduction in velocity through the holding pit causes the litter to desegregate into floatables and sinkables which are (theoretically) unable to follow the torturous path followed by the flow and are therefore trapped in the chamber. During high flows, the hinged boom floats out of the way allowing the flows to bypass the holding pit without disturbing previously trapped litter. See Section 7.4.
2. **Application :** On conduits up to about 900 mm in diameter.
3. **Supplier :** Marketed under the name “Litterguard” and supplied by:

CSR Humes
122a Doherty’s Road
Laverton North, Victoria
AUSTRALIA

Phone : [++61] (3) 9360 3888
Fax : [++61] (3) 9360 3887
4. **Installation costs :** A\$4 000 - A\$8 000 depending on the pit size, depth of pipe and type of pit cover required.
5. **Cleaning costs :** No information available. Will probably be in the order of R50 per unit per clean. The unit would probably have to be cleaned monthly or after every major storm.
6. **Head requirement :** Less than 200 mm.
7. **Size :** Whilst considerably smaller than the CDS unit, the ILLS never-the-less extends from one and a half to two metres from one wall of the pipe.
8. **Trap efficiency :** Little information is available. Likely to be a very inefficient with polyethylene sheeting - for example in the form of shopping bags. This is problematical as shopping bags make up a large percentage of water-borne litter. By-passing also commences at a fairly low flow rate to keep the head requirement to a minimum. As considerable quantities of litter are carried in high flows, the overall efficiency of the device is likely to be low.
9. **Method of cleaning :** Hand-held scoop or vacuum eduction.

10. Advantages :

- Fairly easily retro-fitted to existing stormwater systems.
- Very low head requirement means that it has great flexibility.
- Can also trap oils and grease.
- Retains previously trapped litter during periods of bypass.
- Relatively easy to clean.

11. Disadvantages :

- Unreliable trapping performance.
- Boom might be damaged by fast moving heavy objects.
- Boom hinging mechanism might be damaged causing flooding during periods of high flow, or loss of litter once flows have dropped.
- Lack of field data.

12. Comments : The ILLS is probably only viable as a retro-fit system in situations where flat gradients and lack of space preclude other options.

A.4 The Continuous Deflective Separation (CDS) device

1. **Operation :** Conduit flow is diverted into a circular chamber by means of a low weir. A circular screen allows litter-free water to return to the conduit downstream of the weir. The continuous motion across the surface of the circular screen keeps it from blocking whilst litter collects in the inner chamber. Material more dense than water sinks into a sump. Material less dense than water rises to the surface. See Section 5.10.
2. **Application :** Typically on conduits greater than one metre in diameter. They can be installed on open channels carrying flows up to about 50 m³/s provided a high bypass ratio (during floods) is acceptable.
3. **Patent holder :** CDS Technologies Pty Ltd
1140 Nepean Highway
Mornington, Victoria, 3931
AUSTRALIA.

Phone : [++61] (3) 5977 0305
Fax : [++61] (3) 5977 0302
Email : info@cdstech.com.au
Internet : <http://www.cdstech.com.au>
4. **Installation costs :** Little data currently exists. The three metre diameter unit constructed in Coburg (see Sections 2.5.2 and 5.9), which is capable of treating 550 litres per second, cost A\$230 000, but this including many extra costs associated with construction including realignment of power, water, telephone and gas lines, and strengthening of the covers to allow the passage of large trucks. The cost of the unit excluding site works was about A\$100 000 (Allison, 1997). CDS Technologies have recently installed units treating from 0,8 - 1,75 m³/s for costs in the range A\$140 000 - 160 000. These prices might be reduced by 15 - 20% once precast units become available (CDS Technologies, 1997). Further information regarding costs should be obtained from CDS Technologies Pty Ltd.
5. **Cleaning costs :** Little data currently exists. The Coburg unit costs about A\$1 000 per clean. In Australia, these units are cleaned about four times a year (Allison, 1997). In South Africa, with much higher litter loads, cleaning might be required more frequently.
6. **Head requirement :** Approximately 400 mm at commencement of bypass flow (Allison, 1997).
7. **Size :** A large off-channel structure. The Coburg unit required a 6 x 6 x 4 m excavation. The unit may however be installed underneath road surfaces (Allison, 1997).

8. **Trap efficiency :** A typical screen has a 5 mm opening. Studies by Wong et al. (1995) indicate that approximately 95% of material down to 50% of the separation screen aperture size is also trapped. Litter loss is predominantly as a result of bypass during high flows. The litter already trapped in the unit is unaffected by bypass.
9. **Method of cleaning :** CDS Technologies Pty. Ltd have designed a “basket” that fits within the sump of the unit. This basket can be raised by means of an external crane, and the contents deposited into waiting trucks (Blanche and Crompton, 1996). In Melbourne, the CDS Technologies have invested in a truck mounted telescoping grab to achieve fast and cost effective mechanical without dewatering (CDS Technologies, 1997). Alternatively the unit can be pumped dry using a specially designed eductor truck that strips the litter off and returns the liquid to the conduit downstream of the bypass weir. If the unit is cleaned manually, special training and equipment is required - but this method of cleaning is not recommended (Allison, 1997).
10. **Advantages** (after Melbourne Water Waterways and Drainage Group, 1995) :
 - High percentage removal of all litter.
 - Will not block (except if the unit is completely full of litter).
 - Minimal maintenance.
 - Can be located anywhere in the drainage system.
 - Effective even in high flows - a bypass operates if the system is overloaded.
11. **Disadvantages** (after Melbourne Water Waterways and Drainage Group, 1995) :
 - Very high capital cost.
 - High cost of acquiring a special truck designed for litter collection from the unit.
 - May require annual eduction of sediments from the sump.
 - Trapped material might ferment to produce toxic substances.
12. **Comments :** Although an extremely efficient device from an hydraulic point of view, the high installation and cleaning costs make this unit suitable only for high value land where there is limited space for alternatives.

A.5 The Baramy® Gross Pollutant Trap (BGPT)

1. **Operation :** Conduit flow is dropped over a declined trash-rack. The momentum of the flow combined with gravity propels the litter into a holding shelf ready for collection. The litter-free water either flows under the collection shelf (direct flow version) or around it (low profile version). See Section 5.8.
2. **Application :** On pipes or channels from 300 mm diameter upwards. The direct flow version has no particular upper flow limit as long as there is sufficient space and drop available (as much as 4,5 m is required in some instances). It is unlikely that a BGPT would ever be installed on a channel with a maximum flow in excess of 50 m³/s.
3. **Patent holder :** Baramy Engineering Pty. Ltd
P O Box 357
Katoomba, New South Wales, 2780
AUSTRALIA

Phone : [++61] (47) 82 5741
Fax : [++61] (47) 82 3430
Email : Baramy@Lisp.com.au
4. **Installation costs :** Depends on size and layout. The estimated costs of the basic units (they are usually prefabricated and delivered to site for installation) is given in Table A-2:

Pipe diameter (mm)	Installation Cost (A\$)
300 - 450	6 000 - 8 000
525 - 900	12 000 - 16 000
1 000 - 1 500	20 000 - 24 000
Multiple pipes	From 34 000
Flows in excess of 30 cumec	From 40 000

Table A-2 : The basic installation cost of Baramy® Gross Pollutant Traps

To the above must be added site costs which would be site specific and could double the cost of the installation (Baramy, 1997).

5. **Cleaning costs :** Little data currently exists. Seeing that the device is cleaned in much the same way as the SCS structure (see Section A.6 below), the cleaning costs are probably of the same order of magnitude ie. R35/m³ litter.

6. **Head requirement** : Typically between 700 mm and 1,5 m (Baramy, 1997). However, some units require as little as 350 mm, whilst others require as much as 4,5 m (Baramy).
7. **Size** : The relative size of the structure varies from installation to installation. The smallest units for installation on pipes are about 3 m wide including the access ramp. The larger units are typically three times the width of the channel. Installations on very wide channels may only be 50% wider than the channel.
8. **Trap efficiency** : The screen opening is typically 15 mm and, since the trap is usually designed to intercept the entire flow range, the trap would thus be expected to catch virtually all material with a minimum dimension larger than this. If a bypass is provided, litter carried over the bypass would naturally be lost.
9. **Method of cleaning** : Generally by skid steer loader (Bobcat or similar). The units are also easily cleaned by hand using ordinary shovels and buckets / barrows.
10. **Advantages** :
 - Generally designed to remove litter over the entire flow range.
 - Can handle relatively high flows (up to say 30 m³/s) with ease.
 - Negligible maintenance.
 - Easy to clean.
 - Little risk of toxic fermentation.
 - Relatively safe for public and workers.
11. **Disadvantages** :
 - High head requirement.
 - Requires a large amount of ground that must generally be fenced off to prevent the public from coming into contact with trapped litter.
12. **Comments** : If it was not for its high head requirement, this device would be the first choice in most situations. Head may however be created by means of an hydraulically actuated sluice gate as with the UWEM concept. In some instances, the drop in trapping efficiency occasioned by the use of a sluice gate may be more than compensated for by the hydraulic efficiency of the structure.

A.6 The Stormwater Cleaning Systems (SCS) Structure

1. **Operation :** In a typical layout, a weir deflects water from a channel into another channel parallel to, but higher than, the original. The flow is then turned through 90° over a side-channel spillway, through a declined screen, and returned to the original channel downstream of the weir. The litter carried by the flow is stripped off by the screen and deposited, ready for removal, into a self-draining basin that runs parallel to the two channels. High flow peaks are allowed to bypass the structure over the weir (See Section 5.5). An alternative sees the screen rotated into line with the channel when the SCS structure, to all intents and purposes, becomes identical to the Baramy® structure. Another alternative replaces the weir with an hydraulically operated sluice gate as with the UWEM approach (See Appendix A.7)
2. **Application :** Although the SCS principle can be applied to any flow rate and situation, the typical application described in 1. above would generally be most suitable for channel flows with peak flow rates in the range 1 - 30 cumecs.
3. **Patent holder :** Mr Christo Nel
Stormwater Cleaning Systems Pty. Ltd.
P O Box 7210
Ulundi, KwaZulu-Natal, 3838
SOUTH AFRICA

Phone : [++27] (358) 70 3196
Fax : [++27] (358) 70 3197
Phone & Fax : [++27] (358) 70 3301
4. **Installation costs :** The Springs structure, which is capable of treating 7,5 cumecs, cost R127 500 in 1990 - equivalent to about R250 000 in 1997. However this included the model studies (R46 000) and application for patents (R7 000). On the other hand, the structure was constructed “in house” by the municipality under the direct supervision of the designer who was an employee of the municipality at the time. This might mean that construction by a contractor would be more expensive. The estimated 1996 costs for various alternatives for installation on the Jukskei River in Alexandria near Johannesburg, which included hydraulically actuated sluice gates were as listed in Table A-3:
5. **Cleaning costs :** Estimated to be about R35/m³ at Springs (Nel, 1996).
6. **Head requirement :** At least 400 mm, but generally in the order of 1 300 mm. This head is usually created by means of a low weir or hydraulically actuated weir. The weir is cheaper but will however raise upstream flood levels.
7. **Size :** Depends on the application. The Springs structure extends for over 70 m and is some 13 m wide at its widest point. The channel it is installed on is only some 6 m wide at the same place. A more space efficient structure than this has however recently been installed in Port Elizabeth.

Size (m ³ /s)	Cost (R)
10	250 000
20	550 000
30	800 000
40	1 010 000
50	1 220 000
60	1 420 000
70	1 600 000
80	1 760 000

Table A-3 : Estimated 1996 costs of an SCS structure across the Jukskei River in Alexandria (Nel, 1996)

- 8. Trap efficiency :** A 20 mm opening was used at Springs (Nel, 1996), and therefore the structure would be expected to capture all material with a minimum dimension greater than this. The opening could of course be reduced, but this would tend to affect the hydraulic performance of the structure. In Springs, flood peaks greater than 7,5 m³/s are allowed to bypass the structure and this is the greatest source of litter loss. As a result of bypassing, the Springs structure is estimated to be about 72% efficient. Efficiencies up to about 95% could easily be obtained, but at considerable extra cost.
- 9. Method of cleaning :** By skid steer loader (Bobcat or similar) or by hand using ordinary shovels and buckets / barrows.
- 10. Advantages :**
- Can handle relatively high flows (up to 80 m³/s or more if necessary) with ease.
 - Negligible maintenance.
 - Easy to clean.
 - Little risk of toxic fermentation.
 - Relatively safe for public and workers.
- 11. Disadvantages :**
- High head requirement.
 - Requires a large amount of ground that must generally be fenced off to prevent the public from coming into contact with trapped litter.
- 12. Comments :** Like the Baramy® device (see Appendix A.5), the SCS device would be a popular choice in many situations if it were not for the high head requirement. Head may however be created without substantially increasing the upstream flood risk by means of an hydraulically actuated sluice gate as with the UWEM concept (see Appendix A.7).

A.7 The Urban Water Environmental Management (UWEM) concept

1. **Operation :** An hydraulically actuated sluice gate provides a relatively constant upstream head sufficient to divert channel flow through a series of suspended screens whose clearance systematically decreases in such a way as to provide an in-depth filter. A suspended baffle wall followed by a low weir ensure that the flow depth and consequently the flow area in the vicinity of the screens is kept large throughout the flow range. This in turn ensures that the flow velocity through the screens is kept low to reduce the risk of blockage. In the event of blockage of the screens and / or very high flood peaks, the hydraulically actuated sluice gate opens from the bottom in such a way as to keep upstream flood levels constant until such a point that the sluice gate is effectively out of the main channel and the flood peak can pass the structure with negligible increase in flood risk. The sluice gate automatically closes once the flood peak has passed.
2. **Application :** Although the UWEM concept can theoretically be applied to any flow rate and situation, practical difficulties associated with the cleaning of the structure tend to limit its application in the form described above to the use in open channels handling flows in excess of 15 m³/s. The use of an hydraulically actuated sluice gate as a method of providing temporary head can be used in conjunction with both the Baramy® and SCS traps (see Appendices A.4 and A.6).
3. **Patent holder :** Urban Water Environment Management
P O Box 2673
Pinegowrie, Gauteng, 2123
SOUTH AFRICA

Phone : [++27] (11) 789 6257
Fax : [++27] (11) 789 6499
4. **Installation costs :** Site specific - the Robinson canal structure, which has a design capacity of 15 m³/s, cost approximately R600 000 in 1994 (equivalent to about R800 000 in 1997), but this included a considerable amount for the low-flow sewer connection. A more recent structure designed to treat 40 m³/s had an estimated capital cost of R450 000. The hydraulically actuated control gates (for further information see Appendix C) typically cost about R2 500 per cumec of full design capacity. For preliminary costing, assume that the basic 15 m/s unit would normally cost about R300 000.
5. **Cleaning costs :** R15 - 35 per cubic metre of trapped litter depending on the size and location of the structure. As the size of the structure increases, the unit rate drops due to economies of scale.
6. **Head requirement :** 1,5 - 2 m - but this is provided in-situ by the hydraulically actuated gate. The UWEM concept can be applied to near horizontal channels.

7. **Size :** Large. The Robinson Canal structure (see Sections 2.3 and 6.6), which is capable of treating 15 cumec before bypassing commences, has a gross plan area of approximately 50 x 25 m excluding the de-grit channel for the low-flow sewer line. The plan area of the (off-channel) screens alone is approximately 30 x 10 m. At that point, the Robinson Canal is approximately 9 m wide.
8. **Trap efficiency :** This is strongly dependent on the mesh size and the capacity of the structure relative the flood peaks. In the case of the Robinson Canal, the screens fined down to 50 mm centre to centre giving a clearance of about 40 mm. However, as debris starts to pile up on the screens, the effective clearance decreases thereby improving the trap efficiency of the structure. On the other hand, the 15 m³/s capacity of the trap is only sufficient for 85 percentile of all flows and consequently litter will be lost when peaks in excess of this pass under the sluice gate. It was not considered to be cost effective to attempt to treat the entire flow range - the annual flood flow peak is approximately 56 m³/s, and the 10 year recurrence interval flow peak is approximately 92 m³/s. The Robinson Canal structure is probably in the order of 70% efficient.
9. **Method of cleaning :** Generally by skid steer loader (Bobcat or similar). The units are also easily cleaned by hand using ordinary shovels and buckets / barrows.
10. **Advantages :**
 - Can be used in channels with very flat gradients.
 - Suitable for treating very high flows (0,8 m³/s per metre length of trap).
 - Can be easily adapted to trap other gross pollutants eg. oils, low flow sewage spills, sediments.
 - Minimal maintenance.
 - Relatively easy to clean.
 - Relatively safe for public and workers.
 - Cost effective for very large structures.
11. **Disadvantages :**
 - Requires a large amount of ground that must generally be fenced off to prevent the public from coming into contact with trapped litter.
 - There is a slight risk that the sluice gate might fail to open at the critical moment causing upstream flooding and consequent damage claims.
 - Harder to clean than the Baramy® and SCS devices.
12. **Comments :** Eminently suitable for very large flows eg. equal to or greater than 15 m³/s. For flows a little less than this, the Baramy® and SCS devices are likely to be easier to clean and hence more cost effective in the long run. The ILLS is effectively a miniaturised version of the UWEM device without the screens, but, as discussed in Appendix A.3 above, is not likely to be cost-effective in most situations. There is considerable potential for the use of hydraulically operated sluice gates with the Baramy® and SCS devices.

B : Hypothetical trap selection

(N.B. This Appendix was written by the principal author without input from any of the co-authors having a vested interest in the results of the analysis)

To illustrate the trap selection procedure described in Section 11.4, consider the following hypothetical catchment:

- CBD of a medium sized town (50% commercial, 30% industrial, 20% residential);
- Area = 100 hectares (1 square kilometre);
- Situated in the summer rainfall area of South Africa with a MAP = 850 mm;
- Topography and layout permits the installation of any of the seven “Off-the-shelf” devices described in Appendix A;
- Underground drainage system designed for 1:2 year recurrence interval (R.I.);
- 400 catchpits (a density of 4/ha);
- Regular street cleaning;
- No vegetation load;
- Runoff coefficient of 0,7 (70% of the storm rainfall is transported by the drainage system during the storm);
- Time of concentration of the rainfall (the time theoretically taken for a rain drop falling on the most remote point of the catchment to reach the trap) is 30 minutes;
- 50 significant rainfall events (more than 1 mm rainfall) a year concentrated in the summer rainfall season;
- Only recurrence intervals of 1:1 month and 1:2 years to be considered. Assume that the associated critical rainfall intensities are 21 and 51 mm/hour respectively;
- Litter density standardised to 95 kg / m³;
- Economic analysis to be carried out assuming a repayment period of 20 years and a real interest rate (after taking inflation into account) of 6%.
- Effective exchange rate is A\$1,00 = R3,00.

B-2

Solution:

1. Assume that the data for all sub-catchments is in the ratio of their areas.
2. According to the data supplied:

commercial	=	50 ha
industrial	=	30 ha
residential	=	20 ha
3. To estimate the total litter load, apply Equation 2-1:

$$T = \sum f_{sci} \cdot (V_i + B_i) \cdot A_i \quad (\text{Equation 2-1})$$

$$\begin{aligned} \Rightarrow T &= 1,0 \times 1,20 \times 50 = 60,0 \text{ m}^3/\text{year} \text{ (commercial)} \\ &+ 1,0 \times 0,80 \times 30 = 24,0 \text{ m}^3/\text{ha/year} \text{ (industrial)} \\ &+ 1,0 \times 0,01 \times 20 = 0,20 \text{ m}^3/\text{ha/year} \text{ (residential)} \end{aligned}$$

$$\Rightarrow T = 84,2 \text{ m}^3/\text{ha/year}.$$

4. The well known Rational Formula is:

$$Q_p = C \cdot I \cdot A / 3,6$$

where	Q_p	=	peak flow (m ³ /s)
	C	=	runoff coefficient (fraction)
	I	=	critical rainfall intensity (mm/hour)
	A	=	catchment area (km ²)

Applying the Rational Method to the hypothetical catchment gives a 1:1 month peak flow of approximately 4,0 m³/s, and a 1:2 year peak flow of approximately 10 m³/s.

Assume further that a structure designed for the 1:1 month peak flow will treat only 90% of the total flow whilst a structure designed for the 1:2 year peak flow will effectively treat all of the flow.

5. All seven structures described in Appendix A will be costed.
6. The minimum storage capacity of the traps is determined from Equation 2-2:

$$S = f_s \cdot T / \sum f_{si} \quad (\text{Equation 2-2})$$

$$\Rightarrow S = 4,0 \times 84,2 / (1,1 \times 50) = 6,1 \text{ m}^3$$

7. The cost effectiveness of the structures are determined in B.1 to B.7 below with any structure specific assumptions stated where relevant.
8. B.8 contains a summary of the calculations and makes some comments.

B.1 Side-entry catchpit traps (SECTs)

B.1.1 100% coverage

Assume that every catchpit is fitted with a SECT to give a total of 400 SECTs.

- a) **Efficiency** : The efficiency of SECTs may be estimated from Allison, 1997:

$$E = 1,18 \times 10^{-4} \cdot T^3 - 2,58 \times 10^{-2} \cdot T^2 + 2,184 \cdot T \quad (R^2 = 0,91)$$

$$\Rightarrow E = 1,18 \times 10^{-4} \times 100^3 - 2,58 \times 10^{-2} \times 100^2 + 2,184 \times 100 = 78\%$$

Since this is the system efficiency, $\eta_o = 78 / 100 = 0,78$

- b) **Storage capacity** : Assume a cleaning frequency of 14 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about $1,5 \text{ m}^3$ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 14 \times 0,78 \times 1,5 / 4 = 4,1 \text{ m}^3$$

Since this is not greater than the minimum calculated in Step 4 above = $6,1 \text{ m}^3$, the minimum storage capacity per trap = $6,1 \text{ m}^3 / 400 \text{ traps} = 0,015 \text{ m}^3$.

- c) **Capital recovery amount** : Assume an average installation cost of R300 each to give $400 \text{ traps} \times \text{R}300 / \text{trap} = \text{R}120\,000$. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 120\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = \text{R}10\,462 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,78 = 65,7 \text{ m}^3 / \text{year}$$

- e) **Annual cost of the structure** : If the wet season is approximately 30 weeks long, the traps will have to be cleaned 15 times a year on average. Assume an average cost of R20 per catchpit per clean to make the annual cost of cleaning = $400 \text{ traps} \times 15 \text{ cleans} / \text{year} \times \text{R}20 / \text{trap} / \text{clean} = \text{R}120\,000 / \text{year}$. This assumes the requisite equipment is available. In not, add for the additional cost of the eductor truck etc..

B-4

The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 10\,462 + 120\,000 = \text{R}130\,462 / \text{year}$$

f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 130\,462 / 65,7 = \text{R}1\,986 / \text{m}^3 \\ &= \text{R}20,90 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= \text{R}1\,305 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.1.2 50% coverage

Assume that the 50% of catchpits trapping the highest load can be correctly identified in advance to give a total of 200 SECTs.

a) **Efficiency** : The efficiency of SECTs may be estimated from Allison, 1997:

$$E = 1,18 \times 10^{-4} \cdot T^3 - 2,58 \times 10^{-2} \cdot T^2 + 2,184 \cdot T \quad (R^2 = 0,91)$$

$$\Rightarrow E = 1,18 \times 10^{-4} \times 50^3 - 2,58 \times 10^{-2} \times 50^2 + 2,184 \times 50 = 59\%$$

Since this is the system efficiency, $\eta_o = 59 / 100 = 0,59$

b) **Storage capacity** : Assume the same as for 100% coverage = $0,015 \text{ m}^3 / \text{trap}$

c) **Capital recovery amount** : Half of that for 100% coverage or $\text{R}5\,231 / \text{year}$

d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,59 = 49,7 \text{ m}^3 / \text{year}$$

e) **Annual cost of the structure** : Assuming that cost of cleaning is proportional to the loads captured, the annual cost of cleaning is given by $\text{R}120\,000 / \text{year}$ (the cost for 100% coverage) $\times 59 / 78$ (the ratio of the efficiencies) = $\text{R}90\,769 / \text{year}$.

The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 5\,231 + 90\,769 = \text{R}96\,000 / \text{year}$$

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 96\,000 / 49,7 = R1\,932 / m^3 \\ &= R20,33 / kg \text{ (dividing by the density } = 95 \text{ kg/m}^3\text{)} \\ &= R960 / ha \text{ (dividing the cost by the area)} \end{aligned}$$

B.2 The North Sydney Litter Control Device (LCD)

Assume the installation of as many as is required (costs are given on an area basis).

- a) **Efficiency** : Assume a system efficiency of 25%, ie. $\eta_o = 25 / 100 = 0,25$
- b) **Storage capacity** : Assume a cleaning frequency of 30 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about $1,5 \text{ m}^3$ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 30 \times 0,25 \times 1,5 / 4 = 2,8 \text{ m}^3$$

Since this is not greater than the minimum calculated in Step 4 above = $6,1 \text{ m}^3$, the minimum storage capacity = $6,1 \text{ m}^3$ distributed over all the traps.

- c) **Capital recovery amount** : Assume an average installation cost of R8 700 / ha to give a total installation cost of R8 700 / ha x 100 ha = R870 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 870\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = R75\,851 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,25 = 21,1 \text{ m}^3 / \text{year}$$

- e) **Annual cost of the structure** : If the wet season is approximately 7 months long, the traps will have to be cleaned 7 times a year on average. Assume an average cost of R8 per hectare per clean to make the annual cost of cleaning = 100 ha x 7 cleans / year x R8 / ha / clean = R5 600 / year.

B-6

The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 75\,851 + 5\,600 = \text{R}81\,451 / \text{year}$$

f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 81\,451 / 21,1 = \text{R}3\,860 / \text{m}^3 \\ &= \text{R}40,63 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= \text{R}815 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.3 The In-line Litter Separator (ILLS)

Assume an average of 0,5 m³/s per unit giving a total of 20.

a) **Efficiency** : Assume a system efficiency of 25%, ie. $\eta_o = 25 / 100 = 0,25$

b) **Storage capacity** : Assume a cleaning frequency of 14 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about 1,5 m³ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 14 \times 0,78 \times 1,5 / 4 = 4,1 \text{ m}^3$$

Since this is not greater than the minimum calculated in Step 4 above = 6,1 m³, the minimum storage capacity per trap = 6,1 m³ / 400 traps = 0,015 m³.

c) **Capital recovery amount** : Assume an average installation cost of R18 000 each to give R18 000 / trap x 20 traps = R360 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 360\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = \text{R}31\,386 / \text{year}$$

d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,25 = 21,1 \text{ m}^3 / \text{year}$$

B-7

- e) **Annual cost of the structure** : If the wet season is approximately 30 weeks long, the traps will have to be cleaned 15 times a year on average. Assume an average cost of R50 per catchpit per clean to make the annual cost of cleaning = 20 traps x 15 cleans / year x R50 / trap / clean = R15 000 / year. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 31\,386 + 15\,000 = \text{R}46\,386 / \text{year}$$

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 46\,386 / 21,1 = \text{R}2\,198 / \text{m}^3 \\ &= \text{R}23,14 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= \text{R}464 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.4 The Continuous Deflective Separation (CDS) device

B.4.1 1:2 year R.I. design

Assume 6 units, each capable of treating about 1,67 m³/s.

- a) **Efficiency** : Assume that the units effectively treat all the flow. Assume that the units are 99% efficient. The overall efficiency of the installation is then given by Equation 11-1:

$$\eta_o = \eta_s \cdot \eta_f \quad \text{Equation 11-1}$$

$$\Rightarrow \eta_o = 0,99 \times 1,00 = 0,99$$

- b) **Storage capacity** : Assume a cleaning frequency of 4 times a year or approximately once every 52 days during the wet season. Assume that the average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about 1,5 m³ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 52 \times 0,99 \times 1,5 / 4 = 19,3 \text{ m}^3$$

Since this is greater than the minimum calculated in Step 4 above = 6,1 m³, the minimum storage capacity per trap = 19.3 m³ / 6 traps = 3,2 m³.

B-8

- c) **Capital recovery amount** : Assume an average installation cost of R480 000 each to give 6 traps x R480 000 / trap = R2 880 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P.i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 2\,880\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = R251\,092 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T.\eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,99 = 83,4 \text{ m}^3 / \text{year}$$

- e) **Annual cost of the structure** : Assume an average cost of R3 000 per unit per clean to make the annual cost of cleaning = 6 traps x R3 000 / trap / clean x 4 cleans / year = R72 000 / year. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 251\,092 + 72\,000 = R323\,092 / \text{year}$$

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 323\,092 / 83,4 = R3\,874 / \text{m}^3 \\ &= R40,78 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= R3\,231 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.4.2 1:1 month R.I. design

Assume 3 units, each capable of treating about 1,33 m³/s.

- a) **Efficiency** : Assume that the units effectively treat 90% of the flow. Assume that the units are 99% efficient. The overall efficiency of the installation is then given by Equation 11-1:

$$\eta_o = \eta_s.\eta_f \quad \text{Equation 11-1}$$

$$\Rightarrow \eta_o = 0,99 \times 0,90 = 0,89$$

B-9

- b) **Storage capacity** : Assume a cleaning frequency of 4 times a year or approximately once every 52 days during the wet season. Assume that the average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about $1,5 \text{ m}^3$ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 52 \times 0,89 \times 1,5 / 4 = 17,4 \text{ m}^3$$

Since this is greater than the minimum calculated in Step 4 above = $6,1 \text{ m}^3$, the minimum storage capacity per trap = $17,4 \text{ m}^3 / 3 \text{ traps} = 5,8 \text{ m}^3$.

- c) **Capital recovery amount** : Assume an average installation cost of R480 000 each to give 3 traps \times R480 000 / trap = R1 440 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 1\,440\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = \text{R}125\,546 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,89 = 74,9 \text{ m}^3 / \text{year}$$

- e) **Annual cost of the structure** : Assume an average cost of R3 000 per unit per clean to make the annual cost of cleaning = 3 traps \times R3 000 / trap / clean \times 4 cleans / year = R36 000 / year. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 125\,546 + 36\,000 = \text{R}161\,546 / \text{year}$$

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 161\,546 / 74,9 = \text{R}2\,157 / \text{m}^3 \\ &= \text{R}22,70 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= \text{R}1\,615 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.5 The Baramy® Gross Pollutant Trap (BGPT)

B.5.1 1:2 year R.I. design

Assume 3 units, each capable of treating about 3,33 m³/s.

- a) **Efficiency** : Assume that the units effectively treat all the flow. Assume that the units are 95% efficient. The overall efficiency of the installation is then given by Equation 11-1:

$$\eta_o = \eta_s \cdot \eta_f \quad \text{Equation 11-1}$$

$$\Rightarrow \eta_o = 0,95 \times 1,00 = 0,95$$

- b) **Storage capacity** : Assume a cleaning frequency of 14 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about 1,5 m³ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 14 \times 0,95 \times 1,5 / 4 = 5,0 \text{ m}^3$$

Since this is less than the minimum calculated in Step 4 above = 6,1 m³, the minimum storage capacity per trap = 6,1 m³ / 3 traps = 2,0 m³.

- c) **Capital recovery amount** : Assume an average installation cost of R72 000 each to give 3 traps x R72 000 / trap = R216 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 216\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = R18\,832 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,95 = 80,0 \text{ m}^3 / \text{year}$$

- e) **Annual cost of the structure** : Assume an average cleaning cost of R35 / m³ to make the annual cost of cleaning = R35 / m³ x 80,0 m³ / year = R2 800 / year. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 18\,832 + 2\,800 = R21\,632 / \text{year}$$

B-11

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 21\,632 / 80,0 = R270 / \text{m}^3 \\ &= R2,85 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= R216 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.5.2 1:1 month R.I. design

Assume 1 unit capable of treating the entire $4 \text{ m}^3/\text{s}$.

- a) **Efficiency** : Assume that the unit effectively treats 90% of the flow. Assume that the unit is 95% efficient. The overall efficiency of the installation is then given by Equation 11-1:

$$\eta_o = \eta_s \cdot \eta_f \quad \text{Equation 11-1}$$

$$\Rightarrow \eta_o = 0,95 \times 0,90 = 0,86$$

- b) **Storage capacity** : Assume a cleaning frequency of 14 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about $1,5 \text{ m}^3$ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 14 \times 0,86 \times 1,5 / 4 = 4,5 \text{ m}^3$$

Since this is less than the minimum calculated in Step 4 above = $6,1 \text{ m}^3$, the minimum storage capacity = $6,1 \text{ m}^3$.

- c) **Capital recovery amount** : Assume an installation cost of R85 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 85\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = R7\,411 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,86 = 72,4 \text{ m}^3 / \text{year}$$

B-12

- e) **Annual cost of the structure** : Assume an average cleaning cost of R35 / m³ to make the annual cost of cleaning = R35 / m³ x 72,4 m³ / year = R2 534 / year. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 7\,411 + 2\,534 = \text{R}9\,945 / \text{year}$$

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 9\,945 / 72,4 = \text{R}137 / \text{m}^3 \\ &= \text{R}1,45 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= \text{R}99 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.6 The Stormwater Cleaning Systems (SCS) Structure

B.6.1 1:2 year R.I. design

Assume 1 unit capable of treating the entire 10 m³/s.

- a) **Efficiency** : Assume that the unit effectively treats all the flow. Assume that the unit is 95% efficient. The overall efficiency of the installation is then given by Equation 11-1:

$$\eta_o = \eta_s \cdot \eta_f \quad \text{Equation 11-1}$$

$$\Rightarrow \eta_o = 0,95 \times 1,00 = 0,95$$

- b) **Storage capacity** : Assume a cleaning frequency of 14 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about 1,5 m³ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 14 \times 0,95 \times 1,5 / 4 = 5,0 \text{ m}^3$$

Since this is less than the minimum calculated in Step 4 above = 6,1 m³, the minimum storage capacity = 6,1 m³.

B-13

- c) **Capital recovery amount** : Assume an installation cost of R250 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 250\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = \text{R}21\,796 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,95 = 80,0 \text{ m}^3 / \text{year}$$

- e) **Annual cost of the structure** : Assume an average cleaning cost of R35 / m³ to make the annual cost of cleaning = R35 / m³ x 80,0 m³ / year = R2 800 / year. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 21\,796 + 2\,800 = \text{R}24\,596 / \text{year}$$

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 24\,596 / 80,0 = \text{R}307 / \text{m}^3 \\ &= \text{R}3,24 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= \text{R}246 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.6.2 1:1 month R.I. design

Assume 1 unit capable of treating the entire 4 m³/s.

- a) **Efficiency** : Assume that the unit effectively treats 90% of the flow. Assume that the unit is 95% efficient. The overall efficiency of the installation is then given by Equation 11-1:

$$\eta_o = \eta_s \cdot \eta_f \quad \text{Equation 11-1}$$

$$\Rightarrow \eta_o = 0,95 \times 0,90 = 0,86$$

B-14

- b) **Storage capacity** : Assume a cleaning frequency of 14 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about $1,5 \text{ m}^3$ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 14 \times 0,86 \times 1,5 / 4 = 4,5 \text{ m}^3$$

Since this is less than the minimum calculated in Step 4 above = $6,1 \text{ m}^3$, the minimum storage capacity = $6,1 \text{ m}^3$.

- c) **Capital recovery amount** : Assume an installation cost of R125 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 125\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = \text{R}10\,898 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,86 = 72,4 \text{ m}^3 / \text{year}$$

- e) **Annual cost of the structure** : Assume an average cleaning cost of R35 / m^3 to make the annual cost of cleaning = $\text{R}35 / \text{m}^3 \times 72,4 \text{ m}^3 / \text{year} = \text{R}2\,534 / \text{year}$. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 10\,898 + 2\,534 = \text{R}13\,432 / \text{year}$$

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 13\,432 / 72,4 = \text{R}185 / \text{m}^3 \\ &= \text{R}1,95 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= \text{R}134 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.7 The Urban Water Environmental Management (UWEM) concept

B.7.1 1:2 year R.I. design

Assume 1 unit capable of treating the entire $10 \text{ m}^3/\text{s}$.

- a) **Efficiency** : Assume that the unit effectively treats all the flow. Assume that the unit is 90% efficient. The overall efficiency of the installation is then given by Equation 11-1:

$$\eta_o = \eta_s \cdot \eta_f \quad \text{Equation 11-1}$$

$$\Rightarrow \eta_o = 0,90 \times 1,00 = 0,90$$

- b) **Storage capacity** : Assume a cleaning frequency of 14 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about $1,5 \text{ m}^3$ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 14 \times 0,90 \times 1,5 / 4 = 4,7 \text{ m}^3$$

Since this is less than the minimum calculated in Step 4 above = $6,1 \text{ m}^3$, the minimum storage capacity = $6,1 \text{ m}^3$.

- c) **Capital recovery amount** : Assume an installation cost of R250 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 250\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = \text{R}21\,796 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,90 = 75,8 \text{ m}^3 / \text{year}$$

- e) **Annual cost of the structure** : Assume an average cleaning cost of R35 / m^3 to make the annual cost of cleaning = $\text{R}35 / \text{m}^3 \times 75,8 \text{ m}^3 / \text{year} = \text{R}2\,653 / \text{year}$. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 21\,796 + 2\,653 = \text{R}24\,449 / \text{year}$$

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- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 24\,449 / 75,8 = R323 / \text{m}^3 \\ &= R3,40 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= R244 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.7.2 1:1 month R.I. design

Assume 1 unit capable of treating the entire $4 \text{ m}^3/\text{s}$.

- a) **Efficiency** : Assume that the unit effectively treats 90% of the flow. Assume that the unit is 90% efficient. The overall efficiency of the installation is then given by Equation 11-1:

$$\eta_o = \eta_s \cdot \eta_f \quad \text{Equation 11-1}$$

$$\Rightarrow \eta_o = 0,90 \times 0,90 = 0,81$$

- b) **Storage capacity** : Assume a cleaning frequency of 14 days and an average storm frequency of 4 days during the wet season. The average storm load (after the first storm of the season) is estimated to be about $1,5 \text{ m}^3$ from Equation 2-2. The required storage capacity is then given by Equation 11-2:

$$V_t = F_c \cdot \eta_o \cdot S_{av} / F_s \quad \text{Equation 11-2}$$

$$\Rightarrow V_t = 14 \times 0,81 \times 1,5 / 4 = 4,3 \text{ m}^3$$

Since this is less than the minimum calculated in Step 4 above = $6,1 \text{ m}^3$, the minimum storage capacity = $6,1 \text{ m}^3$.

- c) **Capital recovery amount** : Assume an installation cost of R150 000. The capital recovery amount is then calculated from Equation 11-3:

$$A = P \cdot i(1+i)^n / ((1+i)^n - 1) \quad \text{Equation 11-3}$$

$$\Rightarrow A = 150\,000 \times 0,06 \times (1 + 0,06)^{20} / ((1 + 0,06)^{20} - 1) = R13\,078 / \text{year}$$

- d) **Total volume of litter trapped** : is calculated from Equation 11-4:

$$L = T \cdot \eta_o \quad \text{Equation 11-4}$$

$$\Rightarrow L = 84,2 \times 0,81 = 68,2 \text{ m}^3 / \text{year}$$

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- e) **Annual cost of the structure** : Assume an average cleaning cost of R35 / m³ to make the annual cost of cleaning = R35 / m³ x 68,2 m³ / year = R2 387 / year. The total annual cost is then calculated from Equation 11-5:

$$C_t = A + C_c \quad \text{Equation 11-5}$$

$$\Rightarrow C_t = 13\,078 + 2\,387 = R15\,465 / \text{year}$$

- f) **Unit cost of litter removal** : is calculated from Equation 11-6:

$$C = C_t / L \quad \text{Equation 11-6}$$

$$\begin{aligned} \Rightarrow C &= 15\,465 / 68,2 = R227 / \text{m}^3 \\ &= R2,39 / \text{kg} \text{ (dividing by the density = } 95 \text{ kg/m}^3\text{)} \\ &= R155 / \text{ha} \text{ (dividing the cost by the area)} \end{aligned}$$

B.8 Summary and conclusions

The results of the above analysis are summarised in Tables B-1 and Table B-2.

The above analysis clearly shows the much better economic efficiency of the UWEM, Baramy® and SCS devices over the remaining four structures. SECTs might be a little more cost effective in South Africa than indicated in the analysis if they prove to be cheaper to install and clean than in Australia - owing to the lower cost of labour. In addition, they are also a potential catchment management tool as they show where the bulk of the litter is being generated. The CDS units offer very high removal efficiencies, but at a heavy cost. The ILLS and LCD structures appear on the surface to have little to recommend them except that they are small and can be installed under streets in confined spaces, and the ILLS has the additional advantage that it requires very little head.

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. Local litter loadings and cost factors may also bias the analysis differently to that of the example.

The analysis shows that it is quite possible remove litter from stormwater conduits and urban streams for R150 - R350 / m³ (1997 costs). By way of comparison, it cost the City Council of Springs approximately R680 / m³ of litter in 1995 to remove litter from the streets and a further R900 / m³ to remove what they could by hand out of the Blesbokspruit (Nel, 1996). This is approximately R810 / m³ and R1 080 / m³ respectively in 1997 terms.

Rank	Device	Traps	E(%)	R/m ³	R/kg	R/ha/y
1	Baramy® (1:1 month R.I.)	1	86	137	1,45	99
2	SCS (1:1 month R.I.)	1	86	185	1,95	134
3	UWEM (1:1 month R.I.)	1	81	227	2,39	155
4	Baramy® (1:2 year R.I.)	3	95	270	2,85	216
5	SCS (1:2 year R.I.)	1	95	307	3,24	246
6	UWEM (1:2 year R.I.)	1	90	323	3,40	244
7	SECTs (50% coverage)	200	59	1 932	20,33	960
8	SECTs (100% coverage)	400	78	1 986	20,90	1 305
9	CDS (1:1 month R.I.)	3	89	2 157	22,70	1 615
10	ILLS	20	25	2 198	23,14	464
11	LCD	-	25	3 860	40,63	815
12	CDS (1:2 year R.I.)	6	99	3 874	40,78	3 231

Table B-1 : Summary of the analysis ranked in terms of cost effectiveness

Rank	Device	Traps	E(%)	R/m ³	R/kg	R/ha
1	CDS (1:2 year R.I.)	6	99	3 874	40,78	3 231
2	Baramy® (1:2 year R.I.)	3	95	270	2,85	216
3	SCS (1:2 year R.I.)	1	95	307	3,24	246
4	UWEM (1:2 year R.I.)	1	90	323	3,40	244
5	CDS (1:1 month R.I.)	3	89	2 157	22,70	1 615
6	Baramy® (1:1 month R.I.)	1	86	137	1,45	99
7	SCS (1:1 month R.I.)	1	86	185	1,95	134
8	UWEM (1:1 month R.I.)	1	81	227	2,39	155
9	SECTs (100% coverage)	400	78	1 986	20,90	1 305
10	SECTs (50% coverage)	200	59	1 932	20,33	960
11	ILLS	20	25	2 198	23,14	464
12	LCD	-	25	3 860	40,63	815

Table B-2 : Summary of the analysis ranked in terms of removal efficiency

C : Hydraulically operated sluice gates

A major problem with many of the more cost effective litter removal technologies, is that they require considerable head - often up to 2 m - for their successful operation. This is seldom available. Most cities are built on relatively flat land.

A potential solution is to incorporate an hydraulically operated sluice gate which supplies the required head during low flow periods, and lifts out of the way to pass flood peaks without raising upstream flood levels. This approach was pioneered in the UWEM concept described in Section 6.6.

There are many patented designs of gate, each operating in a slightly different way. Two designs by Fluid Dynamics Systems are described here as examples.

C.1 Fluid Dynamics Systems Regulating Gate

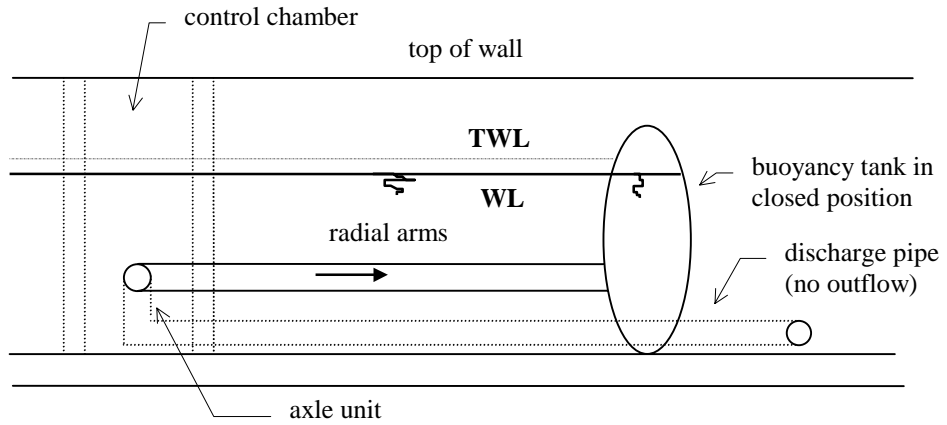
A modified Fluid Dynamics Systems Regulating Gate was installed on the Robinson Canal trap (see Sections 2.3 and 6.6). It comprises a buoyancy tank (whose shape is determined from model testing) connected by two hollow radial arms to an axle unit, which is in turn attached a control chamber. An automatic level controlling valve installed in the control chamber allows water into and out of the buoyancy tank via the axle unit.

The gate operates as follows:

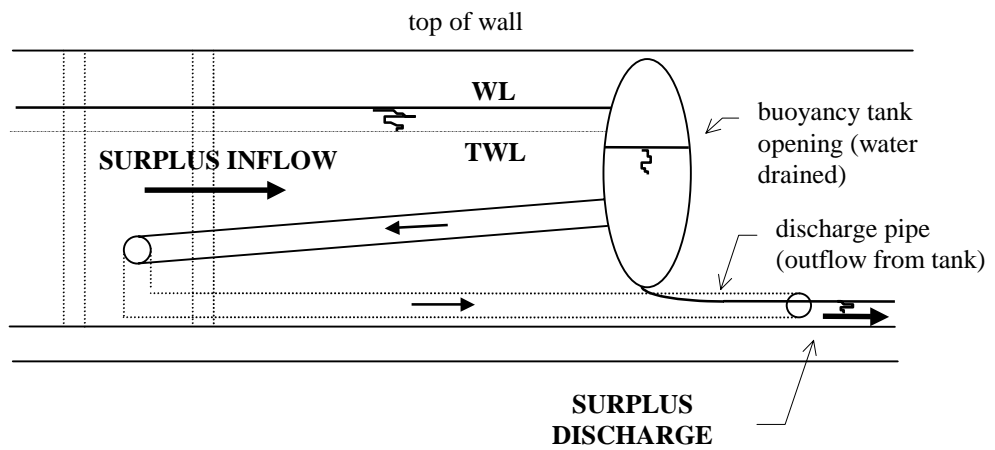
1. For all water levels (WLs) less than or equal to the required top water level (TWL), the control valve ensures that the buoyancy tank is kept full of water, and the gate closed, by allowing water from the upstream channel to flow into it through the radial arms. The balance of the channel flow is thereby diverted through the screens so that the litter may be removed.
2. When the design flow is exceeded, the WL rises to above the required TWL. The control valve now stops the inflow into the buoyancy tank whilst simultaneously opening the discharge pipe. Water drains from the buoyancy tank thereby lightening it until a point is reached where the tank starts to float and the gate opens. Surplus flood waters are now released underneath the gate.
3. The gate continues to rise until water is being discharged at a slightly faster rate than the upstream flow. At this point, the WL starts to drop. As soon as it drops below the required TWL the control valve shuts off the discharge and opens up the inflow line into the buoyancy tank. As the buoyancy tank fills with water, it sinks thereby reducing the discharge. If the discharge drops below the upstream flow, the tank is drained a little to open the gate a bit more. In this manner the structure is able to maintain the upstream WL to within 50 mm of the required TWL. If the upstream flow drops below the design capacity of the litter removal structure, the gate closes completely.

The operation of the Fluid Dynamics Systems regulating gate is illustrated in Figure C-1.

(a) Closed position



(b) Opening



(c) Closing

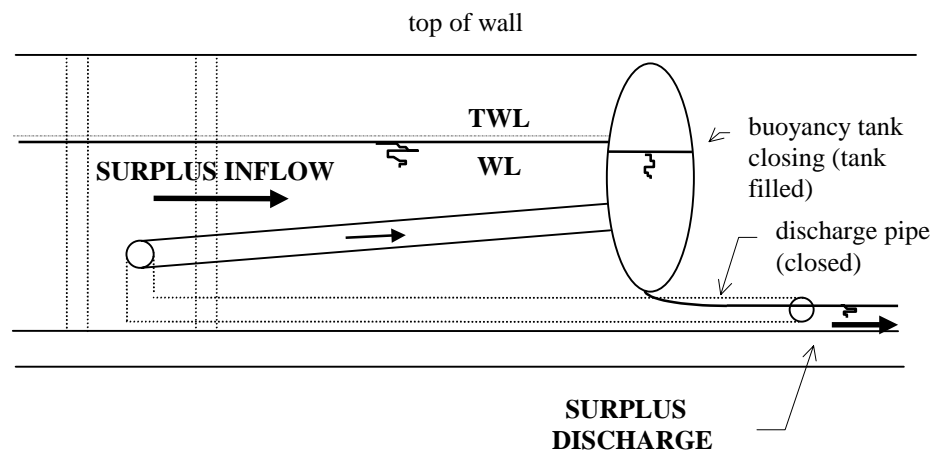


Figure C-1 : The operation of the Fluid Dynamics Systems Regulating Gate

C.2 Fluid Dynamics Systems Scour Gate

An alternative type of gate, the Fluid Dynamic Systems scour gate, is also suitable for level control, particularly in higher head schemes. It also comprises a buoyancy tank attached to radial arms and rotating on two axle units. In this design however, the buoyancy gate remains empty at all times, and is housed in a floatation chamber with a scour tunnel beneath. The floatation chamber is filled by an inlet pipe whose inlet is located in the upstream channel at the required TWL and is drained by an outlet pipe that is always open to the downstream channel. The scour tunnel is closed off by means of a leaf plate attached to the buoyancy tank.

The gate operates as follows:

1. Whilst $WL \leq TWL$, no water flows into the floatation chamber, the chamber is dry, and the scour gate remains closed.
2. When the upstream WL rises above the required TWL, water starts to flow through the inlet pipe into the buoyancy chamber. Since the outlet pipe has a relatively small diameter compared with the inlet pipe, a condition is soon reached where the inflow exceeds the outflow and the buoyancy chamber begins to fill with water. As the water level in the chamber rises, the buoyancy tank and attached leaf gate also rise. Surplus flood waters are now released from beneath the gate.
3. The gate continues to rise until water is being discharged at a slightly faster rate than the upstream flow. At this point, the WL starts to drop. As soon as it drops to a point where the inflow into the floatation chamber is less than the discharge out of it, the chamber starts to drain and the buoyancy tank and attached gate are lowered. If the discharge drops below the upstream flow, the tank is filled a little to open the gate a bit more. In this manner the structure is able to maintain the upstream WL to within 50 mm of the required TWL. If the upstream flow drops below the design capacity of the litter removal structure, the gate closes completely.

The operation of the Fluid Dynamics Systems Scour Gate is illustrated in Figure C-2.

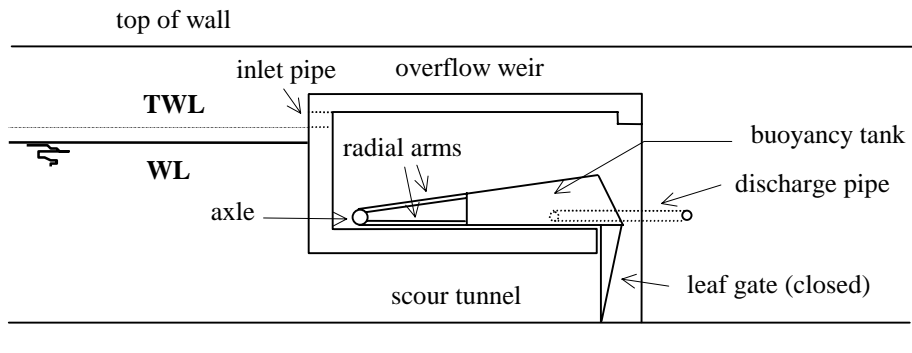
This type of gate is particularly suitable for large watercourses because it is able to pass large objects such as tree stumps, drums and bricks without damage.

Further information may be obtained from:

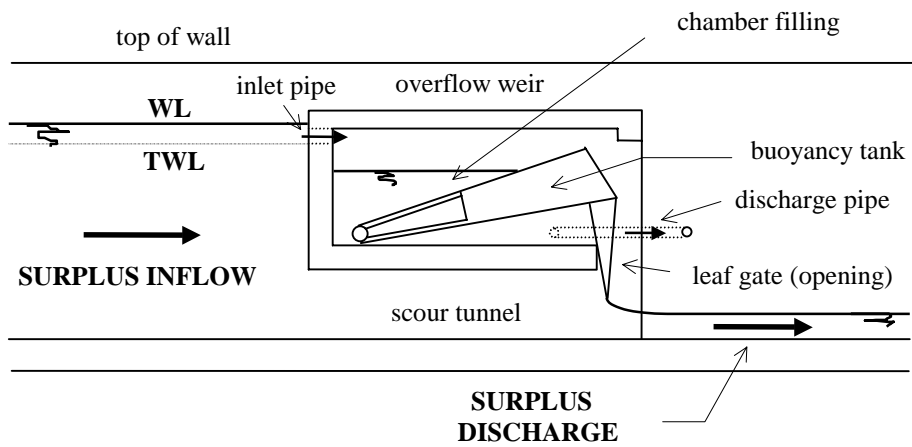
Attention : Mr P Townshend
Flowgate Projects
P O Box 3677
Randburg, Gauteng, 2125
SOUTH AFRICA

Phone : [++27] (11) 781 3910
Fax : [++27] (11) 781 3911

(a) Closed position



(b) Opening



(c) Closing

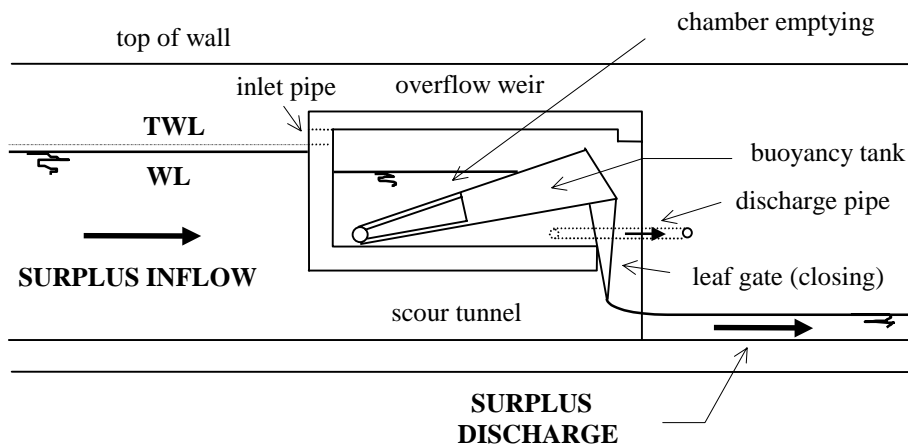


Figure C-2 : The operation of the Fluid Dynamics Systems Scour Gate