The real issues with in-ground SUDS in Scotland

W. Schlüter [1*] and C. Jefferies[2]

[1] *RPS-MCOS West Pier Campus, DunLaoghaire, Dublin, Ireland*
[2] *Urban Water Technology Centre, University of Abertay Dundee, Bell Street, Dundee, DD1 1HG, Scotland*
**Corresponding author, e-mail wolfram.schluter@rpsgroup.ie*

ABSTRACT
The aim of this research was to produce enhanced detailing and improved operation of in-ground SUDS. Data from on-site monitoring at three filter drain and three infiltration trench systems were analysed and the results were combined with information gathered from 40 assessments of *in-situ* systems in Eastern Scotland. Current findings showed that almost 50% of all systems were found to be unsatisfactory and more than half of these were rated as having failed. 36% provided fair and 16%, good performance. Only one system was considered to be performing excellently. Several reasons were identified for the poor performance. The principal cause of problems was runoff from unstabilised areas or construction runoff, which was found to be affecting the systems' longevity. Almost 30% of all sites were affected by construction runoff. Another major problem was related to system maintenance since maintenance programs were generally not in place. This study has shown that regular maintenance is vital for the longevity of in-ground SUDS.

KEYWORDS
Sustainable Urban Drainage Systems; infiltration trench; filter drain; hydraulic performance

INTRODUCTION
In-ground SUDS are often the developer's preferred choice in urban areas as they require little space, are inexpensive and permit development where sewerage capacity is limited. Despite the extensive use that has been made of infiltration pits and trenches or soakaways there has been only limited examination of their performance (Warnaars et al., 1999 and Abbott & Comino-Mateos, 2001) and a general expectation that failure through blockage and inadequate maintenance would necessitate reconstruction within a limited time period (Pratt, 2001). This paper reports on information gathered from several site inspections and works towards enhanced detailing and improved operation of in-ground SUDS.

METHODS
Appropriate developer, water authority and Scottish Environment Protection SEPA personnel were contacted for information on systems' concepts, record plans and for other information. In addition to flow monitoring of six systems, another 37 sites were inspected by manhole entry and general visual inspection. Fifteen sites were selected for closed circuit TV (CCTV) inspection from within the perforated inlet pipe. Monitoring results, findings from the visual inspection in combination with record drawings etc. and results from the CCTV survey were synthesised and a rating system has been developed to enable inter-system comparison and to

emphasise the systems' good and bad design. Maintenance procedures from highway operators and Water Authorities were also assessed. Highway operators were found to undertake routine inspections and to carry out preventative maintenance programmes. Otherwise, the maintenance programmes and frequencies proposed here are based on informed estimates of the likely accumulation of sediment and contaminants.

DESIGN AND DETAILING ISSUES

Overall Performance

A numerical scoring system has been introduced to provide an overall performance for the systems investigated. Scores were assigned under 5 categories relating to water quality, hydraulic performance, detailing design and maintainability. If a system scored 1 (Failure) in a critical category, the system's overall score resulted in Failure, otherwise the average of all categories provided the overall score. This procedure prevented the scoring-system from generating unrealistic results; i.e. blocked system or systems with highly turbid outflow could otherwise get a Fair or even a Good performance score. Table 1 gives definitions of the introduced scoring system and a description that is associated with each score.

Table 1. Scoring system for performance comparison

Score	Category	Example Description
5	Excellent	System with excellent detailing, promoting flow attenuation and pollutant retention. System is well maintainable.
4	Good	System provides good flow attenuation and pollutant retention. Some maintenance required.
3	Fair	Does provide some pollutant retention and little flow attenuation. May show significant sedimentation and may need maintenance
2	Poor	Poorly designed with expectation to fail. Maintenance urgently required
1	Failure	Blocked system or system with sediment breakthrough at outlet, i.e. pollutants travelling through the system

Overall results are presented in Figure 1 showing that almost 50% of all systems were found to be unsatisfactory and more than half of these were rate as failed. 36% provided fair performance and 16% showed good performance. Only one system was considered to be performing excellently

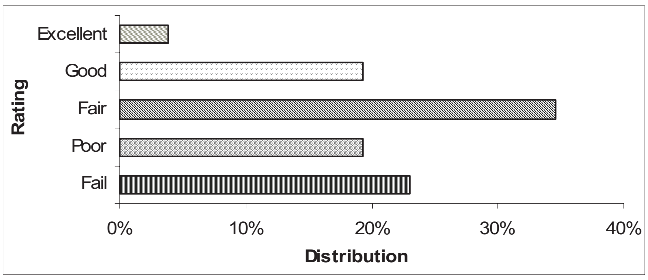

Figure 1. Results from the overall scoring system.

General findings

This survey of in-ground SUDS showed that almost 75% of all systems discharge to natural watercourses, disconnecting a significant amount of impermeable area from combined sewer systems. Catchment areas varied from 392m^2 to 200,000m^2. High-level bypasses or overflows are used to ensure hydraulic performance in case of extreme rainfall events and overflows were found at more than 50% of all systems. There is a growing concern in the Water Authority and SEPA that many systems are permanently blocked, which may never be noticed at locations with overflows. The survey showed that more than 30% had signs of partial blockage and one site was found which was permanently blocked. Runoff carrying a sediment load from unstabilised areas or due to construction activities was found to be affecting the longevity of in-ground SUDS, almost 30% of all sites being affected by construction runoff. These problems could have been prevented by protecting the drainage inlets until construction and site cleanup was finished and the drained area stabilised. Various tools are available to stop high sediment load entering storm drains, these are extensively used in the US (USEPA, 2002) but not in the UK.

Detailing examples

Good detailing. Only one of the systems under investigation was found to be performing excellently and this is shown in Figure 2. The inlet pipe of the infiltration trench runs for the system's full length and this maximises the inflow capacity. This system is 43m long and 0.75m wide, the sump is 1.0m deep and the inlet and outlet pipes (of the inlet sump/ chamber) are level, promoting good debris settlement.

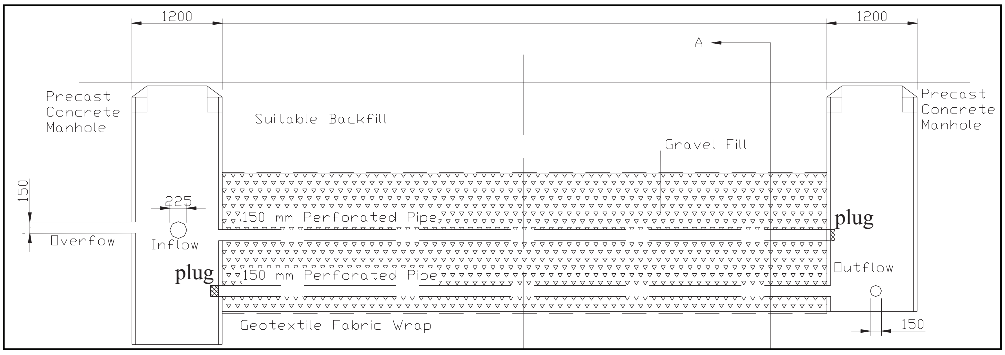

Figure 2: Infiltration trench at Broxden

Crucial for the performance of the system at Broxden are the two plugs, cutting-off flow at either end of the drainpipes. They can be removed for inspection and to enable cleaning by high pressure jetting and flushing of drainpipes. However, there are a number of points, which could further improve the system at Broxden: Installing a dip plate in the inlet to retain floating debris; Raising the elevation of the outlet to utilise additional storage; raising the top perforated pipe to improve filtration; Increasing the elevation of the overflow to provide additional storage.

Good flow distribution. An alternative an end-pipe soakaway arrangement is illustrated in Figure 3. It is also located downstream from a conventionally drained suburban development (of around 24 houses). In this case there is a reasonable chance of longer-term good behaviour, firstly because there are three routes from the inlet manhole into the filter material, providing good flow distribution and giving a reduced pollutant load per length of pipe. The elevation of the pipe maximises the system's storage as it is located close to the top of the filter material. The site visit to this location provided unexpected findings as the inlet sump of the system was filled with sediments and there was also a considerable amount of sediment in each perforated pipe (Figure 3).

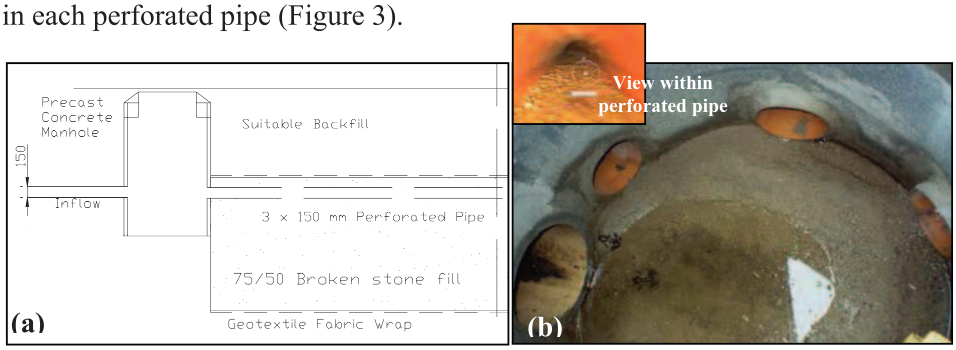

Figure 3. Shallow soakaway arrangement (a); sedimentation in chamber (b)

Findings at this site show the typical impact of construction runoff and poor site management. Although both the design and construction of the system showed good practice, the system silted up quickly as it was connected to the surface drainage too early and sediment management was poor.

Problems with filter drains & lateral inlets. A further commonly used technique is the French drain installed in car parking areas and roadsides. These systems should improve water quality performance due to the filtering out of pollutants and this is promoted by disconnecting the drainpipe from runoff. However, a number of problems were discovered as follows:

- Filter material was distributed onto the road (see figure 4(a)).
- Blocked lateral inlets resulted in local flooding (see figure 4(b)).
- Broken lateral inlets at three locations (see figure 4(c)).

Figure 4: Problems with offlet kerb arrangements along Spine Road

Insufficient flow capacity. The next example is a filter drain along a busy commuter route in an older urban area (known as Lang Stracht). The inlets to this system (shown in figure 5) comprise trapped gully pots which discharge directly into the filter media and these were found to have failed hydraulically due to blockage.

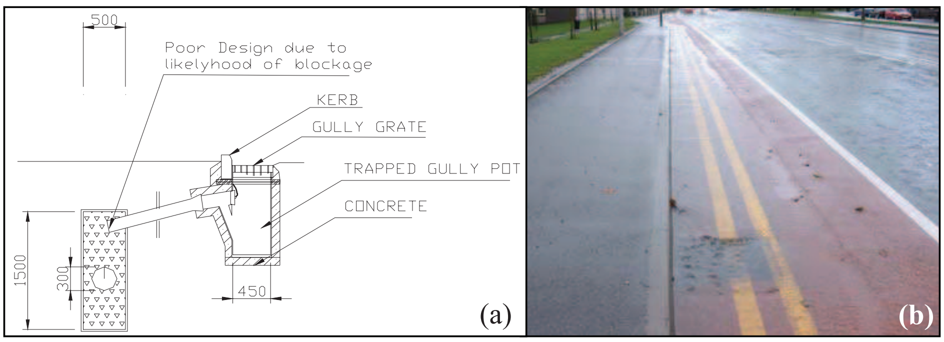

Figure 5: Road side filter drain arrangement (a); Flooding due to blocked gully outlets (b)

The flow capacity at this type of inlet is extremely low and small amounts of debris were found to have blocked the gully pot outlets. Figure 5 shows flooding of the system after an event of relatively small rainfall intensity of 13.2 mm/h.

MAINTENANCE CONSIDERATIONS

Overall findings
From these investigations, the key maintenance issues were:

- No maintenance had been carried out at 39 of the locations.
- Maintenance in the form of removal and replacement of the filter material had been undertaken at two locations.
- Maintenance in the form of jetting had been undertaken at two locations.

In spite of this lack of activity, it was clear that maintenance was urgently required at many of the systems. Of the 32 for which performance and maintenance could be assessed, 50% required substantial work to be undertaken before the system could be considered to be operating satisfactorily and in a condition to be maintained regularly. An inventory of the maintenance activities which were required at all of the sites was prepared, and from this inventory, the long and short term maintenance requirements were assessed. Two categories of maintenance activities were required:

- One off tasks – to restore the SUDS to a satisfactory condition
- Ongoing tasks – to maintain operation throughout the life of the system.

One off maintenance tasks for filter drains
A significant number of in ground filter drains, infiltration trenches and soakaways were found to require major upgrading before they could be considered to be satisfactory. Of the 43 sites examined, one off maintenance tasks were estimated for 32, and Table 2 indicates the range of tasks which would be required.

Table 2. One off maintenance tasks for filter drains, infiltration trenches and soakaways

Description of tasks required	Systems requiring tasks
Complete reconstruction	16%
Substantial replacement of filter material, etc.	22%
System clean-out and jetting of perforated pipes	16%
Inspections and minor cleaning	47%

Complete reconstruction was required at two sites, which were poorly conceived, and key components were below the water table. Several sites suffered from inappropriate site construction practice and at three sites this had led to the system being overwhelmed by construction material. The damage at these sites was so great that a complete reconstruction was required. 22% of the systems required a significant amount of rebuilding. Again, poor site construction practice was one major cause. Although there were accumulations of sands and gravels, these were not considered to require the scale of rebuilding as above. Poor detailing design was the other cause and minor inlet and filter drain installation are required. At a number of locations this required the installation of a distributor pipe along the top of the trench. After exclusion of those sites requiring more significant attention, 16% of the systems required simple cleaning and jetting.

Ongoing routine maintenance tasks for in-ground SUDS

Ongoing maintenance tasks have been categorised into the tasks requiring to be undertaken, and the frequency with which they are likely to be required. The only 'hard' data available were from highways operators who undertook routine inspections and responded to emergent problems with a preventative maintenance programme. Otherwise, the maintenance programme and frequencies proposed were based on informed estimates of the likely accumulation of sediment and contaminants. Table 3 shows the numbers of systems requiring the different ongoing maintenance tasks.

Table 3. Ongoing maintenance tasks for the in-ground SUDS investigated

Description of tasks required	No	Frequency
Inspections by supervisory staff only	All	Annually
Gully pot emptying	30%	Annually
Minor works - jetting, cleaning and sump emptying	60%	10 Years
Minor works - jetting, cleaning and sump emptying,	15%	5 Years
Removal of top layer and cleaning of filter media	Heavily used roads	As required

Inspections should be undertaken on an annual basis at all sites to ensure that systems are continuing to operate satisfactory. More than ¾ of all systems used standard gully pots which are maintained from the surface. A number of instances of blockage of the entry from the gully pot into the filter material were noted and it is essential that this risk is minimised by gully pot emptying. Jetting, minor cleaning and sump emptying are activities that require manhole entry and removal of contaminated sediment and water. Most systems incorporate at least one perforated pipe in the filter material and an inlet manhole that should have a sediment sump.

One particular maintenance technique was found to be used on the filter drains alongside major roads. To ensure quick turn around on site (and to minimise costs), all filter media down to, but not including, the bottom perforated drainpipe is excavated, removed from site for washing or disposal, and new media is installed. This complete replacement has been adopted to reduce the time taken on site with the consequent disruption to the flow of traffic. An alternative method to replacing the gravel is used for roadside filter drains that receive lateral sheet flow where blockage is often caused by sediment blinding the top of the gravel. To rectify this and promote water inflow into the gravel without disruption, a tractor mounted rake is used to scarify and disturb the top layer of gravel. Unfortunately, this approach has the drawback that pollutants which had accumulated in the section below the perforated pipe continue to seep into the adjacent soil possibly causing a risk to ground water.

DISCUSSION

Detailing

The performance and longevity of many in-ground SUDS is impaired by high sediment loads from construction runoff. This problem could easily be prevented by protecting the drainage inlets until the completion of construction and site cleanup and the drained area has stabilised. There are various tools available to stop high sediment load entering storm drains and these are extensively used in the USA.

The survey showed that disconnecting the system's inlet from the outlet provides better pollution retention in comparison with systems which discharge directly via perforated pipes. Sediments, together with associated pollutants, are filtered out and retained within the filter medium rather then flushed through. However, the reduced hydraulic performance from these systems has to be taken into account and frequent flooding was discovered at two sites due to the reduced hydraulic capacity.

A few sites were found which did not incorporate inspection chambers or rodding eyes and these are impossible to maintain and clean and other sites could have been improved further by using additional features, such as a dip plate or a rodding eye. Often the volume of the sediment sump was not sufficient or the level of the perforated pipe was inappropriate, promoting sediment input into the trench. Many sites use a high-level bypass or an overflow and these sites impose the risk that failure due to blockage may never be noticed and the bypass could be operating continuously. The installation of overflows has to be assessed on a site-by-site basis but many installations were found where overflows were not necessary since there was no risk of property flooding. Often the volume of the sediment sump was not sufficient, or the level of the perforated pipe was inappropriate, again promoting sediment input into the trench. High level outlets were found to improve the system performance when situated in soil with a high permeability but allowing water to be retained within the system for long time periods in poor drainage soil.

Offlet kerbs were found to be problematic as inlets to filter drains. This was mainly due to the inability to clean and maintain the inlets. Blocked inlets were found at both sites which incorporated offlet kerbs. Road safety was an issue at one site, where filter material had spilled onto the road

Maintenance

No routine maintenance programmes were in place due to staff and infrastructure limitations. Maintenance is carried out on an incident basis, which may be sufficient for traditional storm water drainage but is a flawed approach for in-ground SUDS where water quality performance is a key issue. Maintenance should be undertaken regularly and this may comprise of drain and gully pot cleaning and sediment chamber inspections. The maintenance intervals are site dependent and these may vary from twice per year up to once every ten years.

This survey showed that roadside filter drains may impose a long-term pollution risk to receiving waters. Maintenance is undertaken with the primary objective to enable hydraulic performance and it is thought that current maintenance techniques allow a great amount of pollution to accumulate within the system. To date, no effective way has been found to extract pollutants from the filter material and once blockage occurs, whole systems have to be replaced. For major trunk roads, replacement is expected every two years to maintain hydraulic functionality. Cleaning techniques were unsuitable for typically trapped gully pots, which discharge directly into the filter material of filter trenches. This included high pressure flushing of the outlet, resulting in the mobilisation of accumulated particles and extremely high turbidity readings at outlets.

CONCLUSION

The ranking procedure introduced showed that almost 50% of all systems were unsatisfactory, and more than half of these rated as failures. 36% provided fair performance and 16% showed good performance. Only one system was considered to be performing excellently.

Results from the overall assessment showed that:

- 75% of all systems discharge to natural watercourses
- 50% use overflows to ensure discharge during extreme events
- 30% had sign of temporary blockage
- 30% were affected by construction runoff & 5 sites require complete reconstruction.
- 22% require major upgrading before they may be considered satisfactory

Several reasons were identified for the poor performance and the main reasons were as follows:

- Runoff from unstabilised areas and construction runoff causing blockages
- Lack of maintenance programs or unsuitable maintenance procedures
- Missing flow control features
- High-level outlets in poor drainage soils causing anaerobic conditions
- Limited inflow capacity causing surcharge/ flooding

The following presents a list of recommendations to improve the long term performance of in-ground SUDS:

- Sufficient inlet sump capacity for sedimentation , between 0.6 m^3 and 1.7m^3
- Installation of a dip plate to hold back any floating matter
- Disconnection of inflow and outflow drainage pipe to promote filtration
- Inspection chamber at either end of the system for maintenance access
- Use of rodding eyes for improved access to flush out of debris
- Maximise inflow capacity, i.e. distributor pipes, etc.
- Maximise the elevation of overflows to maximize available storage volume and to promote filtration.

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