An Assessment of Drainage Best Management Practices in Scotland

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Abstract

The study was carried out to establish the extent to which source-control systems are being used in Scotland. An investigation into the level of knowledge of such systems was also initiated. Over 100 questionnaires were sent to organizations which have been involved in the development of surface-water drainage schemes, and the 43 responses were analysed.

Further work was then undertaken to establish the locations of source-control systems in use. The collated information was utilized and, with the help of the Scottish Environment Protection Agency consent files and correspondence with consultants, a database indicating the locations of sites, was compiled. Information was collected on approximately 79 examples of such systems, currently in use or proposed, in Eastern Scotland.

Key words: **Best management practice; flood control; pollution prevention; questionnaire; Scotland.**

Background to Source Control in UK

Best management practices (BMPs) are a means of protecting the aquatic environment from pollution; this is achieved either by adopting 'clean' procedures or by providing structures to prevent or treat pollution[1]. The term BMP is widely used in the international scientific and engineering literature and can be defined as 'suites of measures and practices for which there are specific design criteria and published performance statistics', e.g. the United States Environmental Protection Agency (USEPA) guidance document[2]. Structures which are designed to intercept pollutants in surface runoff at source, and permit degradation or deposition prior to discharge to a watercourse, are relatively unknown in the UK. Systems to control urban runoff at source include infiltration systems, porous pavements, grass swales (shallow grassed ditches with mild side-slopes), retention ponds, and wetlands[2,3].

Source-control BMPs are passive systems which intercept pollutants at source and dispose of incident rainfall close to the point of precipitation. They include French drains, grass swales, porous surfaces and some sub-soil soakaways. End-of-pipe soft engineering structures (such as ponds and wetlands) are passive-treatment BMPs which offer the potential for multiple benefits as local amenity sites and urban biodiversity habitats[4].

Storm-water source control has been advocated in the UK via the Coventry University Standing Conference on Source Control, which has been a principal forum for the discussion of the subject[5]. The potential for using source control has also been explored through a series of reports for the UK construction industry[6]. Interest in the UK has traditionally been due to flooding concerns, although the polluting nature of urban runoff has long been recognized[7,8]. The quality of water in a number of catchments in the area of the Forth River Purification Board has led to efforts to promote the use of BMPs using a programme of presentations to all local authorities in the Board's area and the publication of a readily accessible guide to BMPs[9,10,11].

Following the implementation of the Environment Act in 1995, both the Scottish Environment Protection Agency (SEPA) and the Environment Agency (EA) have the duty to contribute towards achieving sustainable development[12]. Efforts to promote source control and soft-engineering surface-drainage systems received a major boost with the launch, in June 1996, of a diffuse-pollution video[13]. This was a partnership project involving SEPA, EA, Coventry University, North West Water, and the Scientific Committee on Phosphates in Europe (SCOPE) under the auspices of the International Association of Water Quality (IAWQ). The video has increased the awareness of the problem of urban pollution, and the guide has been reprinted as a joint publication with the EA, providing the support for a UK movement towards the use of BMPs.

Water-Quality Issues

In 1996, a review of the causes of poor-quality waters in the Forth catchment revealed that about 41 km of Class 3–4 rivers were adversely affected by urban runoff. For freshwaters in the catchment, this was equivalent to 25% of the total of Class 3–4 waters. Many modern industrial estates and business parks are not designed with pollution prevention in mind. Yard areas are invariably drained by surface-water sewers, and contamination by oil, grit, detergents and chemicals can be carried into watercourses when the rain scours impermeable yard surfaces[8].

Urban runoff from non-industrial areas can also be polluting. The Forth River Purification Board study[8] found that the most vulnerable watercourses were small urban streams. These were often free from conventional industrial or municipal effluent discharges, but received surface runoff from modern industrial estates, commercial areas, housing developments and roads (Table 1). It

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is also now accepted that pollutants which are transported in highway runoff can result in measurable quantities of contaminants being washed into watercourses[14,15]. In 1991, it was estimated that there were 24.5 million vehicles in the UK. By the year 2010, the Department of Transport estimates that this figure will have increased to 40 million[14].

Table 1. Sources of surface-water contamination in urban areas

Construction sites (sediment, oil)	Dog faeces
Sewage (wrong connections of foul drains, or overflows into surface-water drains from blocked foul drains)	Pesticides (municipal spraying of kerbs and gullies and herbicides used around gardens)
Road runoff (grit, hydrocarbons, trace metals)	Disinfectants (e.g. washing dustbins at kerbside)
Car washing (detergents, hydrocarbons, trace metals)	Wastes (careless disposal of engine oil, paint thinners, litter etc.)
Air pollution (deposition of particulates, hydrocarbons, NO_x and SO_x)	

In a more widescale EPA Report to Congress in the USA, urban runoff was found to be the fourth most extensive cause of the impairment of water quality of US rivers and the third most extensive source of water-quality impairment in lakes[16].

Questionnaire

The University of Abertay questionnaire was devised in response to the lack of understanding, locally, of the solutions needed to contain (and eventually improve) the causes of water-quality degradation. The main target of the questionnaire was to be those dealing with the detail of BMP techniques. A total of 119 questionnaires were sent out to a wide range of engineers, environmental consultants, local councils, water authorities and planners, with 43 being returned. The largest number of questionnaires (75) was sent to consultants, the remainder being split equally between water undertakers and councils. Fig. 1 shows that the responses were dominated by consultants – as would be expected from the issue destinations.

General Analysis of Responses

There is obviously a high level of awareness of water-quality issues, because 98% of those who answered the questionnaire thought that surface water could be polluting. In contrast, the motivation to rectify water pollution using source control was less apparent. Just under half of the 43 individuals had actually been involved in an urban development which required runoff to be controlled, while pollution prevention was the primary concern of 44%. In contrast, the use of runoff for amenity was not popular, with only 12% reflecting the belief that runoff control has amenity objectives.

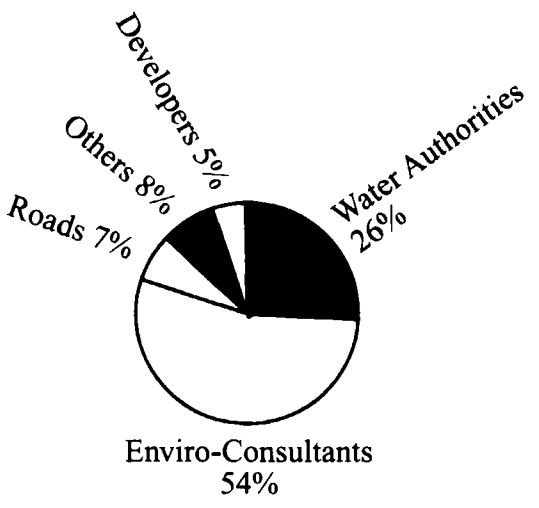

Fig. 1. Replies to questionnaire

It was found useful to test awareness by linking questions using the statistical package MINITAB. For example, when asked what is meant by the two different terms, 'source control' and 'BMP', 27% knew about source control but not about BMPs, while only about 2% knew of BMPs but not of source control – probably indicating selective education on the subject.

The multi-purpose functions of storm-water ponds are relatively widely understood; 72% of respondees knew that storm-water ponds can be used for flood and pollution control but only 18% thought that they could be used for flood control (their traditional use) and not for pollution control.

In Scotland (as in the rest of the UK), little guidance on BMPs is available because their use is a relatively new concept and there is minimal local evidence available to state whether they are effective. It became apparent that developers would rather use traditional approaches to drainage which are trusted, rather than using structures for which they have no experience. Only 2% replied that guidance on the effectiveness of source-control systems was adequate and only 5% believed that adequate guidance on adoption is available. The lack of general understanding of the operation of such systems could mean that structures are being built which do not operate effectively and do not have a high life expectancy. It is easy to conclude that guidance on the matter should be more readily available. At a first glance, this lack of guidance appears to be the cause of any lack of acceptability of such systems. Generally, the level of perceived knowledge on the subject was high, with 72%, 74% and 79% claiming that they know about swales, infiltration systems and storm-water wetlands, respectively. The lowest level of understanding concerned knowledge of infiltration systems when linked together with the term BMP. As earlier, linking answers appeared to reveal better the true level of understanding. Only 48% knew of both infiltration systems and BMPs, while 19% knew of neither – suggesting that the terms may be known, but not the concepts of their operation. Some knew of one and not the other – 23% knowing of infiltration systems but not about BMPs. This lack of knowledge could be due to a number of reasons, the most important of which is education and guidance – leading to their general lack of

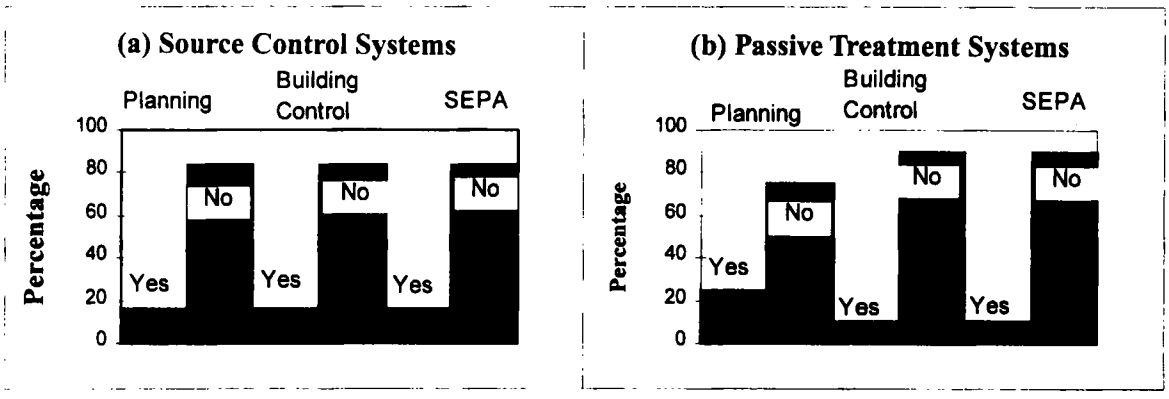

Fig. 2. 'Have you experienced problems in getting systems approved by the following agencies?'

use for urban developments. There might also be a general distrust of the concepts of BMPs, which naturally would deter the promotion and use of such systems.

Environmental regulations do not seem to hinder the use of source control and BMP systems; 90% of relevant respondees had not experienced problems in obtaining approval for passive-treatment systems or source control systems from the river boards/SEPA. Similar responses were registered for planning and building control, as shown in Fig. 2(a).

It is clear that SEPA (the regulator in Scotland) is actively encouraging the use of such systems rather than preventing their use. Planning authorities do not seem to hinder the use of source-control systems; 84% of those involved in the development of such structures, reported no problems in obtaining planning approval for source-control systems (Fig. 2(a)). It is also evident that building-control regulations are not a problem, with 94% replying that they have had no problems in obtaining approval for passive-treatment systems (Fig. 2(b)).

The perceived deterrents to the use of BMPs are illustrated in Fig. 3. Maintenance of systems was found to be the most important issue and is considered in more detail later. However, the cost (or rather the fear of cost) of BMPs appears to deter their use to a significant extent. Although this fear may not be justified, 17% replied that the cost would be a deterrent against the use of such systems.

The factors shown in Fig. 3(a) were analysed in more detail in order to establish if developers' perception of source control changed once they had gained experience in using such systems. The results of this analysis are shown in Figs. 3(b) and 3(c), which illustrate that maintenance of these systems was the main deterrent to their use. Many developers do not want the responsibility and perceived 'financial burden' of maintaining such

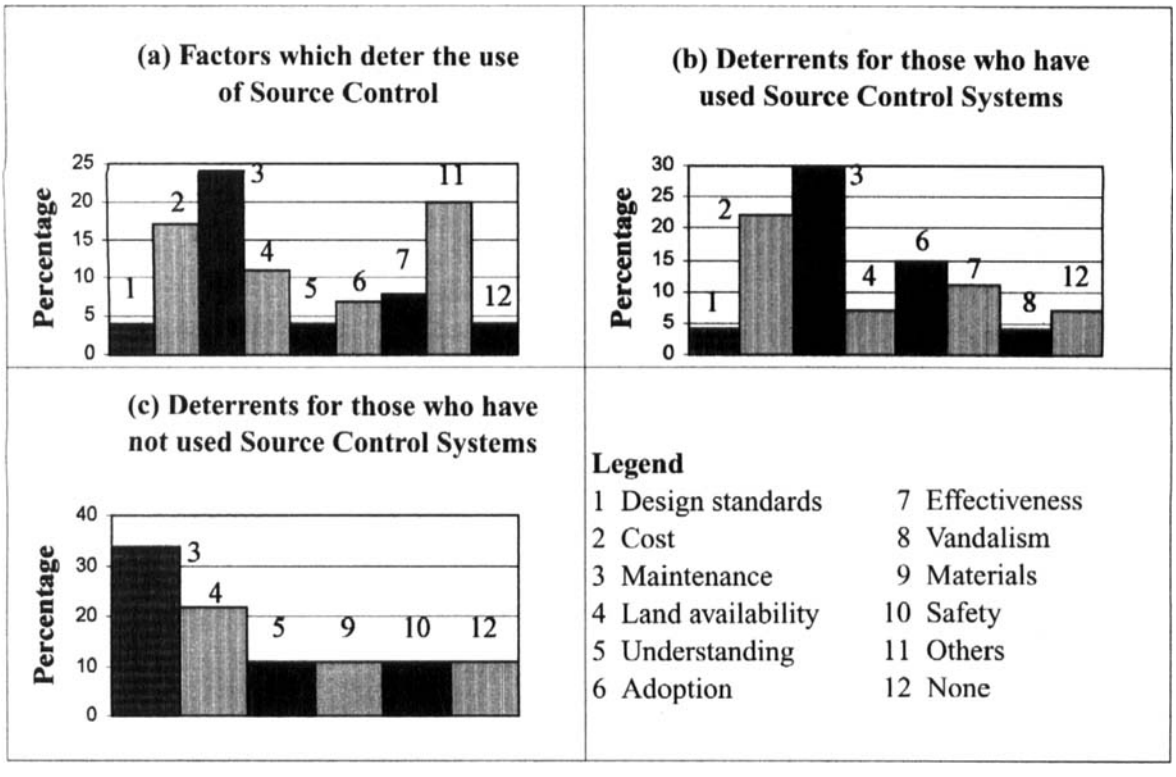

Fig. 3. Perceived deterrents against use of source control

structures. The amount of land which is needed to accommodate source-control structures was also seen as being a principal deterrent, although mainly to those who had not used them. Over 24% of the suggestions from the questionnaire, on the factors which deter the use of source-control systems, replied that maintenance was a deterrent. Urbonas and Stahre[17] have given the simple advice to developers: 'If you do not plan to maintain it, do not build it'. At present, systems are maintained by a variety of organizations which can have conflicting interests, and it is frequently not clear who should be responsible for maintenance. Of the sites identified by the questionnaire, 43% were maintained privately, 23% were maintained by local councils and 34% by water authorities.

Types of System Installed

Following the results of the questionnaire, discussions were held with most individuals and organizations who had been involved in source-control measures. The objective of this phase of the study was to gather more details on their operation than could be conveyed in the somewhat simplistic questionnaire. Additionally, all consents to discharge were examined, and the designers of the systems were contacted. As a result, 79 source-control systems were planned or built in Eastern Scotland. The most popular types of system were infiltration trenches and ponds. Swales, wetlands and porous paving were not found to be popular options, and infiltration basins were the least popular type. This appears to be due to the higher maintenance costs of basins in comparison to detention ponds and other infiltration devices[14] and could also be related to the prevalence of low-porosity soils in Scotland. The types of system, and their occurrence, are shown in Table 2.

Although 79 examples were identified, most had been designed in the absence of detailed knowledge of BMP systems, e.g. a swale should be designed to have gently sloping side-slopes of about 3:1 and should be densely planted with grass[3]. Most so-called 'swales' found in Eastern Scotland are steep-sided ditches, permitting the growth of very little vegetation – leading to erosion and sediment being deposited downstream.

The designs of a number of the ponds were also investigated and many had questionable detention times. The latter should have been in days, rather than hours, to provide sufficient biological treatment. The depth of ponds is also of importance, because they should be limited to 1.5–3.0 m, to minimize the potential for thermal stratification[18]. Very little marginal vegetation was found to have been planted around pond shores. Marginal vegetation is not only needed for safety purposes (to act as a barrier to children), but it is also widely recognized that it can enhance pollutant removal[14]. Safety should also be considered when the margins of a pond are designed. Schueler and Helfrich[19] suggest that side slopes leading to a permanent pool should not be steeper than 3:1.

In some cases the whole layout of the site (rather than just the drainage structure) was found to be problematical, e.g. a 'swale' was described to be draining a car park, but after investigation it was found that the swale was unable to convey the runoff, due to kerb-stones being laid on the periphery, thus preventing the water from draining into the BMP structure. In other cases the system could be inappropriate for the site conditions, because certain BMPs were designed to work effectively only in specific environments. A typical example would be infiltration systems which should be designed to drain completely within 3 days after a storm[20] and are therefore inappropriate for use in areas with low infiltration rates.

BMPs and the Public

Twenty-eight of the BMPs found were in residential areas. Of these, a large percentage was found to be infiltration trenches, which are popular in housing developments because they do not require large quantities of land and are relatively safe for the public in comparison with ponds. Wetlands were not popular for use in residential areas – only three being found. One example in the new town of Livingston, which is situated close to a housing estate, receives runoff from an industrial site. The wetland vegetation is constantly having to be replaced due to vandalism – leading to increased maintenance costs.

Only 17% of the systems in use in residential areas were ponds. Ponds are perceived to be a danger to children, and this has frequently deterred their use. In the past, the loss of large areas of land which could have been developed has also deterred developers from using ponds. In contrast, the construction of a pond in Cumbernauld has been found to be a valuable resource in the local area. The pond was originally developed to control the rate of runoff due to progressive urbanization of the new town of Cumbernauld and was designed so that the peak flow-rate did not exceed the runoff from the undeveloped catchment. The water body was also designed to be suitable for a number of recreational uses.

Table 2. Types of development where BMPs have been used

	BMP option						
Development	Infiltration trenches*	Ponds	French drains	Swales	Wetlands	Infiltration basins	Porous surfaces
Leisure	3	4	2	3	1	—	3
Industrial	5	10	6	4	4	1	1
Housing	11	5	3	4	3	1	1
Roads	1	1	—	1	1	—	—

*Includes soakaways

In addition to the amenity value of the site, the facility has also proved to be an attraction to house-buyers, and homes overlooking the pond are considered to be on a premium site, with their prices reflecting that position.

BMPs and Commercial Developments

Sixteen examples of BMPs being used to drain a variety of leisure developments were identified with ponds serving about 25% of these. Porous surfaces were also found to be incorporated into several leisure developments' construction plans. Thirty-one BMPs were found to be in use at other commercial sites (such as industrial estates and business parks) as well as in other developments; ten of these developments were found to be drained by ponds. Only five infiltration trenches were discovered on industrial sites, which might be due to the fact that trenches are generally only suitable for smaller sites, with reduced volumes of runoff coupled with a greater danger of groundwater contamination from industrial areas.

Porous blocks have not been extensively used in Eastern Scotland, but one car park in Edinburgh incorporates such a system. Adequate maintenance is of primary importance at this site, in order to ensure the continued efficiency of the surface. From previous experience, it has been found in the USA that quarterly vacuum sweeping and/or jet-hosing of porous surfaces is required to maintain porosity[3]. In the UK, concern has ben expressed over problems with such surfaces during freezing conditions; however, this has not been found to be a problem at this site. Air, contained between the blocks, acts as a heat store – leading to any snow and frost thawing significantly more rapidly than on surrounding conventional surfaces.

Conclusions

1. This study has shown that there are no effective guidelines in the UK on the adoption, maintenance and effectiveness of source control and BMP systems. Many of the respondees knew of the structures involved, but most of this knowledge is superficial.
2. Although there are guidelines for the design of BMPs, many developers either do not know of these or choose to ignore them. Adequate design is essential for the effectiveness of BMP systems; however, many of the structures which were investigated in this study were not designed conventionally and may prove to be ineffective.
3. The main deterrent to the use of source-control systems was found to be the question of who should maintain them. The results indicated that both the water authorities and roads departments are reluctant to undertake the responsibility of the maintenance.
4. The advantages of source-control systems are generally not immediately apparent to drainage engineers; however, once they have had the opportunity to view 'tried and tested' systems, attitudes might change. The Dunfermline Eastern Expansion will be the largest BMP site in the UK once it has been completed; if the site facilities are effective, this could be the major turning point for changing perceptions of BMPs.

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