



**ENVIRONMENT
AGENCY**



protecting the quality
of our environment

**A Guide to
Sustainable
Urban Drainage**

Environment Agency
Information Centre
Head Office

Class No ..EA - Water Quality Box 2

Accession No. A788.....

ENVIRONMENT AGENCY



128013

SECTION	PAGE
Introduction	2
The Quality of Surface Water Runoff	3
Best Management Practices for Draining Urban Areas.....	5
Source Control Techniques.....	6
Infiltration Systems	7
Swales.....	8
Source Control Techniques.....	9
Porous Pavements.....	9
Infiltration Trenches.....	10
Infiltration Basins.....	11
Permeable Conveyance Systems.....	12
Filter (or French) Drains	12
Swales	13
Passive Treatment Systems.....	14
Filter Strips	14
Detention Ponds	15
Dry Ponds	15
Wet Ponds	15
Stormwater Wetlands.....	15
Choosing the Best Option.....	16
Objectives	16
Stormwater Ponds and Wetlands.....	17
BMPs as Amenities.....	18
Choosing the Best Option.....	19
Feasibility.....	20
Catchment Area Constraints.....	21
Soil Type	21
Soil Type Constraints.....	22
The Legal Basis for Controls.....	23
References.....	24
Bibliography.....	24
Contacts	25

A survey of the causes of poor river water quality in Scotland in 1995⁽¹⁾ found 20% of the poor quality waters resulted from runoff from urban areas. The causes included drainage from roads, industrial and residential areas.

The rain falling on these areas is normally drained to watercourses via surface water outfalls. These discharges are often thought of as being clean but in fact contain a wide range of contaminants including oil, organic matter and toxic metals. Mis-connections of foul sewage into surface water drains is also endemic.

The discharge of such pollutants occurs throughout every urban area. The discharges are so dispersed and outfalls so numerous that they can not be controlled successfully using numeric consents based on the dilution available in a receiving watercourse. Indeed, where that approach has been extended to surface water outfalls, it has indicated dilutions so large that the discharge of untreated surface water is only possible to the largest of rivers⁽²⁾.

The environmental impact can, however, be minimised through good design and practice. This report aims to raise awareness of the pollution problems arising from surface water outfalls and to present some of the design options which have been found to be effective in reducing them. It is the start of the process of delivering sustainable urban development.

The protection of rivers and groundwater from the effects of these pollutants requires changes to the design of drainage systems and/or the provision of

treatment facilities prior to discharge. The range of structures illustrated in this report are described as Best Management Practice techniques. They represent a flexible series of options which allow a designer to select those that best suit the circumstances of a particular site. This report gives an overview of the main techniques and indicates where further information can be obtained.

The structural techniques described are highly effective at reducing the impact of surface water discharges. It is important to promote their design and construction within a framework defined by a code of Best Management Practice. The code can be applied during the planning process and by means of descriptive discharge consents or conditional Prohibition Notices.

A Best Management Practice approach is already used to good effect in other fields of pollution control such as the Codes of Good Agricultural Practice⁽³⁾, the Fluid Fertilisers Code of Practice⁽⁴⁾ and the Forests and Water Guidelines⁽⁵⁾.

There is no necessity for the drainage from urban developments to damage the freshwater resources of this country. However, to protect the environment, the Scottish Environment Protection Agency (SEPA) and the Environment Agency need the support and co-operation of a wide range of public and private organisations involved in urban development - ranging from the planning and roads authorities to private housing developers. By working together, it will be possible to ensure that drainage from roads and urban areas is designed in a cost effective and sustainable manner.

The polluting nature of urban storm runoff has been well studied, with numerous reports detailing the cocktail of contaminants present^(2,6).

A report produced by the Forth River Purification Board⁽⁷⁾, based on the results from routine discharge sampling, demonstrated the degree of contamination found in surface water drainage from urban areas. The mean concentration of suspended solids was found to be as high as 157mg/l in outfalls serving residential areas, and 225mg/l in those serving industrial areas. Corresponding figures for Biochemical Oxygen Demand (BOD) were 6mg/l and 31mg/l. For comparison, maximum values for treated sewage are frequently 30mg/l for suspended solids and 20mg/l for BOD; often tighter limits are imposed.

Higher levels of contaminants in surface drainage will occur during storm events. Peak values during storm events have been measured from a residential surface water outfall at over 7500mg/l suspended solids. Other contaminants such as oil and toxic metals, are also associated with suspended solids.

Surface water outfalls may also be contaminated with sewage, usually through wrong connections in the drainage network. Outfalls discharging nominally clean surface water have been found in places with faecal coliforms in excess of 500,000/100ml, only a 1:1 dilution of untreated sewage.

A survey of the impact of surface water outfalls elsewhere in the UK showed similar results, summarised in table 1.

Why should surface water discharges be so contaminated? There are four main sources:

- The surfaces drained are not clean. Roads, drives, industrial yards are all contaminated with oil, rubber and other materials from cars and lorries, as well as spillages of goods and chemicals, mud, refuse and organic matter.
- Connection of foul drainage, by accident or ignorance, to the surface water drain. Wrongly plumbed toilets, washing machines and dishwashers are endemic in separately drained systems where the householder has no idea which drain is which or even that two drains exist.
- Similarly, ignorance of the destination of drains can lead to oil and chemicals being poured down the nearest drain. Frequently this is the surface water drain and this inadvertent pollution can occur in residential as well as industrial areas.
- Spillages, particularly of oil, will be flushed into the surface water drainage system and then to watercourses. Oil becomes entrained in stream sediments and is particularly toxic: it therefore has a long term and severe impact on aquatic life.

Most of these sources of pollution are unavoidable in any surface water drainage system and any surface water outfall is, therefore, likely to discharge polluted water. It is not a practical proposition to provide treatment of surface water at each outfall, so, if the quality of these discharges is to be improved the design of the drainage system must be modified. The Best Management Practice techniques aim to do this, in a way which minimises the quantity and improves the quality of the surface water before discharge.

Table 1. Pollutant Concentrations In Urban Sewers (Hall and Ellis^(B))

Sewer Type	Mean pollutant concentrations (mg/l)						
	Solids	BOD	COD	NH ₄	Pb	PAH (ng/l)	E Coli
Separate system sewer	21-582	7-22	33-265	0.2-4.6	0.03-3.1	29-200	10 ² -10 ⁴
Combined system sewer	237-635	43-95	120-560	2.9-4.8	0.15-2.9	12-215	10 ⁴ -10 ⁶
Highway runoff	28-1,178	12-32	128-171	0.02-2.1	0.15-2.9	365-60,000	10-10 ³
Roof runoff	12.3-216	2.8-8.1	57.9-80.6	0.4-3.8	0.001-0.03	na	10 ²
Gully pot liquors	15-840	6.8-241	25-109	0.7-1.39	0.06-0.85	na	10-10 ²
Residential areas	112-1,104	7-56	37-120	0.3-3.3	0.09-0.44	na	10-10 ³
Commercial areas	230-1,894	5-17	74-160	0.03-5.1	0.1-0.4	na	10 ² -10 ⁴
Light industrial areas	45-375	8-12	40-70	0.2-1.1	0.6-1.2	na	10

Notes: BOD, COD = indication of oxygen required for degradation of pollutant
 NH₄ = ammonia, a serious toxic pollutant
 Pb = lead concentration, a non-degradable toxic pollutant
 PAH = Poly Aromatic Hydrocarbons, a range of other toxic chemicals
 E Coli = bacteria whose presence can indicate sewage pollution

The poor quality of water discharging from surface water outfalls can seriously affect the receiving watercourse. Techniques to reduce the impact of these discharges have been developed and collectively form a range of Best Management Practices (BMPs) for dealing with urban runoff.

These techniques deal with the problem in a variety of ways, and the designer or engineer is free to choose the best option(s) for draining any particular area. They fall into three broad groups which aim to:

- Reduce the quantity of runoff collected (source control techniques);
- Slow the velocity of runoff to allow settlement filtering and infiltration via a permeable conveyance system;
- Provide passive treatment to collected surface water before discharge to a watercourse (end of pipe systems).

It is not usually necessary or desirable to use designs from all three groups to solve a particular drainage problem. Conversely, several techniques fall into more than one group and, for instance reduce the quantity of water collected whilst slowing its runoff and providing some treatment.

In designing a drainage system it is beneficial to work through the options in the order presented above.

1. The scope for minimising the quantity of water collected should be considered first, since this determines the sizing of downstream systems and can provide the greatest savings.
2. Collected runoff should be removed from the site in a way which reduces the level of pollution and allows further infiltration and volume loss.
3. Finally, and only if necessary, passive treatment can be installed to improve water quality before final discharge to a watercourse.

The following pages describe in more detail examples of Best Management Practices for dealing with surface water drainage.

These systems, as the name suggests, are designed to deal with the problem as close to the source as possible and to minimise the quantity of water collected. The amount of polluting matter collected and flushed into a watercourse is also reduced, thus further increasing the water quality benefit.

Source control can avoid the necessity of laying surface water sewers. This reduces the potential for foul drainage connections to surface water systems which can lead to the discharge of sewage effluent and debris into watercourses. Where runoff is conveyed via surface channels, wrong connections become obvious to the occupier and can be fixed without the need for the expensive surveys required in traditional piped systems.

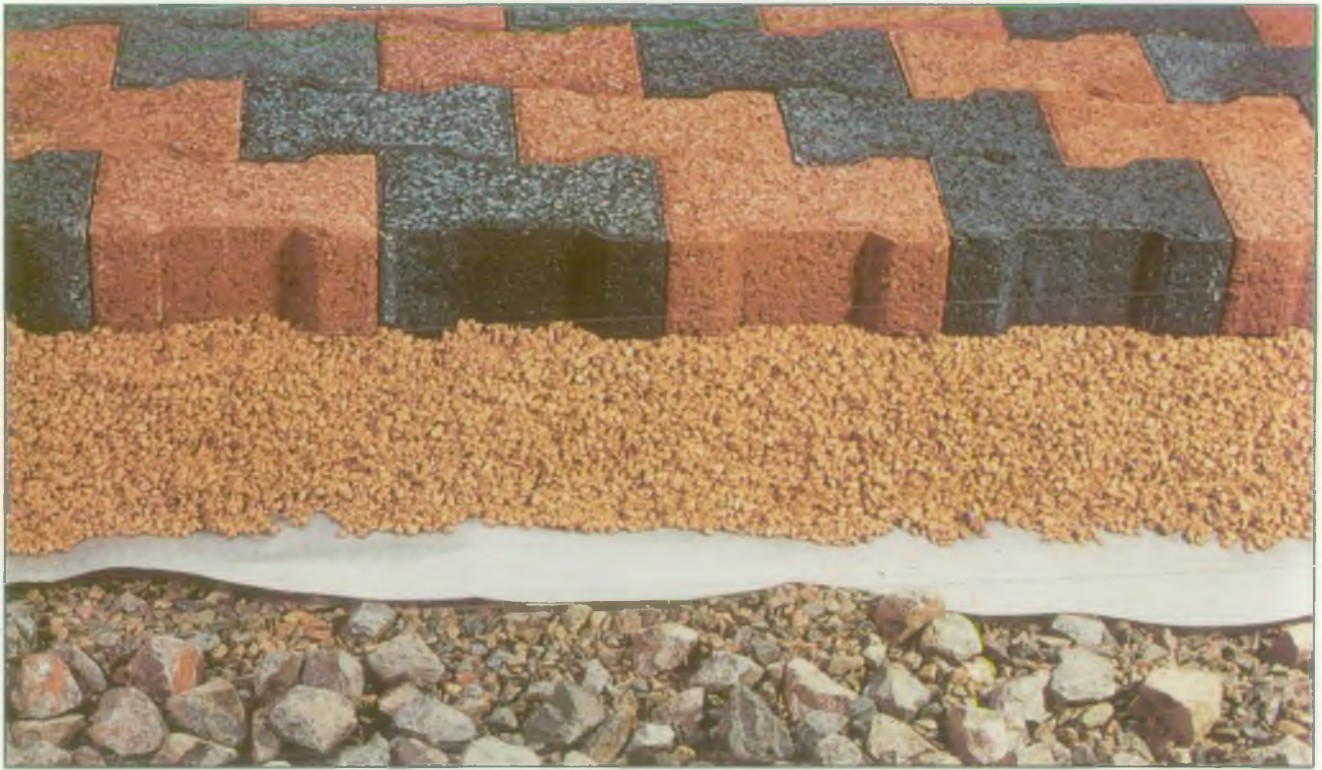
A first step is to determine the minimum area which will require positive drainage. Some areas in a development can be allowed to drain naturally or be led off into nearby areas where the water will soak away.

In those areas which require positive drainage, porous materials can reduce the need to collect runoff from driveways and car parking areas. Materials such as gravel, grasscrete, porous (no fines) concrete blocks and porous asphalt allow water to pass through into the sub-grade.

Water from roofs can be fed into soakaways and infiltration trenches where ground conditions permit. These systems work best when dealing with small quantities of water, and are intended to be distributed throughout a catchment and constructed at the point where runoff is derived. The need for an extensive drainage network can, therefore, be reduced or even avoided.

Source control techniques divert runoff into the ground and therefore can remove the need to discharge surface water into watercourses. They need not be designed to receive very large storms. A system which is designed to accept a twice per year storm without overflow or bypassing will still achieve a useful amount of water quality improvement. It will greatly reduce the frequency of discharge, provide protection from the highly polluting 'first flush' and delay the time of discharge, allowing time for the flow in the receiving watercourse to increase.

Larger source control systems also form a useful function in reducing the volume of flood runoff and help to maintain flows in surface watercourses during dry weather. With good source control design a development can be designed to have a zero impact on the hydrology of a catchment.



UK manufactured porous blocks, being laid on a bed of ground and crushed stone. Porous surfaces are particularly appropriate for lightly contaminated runoff, close to source. The underlying materials provide a useful storage volume for peak storm events, for new or existing developments.



Problems on existing combined sewer systems serving residential areas can also be helped by diverting roof water onto private lawns (opposite).

This example, from Malmo in South Sweden is on a clay soil; the organic content of the topsoil has capacity to absorb the roof water, with only slow release to surface and ground water.



Swales typically utilise the conventional green space of roadside margins. Grass swales filter suspended pollutants, which are deposited in the swale and incorporated into the substrate. The shallow, relatively wide, swale (as compared to a conventional ditch) provides temporary storage for storm water and reduces peak flows discharged to receiving waters.

Swales are appropriate close to source and typically for a drainage network connecting into a pond or wetland, prior to discharge to a natural watercourse.

Swales avoid the need for expensive roadside kerbs and gullies and associated maintenance costs and provide guaranteed drainage of the road surface.



Porous Pavements

Porous pavement is an alternative to conventional paving where water is encouraged to permeate through the paved structure rather than drain off it. Both the surface and the sub-grade needs to be designed with this function in mind. The water can be allowed to infiltrate directly into the subsoil or be temporarily held in a reservoir structure under the paving until infiltration occurs. The porous paving can be materials such as gravel, grasscrete, porous (no fines) concrete blocks or porous asphalt.

Figure 1 shows an example design for a car parking area where a porous covering overlies a storage reservoir filled with graded stone. Rainwater passes through the pervious surface and is stored in the reservoir, which need only be around one metre deep. The stored water can then soak away slowly into the subsoil.

Overflows can be constructed on all these systems

where a surface must be kept free of water in all conditions. Even if the overflow operates, some storage and filtering of the runoff water will have occurred, and a water quality benefit accrues. The overflow can lead into a permeable conveyance system to further increase the benefit and reduce the need for pipe systems.

Pollutant removal rates have been shown to be high, with some pollutants being held within the pavement material where this is asphalt. With other materials the majority of the removal occurs as a result of the infiltration of the water and the subsequent absorption and filtering within the subsoil. Removal of up to 80% of sediment, 60% of phosphorus and 80% of nitrogen has been measured, as well as high removal rates for trace metals and organic matter.

Porous pavements need to be protected during installation from the excessive mud usually present on construction sites.

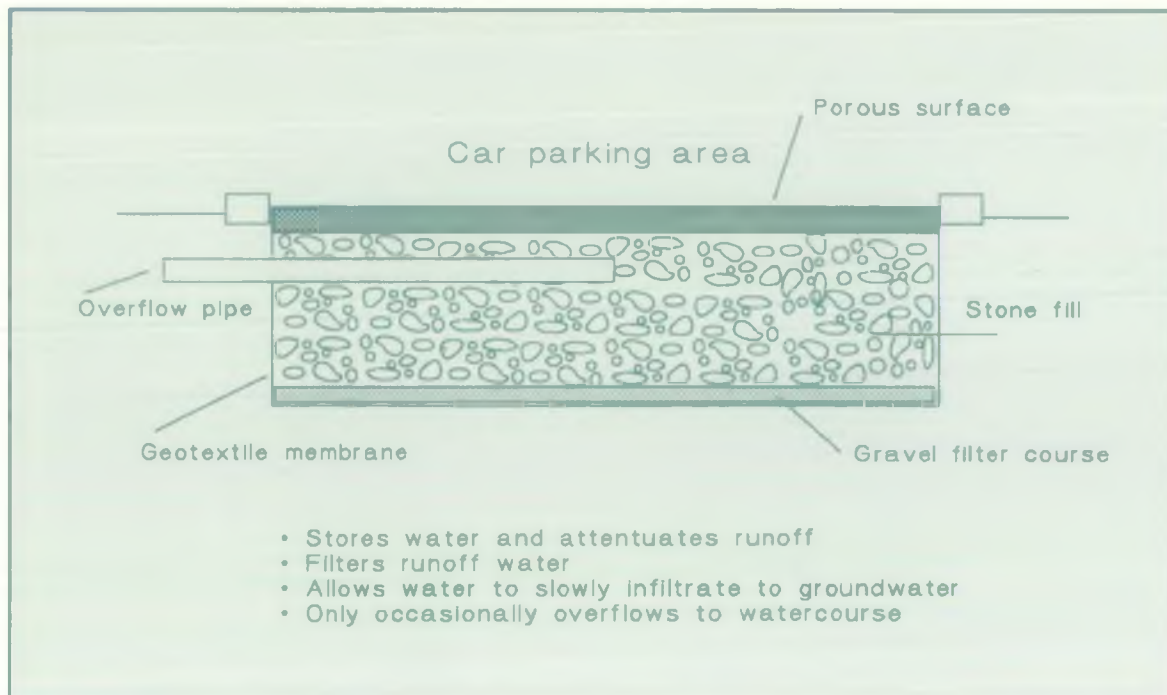


Fig. 1: Porous car park design

Infiltration Trenches

An infiltration trench is a shallow, excavated trench that has been backfilled with stone to create an underground reservoir. Stormwater runoff diverted into the trench gradually infiltrates into subsoil and eventually the water table. An emergency overflow may be provided for extreme rainfalls which exceed the capacity of the reservoir.

The performance of the trench depends largely on the permeability of the soil and the depth to the water table. Soil infiltration rates of better than 12.5 mm/hr are usually required. In common with other source control techniques, infiltration trenches usually serve small catchment areas, perhaps up to 2-3 hectares.

The longevity of the trench may be enhanced by providing pre-treatment for the inflow, such as a

filter strip, gully or sump pit, to remove excessive solids. Regular maintenance will be required for most pre-treatment designs. A design with these features is shown in figure 2.

Pollutant removal mechanisms include adsorption, filtering and microbial decomposition in the soil below the trench and trapping of particulate matter within pre-treatment areas. Properly constructed and maintained, infiltration trenches can be expected to remove in excess of 90% of solids, around 60% of phosphorus and nitrogen and 90% of coliforms, trace metals and organic matter. Removal rates for nitrate, chloride and soluble trace metals are likely to be lower.

Infiltration trenches should be provided with observation wells to allow their performance to be monitored. Design guidance for infiltration systems can be obtained from the Building Research Establishments⁽⁹⁾ and CIRIA⁽¹⁰⁾.

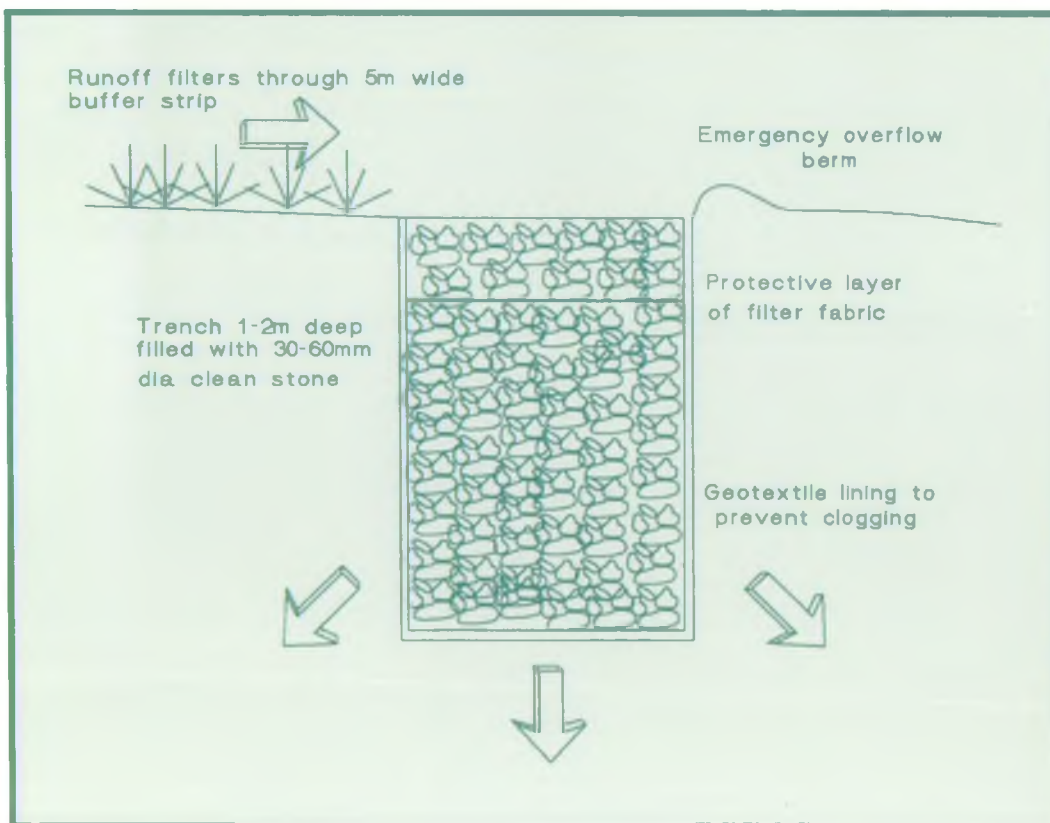


Fig. 2: An infiltration trench

Infiltration Basins

Infiltration basins are surface impoundments where stormwater runoff is stored until it gradually infiltrates through the soil of the basin floor (figure 3). An emergency overflow may be provided for extreme rainfalls which exceed the capacity of the reservoir.

The performance of the basin depends largely on the permeability of the soil and the depth to the water table. Soil infiltration rates of better than 12.5 mm/hr are usually required. Infiltration basins can serve larger catchment areas than infiltration trenches because a larger volume of water can be stored on the surface. They can probably serve catchments of up to 10 hectares.

As with the infiltration trench, the longevity of the infiltration basin may be enhanced by providing runoff pre-treatment, such as a filter strip, gully or sump pit to remove excessive solids. With larger basins these traps will require careful design to prevent scour of collected sediment during storms. Regular maintenance will be required for most pre-treatment designs.

Pollutant removal mechanisms include adsorption, filtering and microbial decomposition in the soil below the basin and trapping of particulate matter within pre-treatment areas. Properly constructed and maintained, infiltration basins can be expected to remove a large proportion of solids and a lower proportion of soluble pollutants.

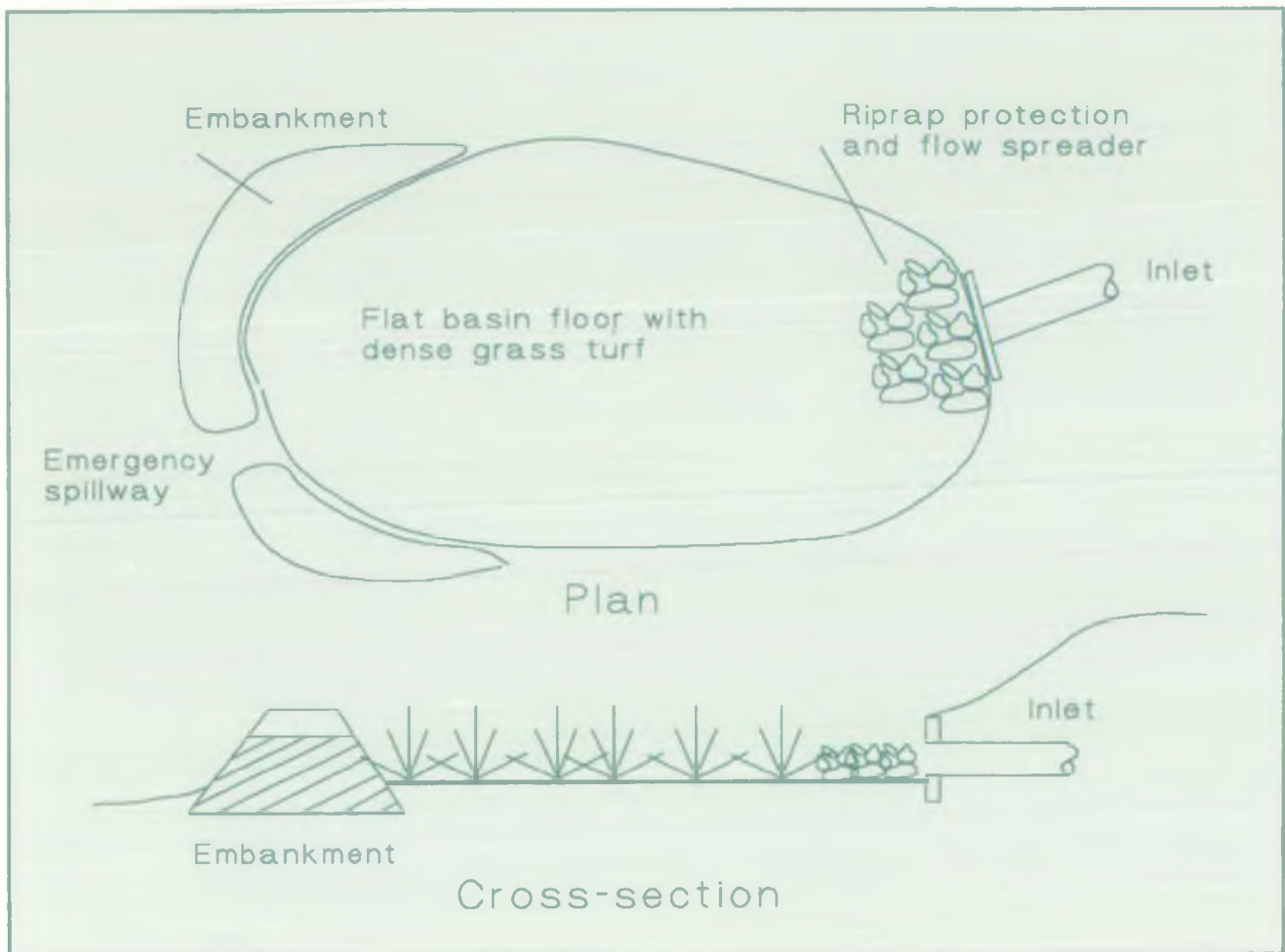


Fig 3: An infiltration basin

These move runoff water slowly towards a receiving watercourse, allowing storage, filtering and some loss of runoff water before the discharge point. There are two main types: underground systems, such as filter drains (or french drains) and surface water swales.

Filter (or French) Drains

The underground systems are known as filter (or french) drains. They comprise a trench, filled with gravel wrapped in a geotextile membrane into which runoff water is led, either directly from the drained surface or via a pipe system.

The gravel in the filter drain provides some filtering of the runoff, trapping organic matter and oil residues which can be broken down by bacterial

action through time. Runoff velocity is slowed, and storage of runoff is also provided. Infiltration of stored water through the membrane can also occur and some filter drains need not lead to a watercourse at all.

Filter drain systems are installed throughout Scotland by the highway authorities on rural roads, major urban roads, and trunk roads such as the proposed A1. This form of drainage is required by SEPA as the minimum level of mitigation for trunk road schemes.

The use of hybrid infiltration systems and filter drains have been used for a variety of developments, including both residential and industrial sites.

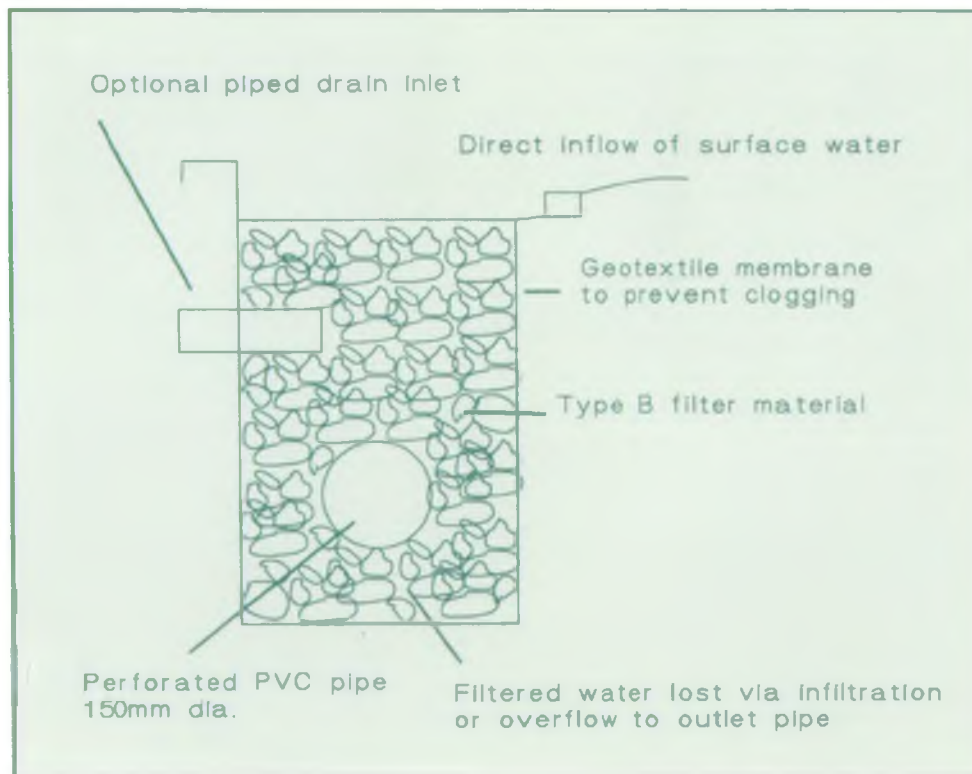


Fig. 4: Filter drain cross-section

Swales

Swales are simply grassed depressions which lead surface water overland from the drained surface to a storage or discharge system. The swale is dry during dry weather but water slowly moves through the grassed area during periods of runoff. The surface water is retarded and filtered by the grass and other vegetation. Sediment is removed and oil residues and organic matter retained in the top layer of soil and vegetation to be eventually broken down by bacteria.

The swales can form a network within a development scheme and be used to interlink storage ponds. During moderate rainfall a considerable proportion of the runoff can be lost from the swale by infiltration, and by evaporation and transpiration in summer. If necessary, overflows can be placed at high level to prevent flooding in times of exceptionally heavy rainfall. Swales should be designed to be dry between storms to enhance their pollutant removal capability.

Swales work best with small gradients both for their side slopes and longitudinally. Longitudinal

gradients greater than 6% should be avoided, as should runoff velocities in excess of 0.5m/s. Erosion of swales does not seem to be a problem where these guidelines have been observed and where grass can become well established.

Pollution removal is by mechanical filtering through vegetation, adsorption onto vegetation and soil and micro-biological breakdown of organic matter in the upper soil layers. Even if swales discharge directly to a watercourse a considerable reduction in pollutant load will have been achieved. It has been reported⁽¹¹⁾ that a swale length of only 30-60m can remove 60-70% of solids and 30-40% of metals, hydrocarbons and bacteria in surface runoff. Performance can be enhanced by placing check dams across the swale to reduce flow velocities.

Some regular maintenance is required to keep a grassed swale operating correctly, chiefly mowing during the growing season. The optimum grass length is around 150mm, so mowing need not be very frequent. Access for mechanised mowing equipment should be provided.

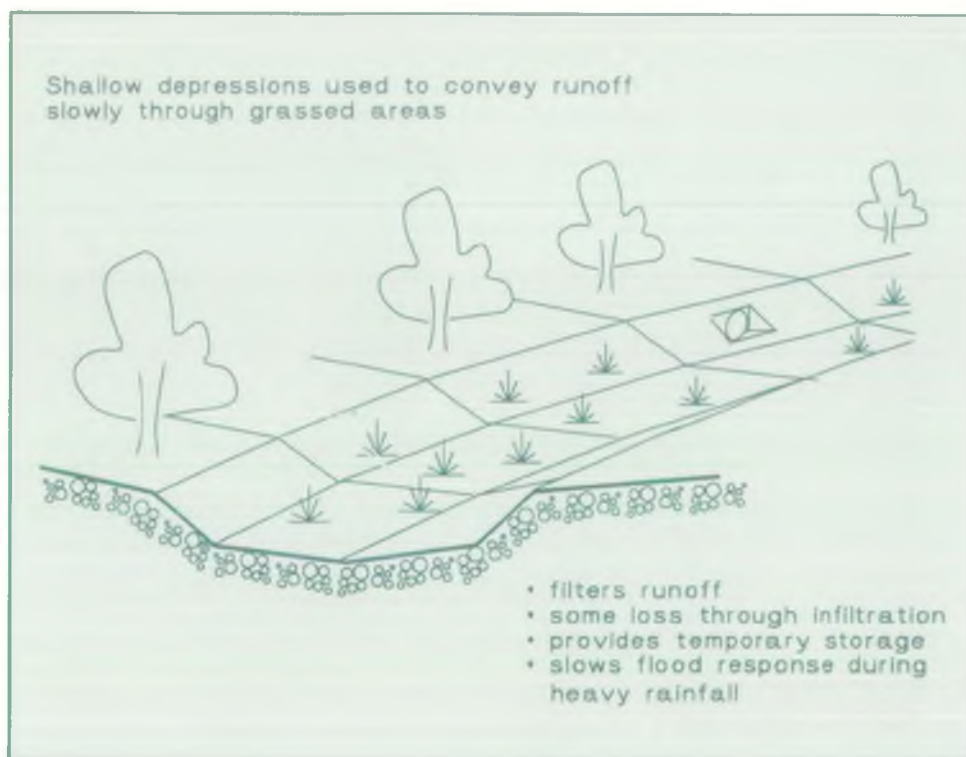


Fig 5: Grassed swale

Passive treatment systems use natural processes to remove pollutants from runoff water. Small scale systems such as filter strips, can be designed into a site's landscaping and are sited upstream of other BMPs, particularly source control methods. Larger, 'end of pipe' systems usually involve storage of water in a constructed lagoon where natural purification processes can be encouraged.

These systems are passive in the sense that no mechanical plant or regular input of chemicals is required to make them work. However, most will require some maintenance. This is normally restricted to landscaping or the periodic removal of silt from ponds.

Filter strips, consisting of small areas of grass or other vegetation, can be used to strain small quantities of runoff close to source.

On a larger scale the simplest treatment system is the clarification lake, which aims to improve water quality by storing it for a number of hours or several days. This allows settlement of the coarser sediment and some aeration.

Most of these systems were primarily installed for flow balancing and flood reduction purposes but a water quality improvement also results. In a study undertaken in the Forth catchment in Eastern Scotland, the outflow from Stenton Pond in Glenrothes, which treats two surface water discharges, was found to have the lowest contaminant concentrations of any surface water outfall system monitored.

Clarification lakes can be designed to be empty during dry weather or to retain a minimum level at all times. Water quality can be further improved by incorporating measures which are designed to specifically remove pollutants in a stormwater wetland. These usually incorporate vegetation which serves to aerate the water and provides a fine filtering effect. A wetland margin or an entire marshland system can enhance pollutant removal and reduce re-suspension of fine material.

Plants also help to avoid algal blooms appearing on the pond by shading the water surface in summer. In addition, a mat of vegetative material develops which provides a greatly increased surface area for the establishment of bacterial films which aid the breakdown of organic matter. An area of deeper

water will allow settlement of solids without clogging the vegetated areas.

Ponds which incorporate vegetation need to be wet all year and must be carefully designed. Guidance on design principles is available from the Scottish Environment Protection Agency and elsewhere⁽¹²⁾. Clarification lakes need not retain water when not in use and may also be designed to lose water by infiltration. However, the appearance of such ponds when dry needs to be considered, particularly if the dry period is limited and a layer of mud develops on the bottom.

Filter Strips

Filter strips are vegetated sections of land designed to accept runoff as overland sheet flow from an upstream development. They may adopt any natural vegetated form, from grassy meadow to small wood. The dense vegetative cover facilitates pollutant removal.

Filter strips are best employed at the upstream end of the drainage system, accepting runoff from small (up to around 2 hectares) areas directly, before it is concentrated in a drainage system. Road runoff can also be treated in this way, provided the road/filter strip boundary is designed so that it does not become blocked by sediment or vegetation.

Filter strips can be used effectively to remove excess solids before discharge to an infiltration system. They may also preserve the character of riparian zones and prevent erosion along stream banks by reducing flow velocities and spreading the flow across a wide area. Used in this way they also provide an excellent urban wildlife habitat.

Pollutant removal can be maximised by ensuring a minimum width of 15m and a cross slope of 5% or less. Wooded filter strips appear to work better than grassed ones: if grass is used it is most effective at a height of 150mm. The strip should not have an uneven terrain which would lead to the development of channels, which concentrate the flow and cause erosion.

Removal of pollutants depends heavily on the type and size of strip. Narrow grassed strips may remove only 25% of suspended sediments, wider and wooded ones over 80%.

Detention Ponds

Dry ponds

These are designed to temporarily detain storm runoff for a few hours to allow for the settlement of solids. Bypasses may be included to ensure the 'first flush' is detained. If dry ponds are designed to retain flood water, they will reduce peak flows and limit the risk of downstream flooding.

Careful design of the pond inlet and outlet will maximise the performance of the pond by preventing scour and short-circuiting.

Detention Ponds drain via an orifice or similar hydraulic structure into a surface water drainage system. The simplest designs are dry outside of storm periods. The need to drain down the entire contents of the pond, and therefore have a low level of outlet orifice, can lead to rapid clogging by collected sediment. The performance of dry detention ponds can be enhanced by including a small pool at the inlet and outlet, designed to act as a sump for collected sediment.

Solids removal is the chief feature of the dry pond, and removal rates in excess of 80% are possible. Nutrient and trace metals removal is more modest.

Pollutant removal can be maximised by allowing a minimum of 6-12 hours detention and seeking to treat a modest volume of runoff. It may be better to treat the 'first flush' of runoff from the catchment and by-pass the rest, rather than to scour out the silt collected by draining all flood water through the pond. Performance is further enhanced with the wet pond and wetland pond systems.

Wet Ponds

These retain a certain volume of water at all times. This can avoid possibly unsightly exposure of banks of collected sediment and enhance performance in removing nutrients, trace metals, coliforms and organic matter. Considerable variation in water level during storms can be incorporated in the design, so that a significant storage volume can still be provided.

The permanent water may be visually more attractive, although elevated nutrient concentrations may result in algal blooms. To be successful as an

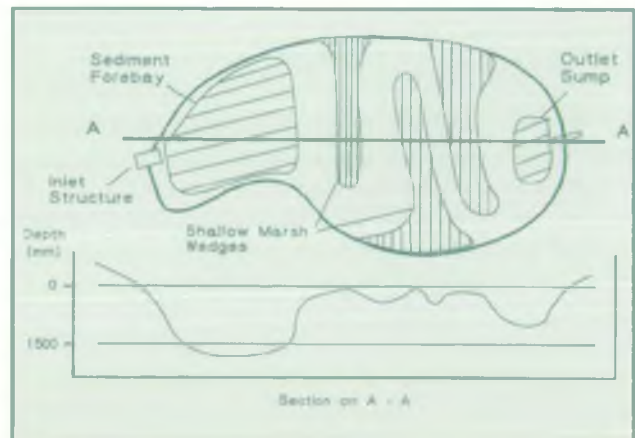


Fig.6: Schematic wetland for treatment of urban runoff

amenity, a wet pond should have a catchment of at least 5 hectares and/or a reliable source of baseflow. Inlet and outlet sumps will, as for dry ponds, enhance performance by trapping sediment and preventing clogging of the outlet. Removal of collected sediment from the inlet sump may be needed, although typically this is not required at a frequency greater than once every seven years.

Stormwater Wetlands

These are a further enhancement of wet ponds, and incorporate shallow areas planted with marsh or wetland vegetation. These provide a much greater degree of filtering and removal of nutrients by algae and, to a lesser extent, by incorporation into plant material. Inlet and outlet sumps, as with dry and wet ponds, will enhance performance and might be considered almost obligatory since excessive sediment can quickly overwhelm the shallow area. Figure 6 shows an example design which incorporates these features.

Only specially constructed stormwater wetlands should be used to treat surface water. It is not normally an acceptable practice to lead surface water into an existing, natural, wetland area.

Stormwater wetlands are no longer considered experimental technology. In many developed countries they have been proven to be effective and provide moderate to high levels of pollutant removal throughout the year. Design of constructed wetlands by specialist consultants will maximise their performance and longevity.

The various designs of Best Management Practice vary considerably in their suitability, maintenance and effectiveness at any particular site. If a BMP is to provide the expected benefit it must be chosen and designed to suit the site and application. It is therefore important to have a clear idea of the requirements at the design stage, so the objectives can be matched against a feasible BMP for a particular site.

The selection of a suitable BMP is likely to be an iterative process involving a wide range of considerations. Planning authorities will be interested in the amenity and safety considerations, whilst maintenance requirements will be relevant to the owner of the site. The Local Authorities in Scotland and the Environment Agency in England and Wales may require mitigation of the flood risk. The pollution risks to surface and groundwater will be assessed by the Environment Agencies who will be aware of what the most critical impacts are likely to be for a development. Early contact prior to the detailed planning stage is essential, indeed developers would be advised to contact the relevant environment agency prior to land purchase in order to assess land-take implications.

Objectives

The main emphasis in this guide is to use BMPs to reduce surface water pollution. The BMP designs vary in their ability to reduce the different types of pollution arising from developments and most BMPs will also provide other benefits. It is therefore important to establish what the objectives are before choosing a BMP.

The pollutants which are generated will depend on the type of development, whilst their impact will depend on the type and location of the watercourse. For instance, it may be of critical importance to protect a fish spawning stream from solids generated from a housing development. This may be less important in an urban river, whilst metals and oils might be of greatest concern in relation to a road drainage discharge. Similarly, nutrient removal might be the priority for a discharge to a lake or loch.

The quantity of pollutants generated will also be important. Source control BMPs enable a developer to reduce the overall quantity of runoff and hence the total load of contaminants. In small developments this alone may be sufficient.

The ability of BMPs to reduce pollution varies considerably and is summarised for a number of designs in table 2 (see page 19). In most cases it is not realistic to expect complete removal of pollutants, and consultation with the relevant environment agency is required to ascertain what would be an acceptable performance.



Ponds can be fed by a swale system (as above, serving an industrial estate), or a filter drain network or a conventional surface water system. The last option will result in much larger peak flows reaching the pond and consequently require a bigger area. A storm water pond will typically have 10-20 days retention time, to permit biological degradation of pollutants. For industrial sites, a pond provides a final opportunity to catch oils and chemicals from accidental spillages around the estate.

Highway junctions (as shown below) provide land between slip roads and the highway that can be utilised for water ponds or wetlands.





Storm water BMPs such as ponds and wetlands provide additional green areas within the urban environment, useful for urban recreation and pollution tolerant wildlife. They can provide a network of varied habitats threading through the urban environment.

BMPs can also be used to protect amenity sites such as this swale trapping sediment before a high amenity pond area (as shown below).



Table 2 - Pollutant Removal capacity

BMP design	Pollutant						
	Solids	P	N	BOD	Metals	Bacteria	Overall
Extended detention pond, 9hr detention						?	good
As above, 24hr detention						?	good
As above, with shallow marsh						?	high
Wet pond, small						?	good
Wet pond, large						?	high
Infiltration trench, infiltrates first flush							good
Infiltration trench, infiltrates all runoff							high
Infiltration basin, infiltrates first flush							good
Infiltration basin, infiltrates all runoff							high
Porous pavement, infiltrates first flush							good
Porous pavement, infiltrates all runoff							high
Filter strip, 6m wide grass						?	low
Filter strip, 30m wide trees						?	good
Grassed swale, low gradient						?	low

Key		0-20% removal	P	Phosphorus
		20-40% removal	N	Nitrogen
		40-60% removal	BOD	Biochemical Oxygen Demand
		60-80% removal		
		80-100% removal		
	?	insufficient knowledge		

Other Objectives

The use of Best Management Practices can bring other benefits which may form an important objective for the developer. Amelioration of flood discharges can be important on heavily urbanised rivers which are already subject to artificially high peak flows. Ponds, particularly extended detention ponds, can help reduce peak flows by storing runoff for gradual release after the flood peak has passed. Grass swales and filter strips can also help to reduce the speed of response to storm rainfall. Infiltration devices reduce the amount of water to be discharged and also help to maintain stream flow during dry weather.

With careful design, BMPs can also increase the amenity, and therefore the value, of a site.

Feasibility

Catchment Areas

Some BMPs require a considerable area draining to them to work effectively, whilst others are best suited to small catchments. Ponds normally require a significant catchment area, probably greater than 5 hectares, to ensure proper operation. The lower range of suitability for dry ponds is set by the minimum outlet size which will function effectively with little maintenance whilst wet ponds need a minimum inflow during dry weather to maintain water levels.

Source control measures, infiltration devices and swales are generally only suitable for smaller sites (less than 5 hectares) due to space requirements, flow velocities and the problems of dealing with larger volumes of water. Source control measures are designed to deal with runoff at source, and should have only relatively small areas draining to them. Larger developments will therefore need several devices, each dealing with a sub-catchment within the whole development.

It should be noted that the contributing area of a site does not always have to be fixed. Site area can be increased or decreased to better accommodate a particular device, either by incorporating runoff derived off-site, to make a pond viable for instance, or routing parts of the site to different devices where the amount of runoff generated is too great for any one source control method.

A guide to the likely suitability of a number of BMPs for a range of catchment sizes is given in table 3.

Table 3 - Catchment Area Constraints

BMP	Area served (hectare)					
	<2	2-4	4-7	7-9	9-15	>15
Dry extended detention pond	X	X	X	?	✓	✓
Wet extended detention pond	X	X	?	✓	✓	✓
Wet pond	X	X	?	✓	✓	✓
Infiltration trench	✓	?	X	X	X	X
Infiltration basin	?	✓	✓	?	X	X
Porous pavement	✓	?	?	X	X	X
Grassed swale	✓	?	X	X	X	X
Filter strip	✓	?	X	X	X	X
Key	✓ Feasible ? Marginal - needs careful design X Not feasible					

Soil Type

The permeability of the underlying soil has a major influence on the effectiveness of most BMPs. The most affected are those which depend on infiltration for their operation. These will generally not be effective if the soil infiltration rate is much below about 10mm/hr. In addition, there should be a reasonable depth of permeable soil below an infiltration device, to allow downward infiltration of water. A close proximity (within a metre) of bedrock, clay layers or the water table will reduce the effectiveness of infiltration devices.

Infiltration BMPs should be designed to drain completely within 2-3 days of heavy rainfall. If the

soil infiltration rate is marginal it will limit the area which can be drained.

Swales, which work by a combination of filtration and infiltration to achieve their benefit, are more tolerant of poor soil conditions, and can operate in clay soils. Wet ponds require low permeability soils to function correctly and necessitate the use of liners in highly permeable soils.

Table 4 overleaf shows the effect soil infiltration rate has on choice of BMP.

Table 4 - Soil Type Constraints

BMP	Soil Infiltration Rate (mm/hr)				
	200-12 (sandy)	12-7 (loam)	7-2 (silty)	2-1.5 (silt/clay)	1.5-0.5 (clay)
Extended detention pond	✓	✓	✓	✓	?
Wet pond	?	✓	✓	✓	✓
Infiltration trench	✓	?	✗	✗	✗
Infiltration basin	✓	?	✗	✗	✗
Porous pavement	✓	?	✗	✗	✗
Swale/filter strip	✓	✓	✓	?	?
<p>Key</p> <ul style="list-style-type: none"> ✓ Feasible ? Marginal - needs careful design ✗ Not feasible 					

The Town and Country Planning Act 1990 and its Scottish counterpart are the prime means by which local authorities define the strategic context for development in their areas and control individual proposals.

Strategic plans, which amongst other things, are concerned with the principles of land use and location of development, may include policies which express a presumption in favour of BMP based drainage for new developments. For example, West Lothian and Falkirk Councils in Scotland have both adopted policies in local plans which support the use of BMPs. Similarly, when specific proposals are considered, the location and layout of sites, and the position of any surface water treatment arrangements are subject to control via the planning process. Thus the planning process can have a major influence on the strategic and technical aspects of site development. This can provide the means of minimising the risks of surface and groundwater contamination and make a major contribution towards achieving sustainable development.

The legal basis of water pollution control differs between Scotland, and England and Wales. In Scotland, regulation is provided by the Control of Pollution Act 1974 (as amended) whilst in England and Wales the equivalent legislation is the Water Resources Act 1991 (as amended).

In practical terms, the control of surface water discharges is achieved by the application of similar principles throughout England, Wales and Scotland. The regulation of surface water discharges is a discretionary power and the agencies involved seek to encourage the adoption of good

practice so that smaller discharges need not be subject to a formal discharge consent. A system of Prohibition Notices enables control over the more significant discharges and can be used to require the formal consent of the agencies where there has been a failure to agree suitable measures. Surface water discharges to soakaways are not subject to control under water pollution legislation.

Building control legislation can influence the positioning and design criteria of drainage infrastructure, whilst the agreement of the drainage authority covering design and maintenance issues is required if a BMP scheme is to be adopted.

Conclusion

In general it is believed that Best Management Practices offer a cost effective answer to preventing pollution by urban runoff. This approach has been successful at tackling other sources of pollution, for example, the Codes of Good Agricultural Practice and the Forest and Water Guidelines.

If required by local circumstances, the adoption of rigorous control over discharges by the imposition of numeric consent standards will remain an option. However, the environment agencies would prefer to achieve environmental protection through the promotion of a BMP approach via conditions on planning approvals and by the selective use of Prohibition Notices and descriptive discharge consent conditions. These conditions will specify the Best Management Practices agreed with the developer to ensure that the development does not pollute the environment.

REFERENCES

1. *State of the Environment Report*, Scottish Environment Protection Agency, 1996.
2. Ellis JB. *The Management and Control of Urban Runoff Quality*. Journal of the Institute of Water and Environmental Management, vol.3 no.4, April 1989.
3. *Code of Good Agricultural Practice for the Protection of Water*, MAFF Publications, London. Prevention of Environmental Pollution from Agricultural Activity, Scottish Office Agricultural and Fisheries Department (SOAFD), Edinburgh.
4. *Code of Practice for the Prevention of Water Pollution from the Storage and Handling of Fluid Fertilisers*. Fertiliser Manufacturers Association, Peterborough, 1995.
5. *Forest and Water Code*. Forestry Authority, 1993.
6. *Surface Water Outfalls: Quality and Environmental Impact Management*. Water Research Council Report UM1400, May 1994.
7. *Urban Surface Water Runoff - Discharge Quality, Impact and Extent of the Problem in the Forth RPB*. Forth River Purification Board, Edinburgh, 1994.
8. Hall, MJ and Ellis, JB. *Water Quality Problems in Urban Areas*. Geo Journal, 11.3, 265-275, 1985
9. *Soak Away Design*. Building Research Establishment Digest BRE 365.
10. *Infiltration Drainage - Manual of Good Practice*. CIRIA Report 156. Construction Industry Research and Information Association, 1996.
11. Ellis, JB. *Quality Issues of Source Control*. Conflo '92-Integrated Catchment Planning and Source Control, 1992.
12. Scheuler, TR. *Design of Stormwater Wetland Systems: Guidelines for Creating Diverse and Effective Stormwater Wetland Systems in the Mid-Atlantic Region*. Metropolitan Washington Council of Governments, Washington, USA, 1992.

BIBLIOGRAPHY

Further information and examples of urban Best Management Practices will be found in the following:

Urban drainage - the natural way. Hydro Research and Development, Clevedon, BS21 7RD, UK. (Tel. 01275 878371).

Scope for control of urban runoff. CIRIA Report 124. Construction Industry Research and Information Association, London SW1P 3AU (Tel 0171 222 8891).

Standing Conference on Stormwater Source Control. School of the Built Environment, Coventry University, Coventry, UK (Tel 01203 631313).

Nature's Way, a 30 minute video and an accompanying booklet with details of the problems associated with drainage from developed areas and how they can be resolved with BMP's. IAWQ, London 1996. (Tel 0171 839 8390). Copies also available from SEPA Public Affairs Department (Tel 01786 457700).

SEPA HEAD OFFICE

Erskine Court
The Castle Business Park
STIRLING FK9 4TR
Tel: 01786 457700
Fax: 01786 446885

EMERGENCY HOTLINE**0345 73 72 71**

24 HRS A DAY
7 DAYS A WEEK
Calls charged at local rate

SEPA REGIONAL OFFICES

SEPA East Region HQ
Clearwater House
Heriot Watt Research Park
Avenue North
Riccarton
EDINBURGH EH14 4AP

Tel: 0131 449 7296
Fax: 0131 449 7277

SEPA North Region HQ
Graesser House
Fodderty Way
Dingwall Business Park
DINGWALL IV15 9XB

Tel: 01349 862021
Fax: 01349 863987

SEPA West Region HQ
SEPA West
5 Redwood Crescent
Peel Park
EAST KILBRIDE G74 5PP

Tel: 01355 574200
Fax: 01355 574688

SEPA Internet address: <http://www.sepa.org.uk>

ENVIRONMENT AGENCY HEAD OFFICE

Rio House
Waterside Drive
Aztec West
Almondsbury
BRISTOL BS12 4UD
Tel: 01454 624400
Fax: 01454 624409

**ENVIRONMENT AGENCY
EMERGENCY HOTLINE****0800 80 70 60****ENVIRONMENT AGENCY REGIONAL OFFICES**

Anglian
Kingfisher House
Goldhay Way
Orton Goldhay
PETERBOROUGH PE2 5ZR
Tel: 01733 371811
Fax: 01733 231840

Southern
Guildbourne House
Chatsworth Road
WORTHING
West Sussex BN11 1LD
Tel: 01903 832000
Fax: 01903 821832

Midlands
Sapphire East
550 Streetsbrook Road
SOLIHULL B91 1QT
Tel: 0121 711 2324
Fax: 0121 711 5824

South West
Manley House
Kestrel Way
EXETER EX2 7LQ
Tel: 01392 444000
Fax: 01392 444238

North East
Rivers House
21 Park Square South
LEEDS LS1 2QG
Tel: 0113 244 0191
Fax: 0113 246 1889

Thames
King's Meadow House
King's Meadow Road
READING RG1 8DQ
Tel: 0118 953 5000
Fax: 0118 950 0388

North West
Richard Fairclough House
Knutsford Road
WARRINGTON WA4 1HG
Tel: 01925 653999
Fax: 01925 415961

Welsh
Rivers House
St Mellons Business Park
St Mellons
CARDIFF CF3 0LT
Tel: 01222 770088
Fax: 01222 798555

Environment Agency Internet address: <http://www.environment-agency.gov.uk/>

