32 INFILTRATION

32.1 INTRODUCTION

Stormwater quality infiltration BMPs are becoming more widespread in use in developed nations. Infiltration facilities rely on the percolation of stormwater runoff through surface soils, where it can remove pollution and recharge ground water. Pollutants are captured by soil particles as the filtered water percolates down into groundwater.

Their application in Malaysian environment is expected to play a significant role in reducing general pollutants in urban runoff, primarily at on-site and community levels. They can offer reduced loadings to downstream major runoff quality BMPs, such as wet ponds or wetlands.

The main types of quality infiltration BMPs discussed in this chapter are

- Infiltration Trench
- Infiltration Basin
- Porous Pavement

They can be located on-site or along public drainage, depending on runoff contributing areas, pollution intensity and landuse practices being dealt with.

The infiltration facilities must be carefully selected, located, designed, and maintained to achieve their design benefits as well as to protect areas where groundwater quality is of concern. Experience overseas has shown that infiltration can be successfully utilised if adherence to proper design, construction, and maintenance standards is followed. However, design life or lifecycle performance should become important criteria in these BMPs.

32.1.1 Runoff Treatment

Acceptance criteria for runoff quality treatment require development sites to provide control facilities to capture 3 month ARI design storms. A clear distinction was made between infiltration BMPs used for runoff treatment against those used for runoff quantity control (refer Chapter 21). For runoff treatment, soil must contain sufficient organic matter to accomplish pollutant removal. In contrast to runoff quantity control infiltration option, coarser soils cannot be used for runoff treatment as they lack clay minerals or an oxide coating and will be less efficient at adsorbing heavy metal and nutrient ions.

A more likely scenario is that the infiltration BMP used for runoff treatment will be located “off-line” from the main conveyance system and that the infiltration BMP with coarser soils will be located “on-line” to provide runoff quantity control.

Runoff treatments are accomplished by infiltration BMPs by utilising the ability of soils and vegetative root system to bind, decompose, and trap pollutants contained in stormwater runoff. Soil must have an adequate infiltration rate, contain sufficient organic material, and maintain aerobic conditions in order to provide optimum treatment of runoff.

In cases where infiltration is feasible but cannot fully meet runoff treatment control, it should still be utilised to the maximum extent possible in conjunction with other BMP facilities. Note, however, that soils suitable for runoff treatment will likely drain too slowly to be used for runoff quantity control. Likewise, soils suitable for runoff quantity control will be too coarse to adequately treat runoff.

32.1.2 Pollutant Removal Capabilities

Pollutant removal mechanisms in an infiltration system include absorption, filtering and microbial decomposition below the infiltration facility. Pre-treatment BMPs, such as grassed swales leading to the infiltration facility are typically required to remove coarse particulate contaminants and to reduce excessive pollutants entering the facilities. Based on overseas studies, the long-term removal rates for estimating performance of quality infiltration facilities are summarised in Table 32.1.

Table 32.1 Typical Pollutant Removal Efficiencies for Infiltration Facilities

Parameters	BMP Types: Infiltration Trench	Infiltration Basin	Porous/ Modular Pavements
TSS	75 – 90	75	80 - 95
TP	60 – 70	65	65
TN	45 – 60	60	80 - 85
BOD	70 – 90	80	-
COD	65	65	80
Pb	70 – 80	65	>90
Zn	70 – 80	65	>90

Sources: Schueler, 1987; Yu, 1993; City of Portland, 1995.

32.2 PLANNING AND FEASIBILITYANALYSIS

This section again provides the basis for an assessment of the maximum amount of on-site infiltration that is practically achievable for each hydrologic soil group. In addition, it provides guidance in determining important design variables. The most desirable situation, of course, is to mimic the natural situation by infiltrating an amount of runoff volume in the developed state such that the amount of runoff occurring in the pre-development state is maintained. In practice, this becomes difficult to achieve when there are large increases in impervious surface and pollutants.

For a site to be suitable it must meet or exceed all of the specific criteria listed under GL-1 through to GL-6 (of Section 21.1.2). Should a site investigation reveal that any one of the General Limitations could not be met, the implementation of the infiltration practice should not be pursued.

32.2.1 General Limitations

The discussion in this section is similar to those discussed earlier in Section 21.1.2. However, it is essential to read this section for water quality general limitations since additional information is included.

The General Limitations (GL's) are governed by the physical suitability of the site and the need to prevent pollution of ground water. They include:

GL-1 Soil suitability

GL-2 Depth to bedrock, water table, or impermeable layer, or dissimilar soil layer

GL-3 Proximity to drinking water wells, septic tanks, drainfields, building foundations, structures and property lines

GL-4 Land slope

GL-5 Drainage area

GL-6 Control of siltation

GL-1 *Soil Suitability*

The suitability of soil for quality infiltration is to be based on evaluating the following:

- there is limitation on soil infiltration rate but a value, lower than that used for quantity control, is recommended for quality control,
- runoff must infiltrate through at least 400 mm of soil which has a minimum cation exchange capacity (CEC) of 5 milliequivalents per 100 grams of dry soil (refer Table 32.2) with minimum infiltration rate (f_c) of 13 mm/hr,
- soils with 30% or greater clay content or 40% greater silt/clay content shall not be used,
- aerobic conditions are to be maintained to the fullest extent possible for runoff treatment BMPs by designing them to drain the water quality design storm in 48 hours or less.

In addition, it is recommended that a more detailed soils investigation be conducted if potential impacts to ground water are a concern, or if applicant is proposing to infiltrate in areas underlain by impermeable layers or till. Refer to Appendix 21.A in Chapter 21 for soil infiltration test procedures.

For further investigations, consultation with soils and ground water specialists is recommended. For runoff treatment, the most suitable will generally be less permeable soils, from Sandy Loam or Loam soil to Clay Loam.

The general soil properties classification by soil texture is presented in Table 32.2.

Table 32.2 Soil Properties Classified by Soil Texture

Texture Class	f_c (mm/hr)	CEC	Quantity	Quality
Coarse Sands	500	<5.0	✓	
Sand	210	<5.0	✓	
Loamy Sand	61	=5.0	✓	✓
Sandy Loam	26	>5.0	✓	✓
Loam	13	>5.0	✓	✓
Silt Loam	7	>5.0		
Sandy Clay Loam	4	>5.0		
Clay Loam	2	>5.0		
Silty Clay Loam	1.5	>5.0		
Silty Clay	1	>5.0		
Clay	0.5	>5.0		

Source : Puget Sound (1992)

GL-2 *Depth to Bedrock, Water Table, or Impermeable Layers*

The base of all facilities should be located at least 3.0 m above the seasonal high ground water level, bedrock (or hardpan) and/or impermeable layer. A high water table can indicate the potential for faster ground water contamination due to saturated conditions' concentration gradient and convective effects.

GL-3 *Proximity to Drinking Water Wells, Septic Tanks, Drainfields, Building Foundations, Structures and Property Lines*

The proximity of infiltration facilities to other structures and facilities must be taken into account. Otherwise the potential exists to contaminate wells, disrupt the proper functioning of septic tank systems, damage foundations and other property. The site designer/engineer must conduct an investigation to determine the most appropriate locations of infiltration facilities; this is best done on a case-by-case basis but the following basic criteria is provided for information purposes:

- the facilities are not allowed in wellfield areas or near wells/springs used for drinking water supply,
- infiltration facilities on commercial and industrial sites should be placed no closer than 35 m from septic tanks or drainfields,

- infiltration facilities should be situated at least 7 m downslope and 50 m from building foundations. An exception is OSR facilities should be located at a minimum of 3 m from any structure and 10m from a water supply well, septic tank or drainfield.

GL 1,2 and 3 must be adhered to for important aquifer areas such as Kota Bharu, Kelantan.

GL-4 *Land Slope*

Slope restrictions depend on the BMP selected. Application of infiltration practices on a steep grade increases the chance of water seepage from the subgrade to the lower areas of the site and reduces the amount of water that actually infiltrates.

Infiltration facilities can be located on slopes up to 15% as long as the slope of the base of the facility is less than 3%. All basins should be located at minimum distance of 20 m from any slope greater than 15%.

GL-5 *Drainage Area*

Infiltration BMPs are limited in their ability to accept flows from larger drainage areas. The following drainage area limitations will be applied:

- Dispersion trenches – maximum of 500 m^2
- Infiltration sumps – maximum of 500 m^2
- Infiltration trenches – maximum of 4 hectares
- Infiltration basins – maximum of 15 hectares
- Pavement - maximum of 4 hectares

GL-6 *Control of Siltation*

Siltation is one of the major reasons for failure of infiltration facilities. This often occurs during construction, thus it is most important not to excavate trenches or ponds to final grade during this phase. Even after construction, it is vital to prevent as much sediment as possible from entering by first routing the water through a pretreatment BMP. Also there may be other construction activities upstream that take place and could result in surges of sediment entering the site.

The following conditions also apply:

1. Final construction of infiltration facilities shall not be done until after other site construction has finished and the site has been properly stabilised with permanent erosion control practices as outlined in Chapters on Erosion and Sediment Control (Part I).
2. Infiltration facilities are not recommended for use as temporary sediment traps during the construction phase. Infiltration facilities should be constructed only after upstream drainage areas have been stabilised. If an infiltration BMP is to be used as a sediment trap it <u>must</u> not be excavated to final grade until after the upstream drainage area has been stabilised. Any accumulation of silt in the basin must be removed before putting it in service.
3. Inflow to infiltration, other than roof downspout systems, must first pass through a pretreatment BMP in order to minimise the suspended solid load and prevent siltation of the infiltration facility.

32.2.2 Water Quality Feasibility Analysis

Infiltration facilities are designed to intercept and reduce direct site surface runoff. They hold runoff long enough to allow it to enter and percolate the underlying soil. They can include layers of course gravel, sand, or other filtering media. The feasibility of using infiltration depends not only on the nature of the soils, but also on the need to protect groundwater quality.

Calculation for stormwater quality design is primarily influenced by the volume of rainfall. On long term average basis, 90% of the total rainfall occurs in storm equal to or smaller than 3 month ARI. Thus, the water quality volume required for the storage and the treatment needs is to be derived by capturing and treating the 3 month ARI stormwater volume.

Additional information that should be included in designing water quality infiltration structures are:

- Evaluation of land use practices
- Evaluation of toxic pollutant loading
- Evaluation of sediment loading
- Inclusion of pretreatment BMPs and other protection measures

(a) Evaluation of land use practices

Infiltration facilities are only intended to handle the runoff from developed residential, and in some cases, commercial areas. Runoff from industrial or other high pollutant load generating areas is not compatible with these facilities.

Infiltration trenches are well suited to small and/or under-utilised areas, including:

- perimeters of subdivisions and parking lots;
- in medians and landscape strips associated with streets and highways;
- in greenways and open spaces in residential and commercial developments; and
- along the bottom of swales and ditches.

Concrete grid or porous pavement is usually limited to low-volume and low-load parking/driving areas where heavy trucks are restricted, such as:

- fringe and overflow parking areas;

- residential driveways;
- emergency lanes and vehicle cross-overs on highways not expected to carry large volumes of hazardous materials;
- small plane airport parking aprons, taxiways, and runway shoulders;
- low-volume roadways; and
- pedestrian walkways.

(b) Evaluation of toxic pollutant loading

If the runoff contain toxic pollutants, infiltration facilities alone are not suitable unless significant pretreatment is provided, because of the potential for groundwater contamination. In these cases, check the Local Authority's requirements before choosing a facility and beginning design. Infiltration facilities should not be used, or should only be used with significant pretreatment (refer Chapter 31 and Chapter 33), in the following situations:

- in most industrial areas and in commercial developments where petroleum products, herbicides, pesticides, or solvents may be loaded/unloaded, stored, or applied within the drainage area, especially locations with soluble heavy metals and toxic organics in the runoff;
- where hazardous materials are expected to be present in greater than "reportable quantities" as defined by the Department of Environment; or
- for sites with high risks for spills of toxic materials, for example, gas stations and vehicle maintenance facilities.

Note that no stormwater facilities are designed to treat runoff with consistently high levels of toxic pollutants. Source controls (e.g., dead end sumps, contained areas, good housekeeping, etc.) should be applied to eliminate the pollutants at their sources before they enter the site runoff.

Infiltration facilities for vehicle parking areas are acceptable provided that:

- industrial/commercial vehicles are not routinely parked there;
- vehicle maintenance is prohibited; and
- a level of pretreatment (refer Chapter 31 and Chapter 33) is provided.

Evaluation of sediment loading

High sediment loads can clog infiltration facilities and render them ineffective. Therefore, infiltration facilities are not suitable where construction is expected to occur in the future - or where sediment loads are high for other reasons such as natural erosion - unless:

- effective construction (temporary) and permanent erosion controls are applied;
- pretreatment sedimentation facilities are provided and regularly maintained; or
- frequent cleaning/reconstruction of the facility is acceptable and guaranteed.

(c) Inclusion of pretreatment and other protection measures

Pretreatment BMPs are important under the following conditions:

- When infiltration facilities are installed in relatively fine textured soils, or when high sediment loads are expected, include pretreatment mechanisms such as grass swales, settling basins, filter strips, and sand filters (refer Chapter 31 and Chapter 33). Consider trash racks (leaf catchers) if there is the potential for leaf and debris accumulation.
- Include at least three internal protection measures. Examples are near-surface filter fabric layers, bottom sand layers, backup underdrains, and bank run gravel.

32.3 GENERAL DESIGN CRITERIA AND PROCEDURE

32.3.1 Design Methods

This section is similar to those previously discussed in Chapter 21. However, the repetition of the information in this section is essential to ensure that the design procedure is followed. (Please refer to the Tables and Figures in Chapter 21 for further clarification).

The general principle in designing water quality infiltration facilities is to capture entire runoff volume for 3 month ARI, whereas in water quantity, the design acceptance criteria requires that the peak be reduced to the pre-developed value. Thus, the acceptance criteria for the design infiltration facilities requires satisfying both standards. For example, if the capture volume required for water quantity design is larger, it means that the facilities capture more than the requirement of water quality (thus, more pollutants being captured) or vice versa.

Similar to Chapter 21, design methodologies in this chapter also emphasises on the two community retention facilities practices: infiltration trenches and infiltration basins; since these types of facilities serve larger drainage contribution area and they have higher tendencies to malfunctions than OSR. The design methodology of the CR facilities can be applied in designing OSR with emphasis of smaller contribution drainage area. Design procedure for basin is applicable to modular/porous pavement BMPs.

The design procedures are based on either intercepting the water quality volume from the area contributing runoff or using the hydrograph method for approximating control of the runoff from an area for downstream protection volume. The design equations may be defined for either case of stormwater quality or quantity control because the volume of water (V_w) stored in the individual infiltration practice may be determined from the methods described in Chapter 15 (for water quality volume).

32.3.2 Design Criteria

Since the design requirements for water quantity and quality aspects are similar, Section 21.2.2 is again adopted to ensure that the correct procedure is followed.

(a) General Criteria

The general design criteria discussed in this section is intended for all retention facilities. This section lists the detail description of terms that are used in the Design Criteria of On-Site Retention and Community Retention Facilities (Refer Table 21.1 or Table 21.2).

(i) Soil Investigation

Soil log is required for any type of retention facilities for each proposed development location. Each soils log should extend a minimum of 3.0 m below the bottom of the facility, describe the series of the soil, the textural class of the soil horizon(s) through the depth of the log and note any evidence of high ground water level, such as mottling. In addition, the location of impermeable soil layers or dissimilar soil layers shall be determined.

(ii) Design Infiltration Rate

The design infiltration rate, f_d, will be equal to eight-tenth (0.8) the infiltration rate (f_c) found from the soil textural analysis ($f_d = 0.8f_c$). This is true for enhancing quantity infiltration but for water quality treatment, factor of safety is not necessary. Note: For water quantity, the design infiltration rate is one-half ($f_d = 0.5f_c$).

(iii) Prerunoff Treatment

Excessive runoff pollutants are to be pretreated prior to discharge to these BMPs.

(iv) Residence Time

For water quality, longer residence time is normally preferred and expected. This duration should be longer than the drawdown time required for the infiltration facilities for quantity control.

(v) Backfill Material

The aggregate material (for trench) shall consist of a clean aggregate with a maximum diameter of 70 mm and a minimum diameter of 30 mm. The aggregate should be graded such that there will be few aggregates smaller than the selected size. Void space for these aggregates is assumed to be in the range of 30 to 40%.

(vi) Overflow Route

An overflow route must be identified in the event that the facilities capacity is exceeded. This overflow route should be designed to meet Minimum Requirement of Preservation of Natural Drainage Systems (within erosive velocities).

(vii) Seepage Analysis and Control

An analysis shall be made to determine any possible adverse effects of seepage zones when there are nearby building foundations, basements, roads, parking lots or sloping sites. Developments on sloping sites often require the use of extensive cut and fill operations. The use of infiltration BMPs on fill sites is not permitted.

(viii) Buildings

OSR facilities shall be located 3 m from building foundations and CR facilities should be a minimum of 50 m upslope and 7 m downslope from any building.

(ix) Slopes

CR facilities should be a minimum of 20 m from any slopes greater than 15%. A geotechnical report should address the potential impact of the basin infiltration upon the steep slope.

(x) Observation Well

An observation well shall be recommended for every OSR and shall be required for every CR. The observation well will serve two primary functions: it will indicate how quickly the trench dewaters following a storm and it will also provide a method of observing how quickly the trench fills up with sediments. The observation well should consist of perforated PVC pipe, 100 to 150 mm in diameter. It should be located in the centre for the structure and be constructed flush with the ground elevation of the trench. The top of the well should be capped to discourage vandalism and tampering.

(xi) Spillways

The spillway requirement is only applied for the infiltration basin. The bottom elevation of the low-stage orifice should be designed to coincide with the one-day infiltration capacity of the basin. All other aspects of the principal spillway design and the emergency spillway shall follow the details provided for detention basins in Chapter 20. These outlets shall fulfil the intended water quality treatment purposes. It shall enhance longer residence time.

(xii) Vegetation

For infiltration basin the embankment, emergency spillways, spoil and borrow areas and other disturbed areas shall be stabilised and planted in accordance with Minimum Requirement of Erosion and Sediment Control.

32.3.3 Design of Trenches

(a) General Considerations

The design procedure outlined in this section shall be used in designing trenches systems that includes dispersion trenches, infiltration sumps and infiltration trenches.

Refer to Section 21.2.3 for the detail design of trenches.

(b) Procedures for Trench System Design

1. Determine the water quality volume required for storage (Chapter 15).
2. Compute the maximum allowable trench depth (d_{max}) from the feasibility equation:

$$d_{\max} = \frac{f_c T_s}{n} \qquad (32.1)$$

   Select the trench design depth (d_t) based on the required depth above the average groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.
3. Compute the trench surface dimension for the particular soil type using Equation 21.4 and 21.5.
4. Compare the required volume for water quantity and water quality and select the larger value for use in the design.

32.3.4 Design of Infiltration Basins

(a) General Considerations

Refer to Section 21.2.4 for the detail design of basin.

(b) Procedures for Infiltration Basin Design

1. Determine the water quality volume required for storage (Chapter 15).
2. Compute the maximum allowable basin depth (d_{max}) from the feasibility equation, $d_{max} = f_c T_p$. Select the basin design depth (d_b) based on the required depth above the average groundwater table, or a depth less than or equal to d_{max}, whichever results in the smaller depth.
3. Compute the basin surface area dimensions for the particular soil type using Equation 21.11. The basin top length (L_t) and width (W_t) must be greater than $2Zd_b$ for a feasible solution. If L_t and W_t are not greater than $2Zd_b$ the bottom dimensions would be less than or equal to zero. In this case, the basin depth (d_b) shall be reduced for a feasible solution.
4. Compare the required volume for water quantity and water quality and select the larger value for design.

32.4 GENERAL CONSTRUCTION, OPERATION AND MAINTENANCE

Since this section is very important to achieve the design standard, it is essential to repeat Section 21.5.

The failure of infiltration facilities to function properly can often be traced back to construction and maintenance issues. By utilising appropriate construction practices and conducting systematic and rigorous maintenance, infiltration BMPs should function properly.

32.4.1 Quality Control in Construction

Obviously, satisfactory performance of local disposal is very much dependent on the installation being built in accordance with the designer's plans, specifications, and/or instructions. Although this is obvious, it is very common to see improper installation of infiltration facilities even in developed countries.

Unlike the construction of large public works projects that have full-time professional inspection, local disposal facilities, because of their small size, will often not have full-time inspection. Even if they do, according to Shaver (1986), the inspectors are often not familiar with the technology and functional relationships of such facilities. We need to recognise that a typical construction worker cannot be expected to know the special need of these types of installations.

When selecting infiltration as a functioning part of a community's stormwater management system, proper installation, inspection and quality control procedures will also have to be provided by the community. Inspectors will have to be hired and trained. They will also need to be trained to call for expert help when unforeseen field conditions are encountered that may require design changes. The importance of attempting to properly deal, on a case-by-case basis, with the installation problems cannot be over emphasised. The successful performance of the entire stormwater system depends on a quality assurance program.

Regardless of the type of infiltration practice to be constructed, careful consideration must be given in advance of construction to the effects of the work sequence, techniques, and equipment employed during construction of the facility. Serious maintenance problems can be averted, or in large part mitigated by the adoption of relatively simple measures during construction.

Previous experiences with infiltration practices in the developed countries have shown that these BMPs must not be put into use, or preferably even constructed, until the drainage areas that contribute runoff to the structure have been adequately stabilised. When this precaution is not taken, infiltration structures often clogged with sediment from upland construction and thus fail to operate properly from the outset. It cannot be emphasised enough how important it is to protect these from sediment deposition at all times.

Care must also be taken not to compact soils during the construction phase as this can seriously affect infiltration rates. If vehicles must be driven over the infiltration BMP during construction, only those with large tracks may be used.

Specific construction methods and specifications are already provided for each infiltration type.

32.4.2 Safeguarding Infiltration Facilities

Infiltration facilities are usually constructed at the same time other facilities structure are constructed. The risk of damage to these facilities is the greatest at this time. To minimise these risks, the following are recommended:

1. Locate infiltration basins away from roads or construction haul routes. Heavy vehicles travelling over these basins can cause the surrounding soil to flow into the pores of the media.
2. Minimise the sealing of infiltration and percolation surface by keeping traffic off those areas where they are to be built. Also, locate other activities that could seal soil surfaces (e.g., cement mixing, vehicle maintenance, etc.) away from these sites.
3. Since runoff from construction sites is heavily laden with fine, suspended solids that clog infiltration and percolation facilities, keep runoff out of these facilities until construction is completed.

32.4.3 Maturing of Infiltration Surface

Newly constructed infiltration surfaces may not have as rapid an infiltration rate as matured surface. This is attributed to freshly compacted surfaces and immature vegetative cover.

After infiltration surface undergo thaw and the vegetation's root system loosens the soil, infiltration rates tend to increase. Use of nursery grown turf in newly installed infiltration basins can achieve the highest possible infiltration rates in the shortest amount of time after construction.

Since infiltration rates in a new facility are likely to be less than anticipated in design, the downstream stormwater conveyance system may appear to be somewhat undersized. It is wise to account for this interim period and to either slightly oversize the local disposal facility or the downstream conveyance system.

As the local disposal facilities begin to age, some of them will fail and will have to be repaired or replaced. When failures begin to occur, the downstream conveyance system will need to handle more runoff. If the conveyance system was not designed with this in mind, it will become inadequate to handle the increase in runoff.

After land development is completed, random erosion occurs at points of concentrated flow (e.g., at edge pavement, at roof downspouts, etc.). The eroded soils are carried to the infiltration or percolation facilities and the infiltration rates are significantly reduced. Control of erosion is very important and can be accomplished through the installation of splash pads at downspouts, the use of rock or paved rundowns, and other measures. Erosion control can go a long way toward reducing the rate of deterioration of local disposal facilities.

32.4.4 Clogging

It is not possible entirely to prevent fine sediments from entering the infiltration facilities and eventually clogging the soil pores. How long it takes will depend on the porosity of the soil, the quality of the stormwater, and how often runoff occurs. It is possible to reduce the amount of sediment through mechanical separation, such as pre-settlement in a holding basin. The use of filtration in advance of percolation beds, mentioned earlier, is very effective in reducing clogging.

If clogging occurs shortly after installation of infiltration facilities, it can indicate excessive sediment loads. One should check for erosion in the tributary area and for any other source of excessive sediment. Frequent clogging may also indicate the blockage of filters at the inlets to the infiltration or percolation beds. If this is the case, the problem can be corrected by simply cleaning out the filter media.

Of a more serious nature is the clogging that will occur over a long period of time. This is due to the accumulation of pollutants in the pores of the soil and in the percolation media. This could take several years, unless there are unusually heavy loads of sediment from the tributary basin. Heise (1977) reported on an infiltration system in Denmark installed in 1950. It was designed to intercept runoff from street surface. Although it functioned well at first, it lost all its infiltration capacity in 20 years. Excavation revealed that the soils were impregnated with oily sediments. Instead of replacement, a storm sewer was installed.

32.4.5 Slope Stability

Because local disposal artificially forces stormwater into the ground, the possibility of creating slope stability problems should always be considered. As the water infiltrates or percolates into soils, the intergranular friction in the soil can be reduced and previously stable slopes can become unstable. Slope failures in urban areas can be disastrous. A geotechnical expert should be consulted whenever on-site disposal is being considered, regardless of the slope of the terrain. Such expertise is especially important if slope stability may be affected.

32.4.6 Effects on Groundwater

The forced inflow of stormwater into the ground will affect the groundwater levels and water quality in the regions where it occurs. The impact on groundwater needs to be considered and accounted for in the design of buildings. This problem may be solved by the installation of underdrains. At any rate, on-site disposal will have an impact on groundwater.

Infiltration may also have an impact on the quality of groundwater and may be of particular concern where groundwater is used as water supply. Studies reported to date by the EPA (1983) and the others suggest that groundwater recharged by nonindustrial stormwater may not have serious water quality problems. Water quality samples taken at several sites revealed that the groundwater underneath infiltration and percolation facilities meets all of the EPA's primary drinking water standards. These findings are still considered site-specific and, as a result, are inconclusive for all conditions.

Recent findings of groundwater contamination by organic toxicants, however, leave room for concern. As our society continues to use various solvents, herbicides, pesticides, and other potentially toxic, carcinogenic, or mutagenic chemicals, many of these chemicals will enter groundwater with infiltrated stormwater. Unfortunately, the potential of these chemicals being present in stormwater runoff is ever present. And although there is no evidence of widespread contamination, as long as these chemicals are in general use we need to consider their potential presence in the stormwater runoff.

32.4.7 Care and Maintenance

Similar maintenance procedures, as mentioned in Section 21.5.8, should be followed for infiltration facilities for quality control.

APPENDIX 32.A WORKED EXAMPLE

32.A.1 Sizing an Infiltration Trench

Problem: An infiltration trench is proposed for a semi-detached bungalow (Figure 32.A1), Ipoh Perak. The catchment area is 171 m^2 (0.0171 ha). The site condition of pre-development is park lawn. From initial site investigation, the characteristic of catchment are,

Soil type : Sandy loam

Final infiltration rate (f): 0.035 m/hr

Ground water level : -3 m (from surface)

The following assumptions are made:

Time of concentration pre-development, t_{cs} = 20 minutes

Time of concentration t_c = 10 minutes

Porosity of fill materials, n = 0.35

Maximum storage time, T_s = 24 hrs

Effective filling time, T_f = 2 hrs

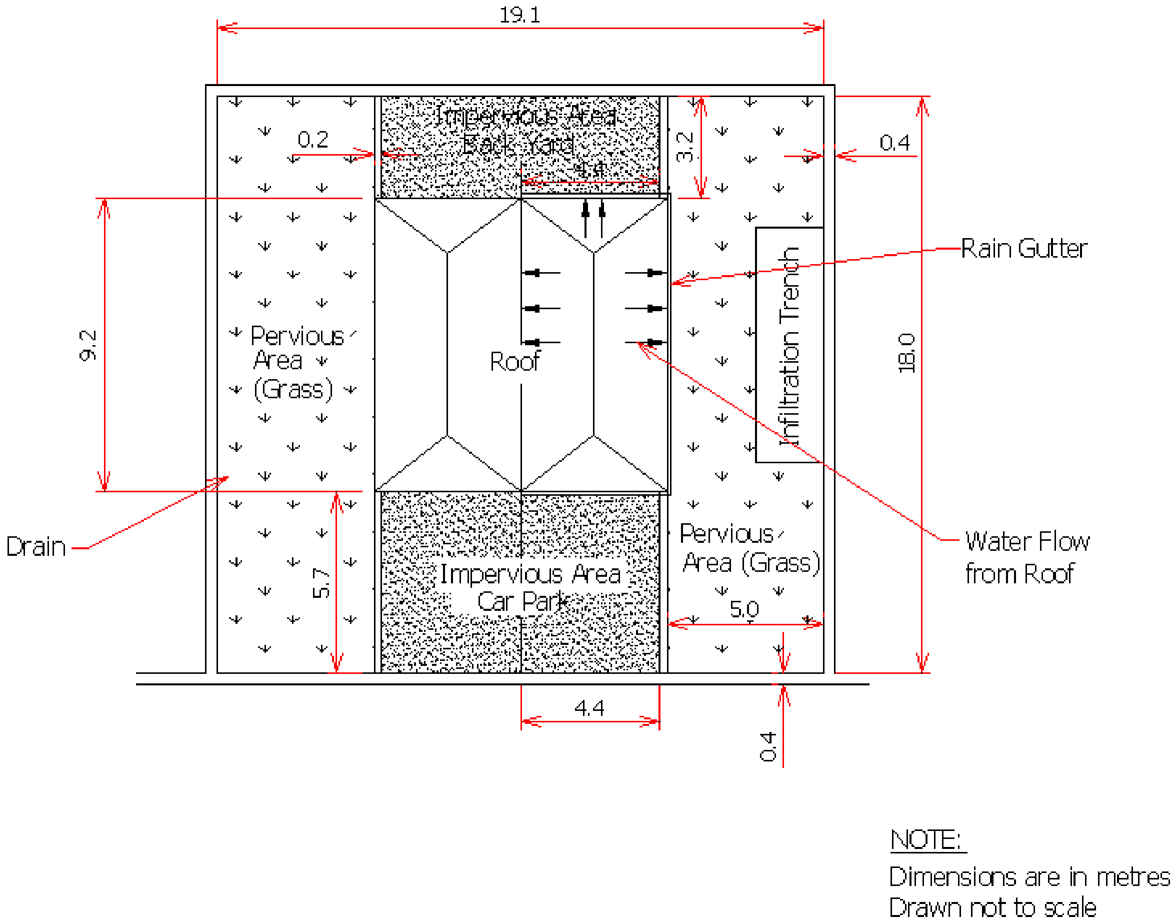

Figure 32.A1 The Semi-detached House in Rapat Setia, Ipoh

Solution:

Step (1) Determine the initial characteristic infiltration trench

Refer Section 21.2 for the detail design.

From Equation 21.1,

Maximum allowable depth (d_{max}) = $f_c x T_c/n$ =2.4 m

Proposed depth (d_t) = 1.5

Design infiltration rate (f_d) = $0.8 f_c$ = 0.028 m/hr

Step (2) Determine design volume enters the trench (V_w) that requires to capture water quality. For 3 month ARI for 1 hour storm, the design storm depth requires is 32.9 mm (Refer Chapter 13 and Chapter 15)

Step (3) Determine the design capture volume for water quality

Volume enters = 4.3 m^3

Step (4) Estimate the dimension of the proposed trench using Equation 21.4, the area of the infiltration trench can be estimated

$$A_t = \frac{V_w}{nd_t + f_d T_f}$$

A_t = 12.4 m^2 ;

Thus, the proposed infiltration trench is 2 m wide and 3.7 m length. This dimension fits the available space in the bungalow compound.

Step (5) Check the requirement of water quantity. Refer Example 21.B.1. The required storage for water quantity is larger than water quality. Therefore, use water quantity dimension (2 x 5.0) to satisfy both requirements.

32.A.2 Sizing an Infiltration Basin

Problem: An infiltration basin is proposed for Sekolah Menengah Seri Ampang (Figure 32.A2), Ipoh Perak. The catchment area is 2.5 ha comprises of 1.26 ha of impervious area (building and parking) and 1.24 of pervious area (playing field and garden). Assume the site condition of pre-development is park lawn. From initial site investigation, the characteristic of catchment are :

Soil type : Sandy loam

Infiltration capacity (f): 0.035 m/hr

Ground water level : -2 m (from surface)

The following assumptions are made:

Time of concentration pre-development, t_{cs} = 30 minutes

Time of concentration t_c = 20 minutes

Porosity of fill materials, n = 0.35

Maximum storage time, T_s = 24 hrs

Effective filling time, T_f = 2 hrs

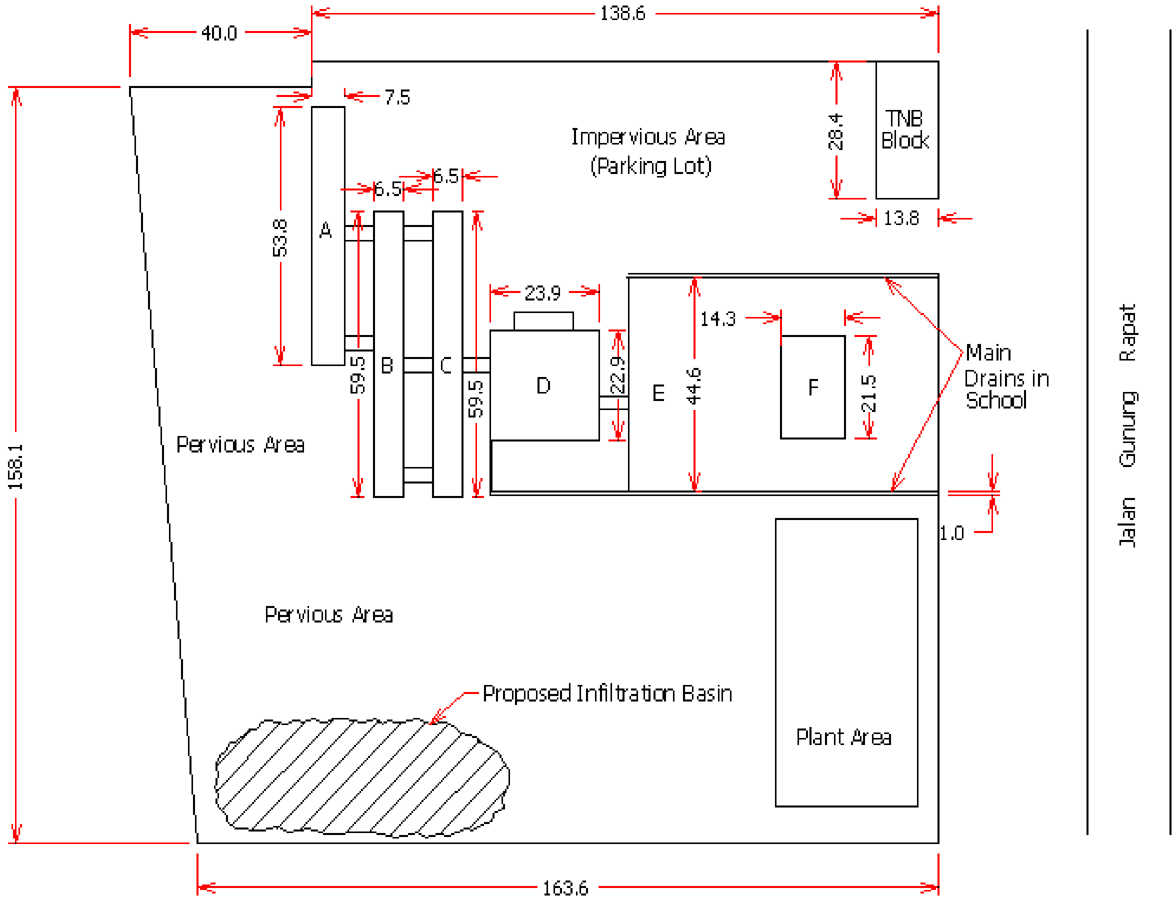

Figure 32.A2 Sekolah Menengah Seri Ampang at Rapat Setia, Ipoh

Solution:

Step (1) Determine the initial characteristic infiltration basin

Refer Section 21.2 for the detail design.

From Equation 21.7,

Maximum allowable depth (d_{max}) = $f_c T_p$ = 0.84 m

Proposed depth (d_t) = 0.5

Proposed side slope 1 : 5 (V:H)

Step (2) Determine design volume enters the trench (V_w) that requires to capture water quality. For 3 month ARI for 1 hour storm, the design storm depth requires is 32.9 mm (Refer Chapter 13 and 15)

Total Area A = 2.5 ha

Predeveloped C_{cs} = 0.48 (category (7))

Developed C= 0.9x1.26/2.5+0.63x1.24/2.5 = 0.77

Impervious Area A_I = 1.26 ha (category (1))

Pervious Area A_P = 1.24 ha (category (6))

Step (3) Determine the design capture volume for water quality

Volume enters = 630 m^3

Step (4) Estimate the dimension of the proposed infiltration basin. The basin top length (L_t) is determined by using Equation 21.11. The basin top width (W_t) should be predetermined by considering the available space in the compound. In this example, the available space is about 40 m wide.

$$L_t = \frac{V_w + Zd_b(W_t - 2Zd_b)}{W_t d_b - Zd_b^2}$$

$$L_t = \frac{630 + 5x0.5(40 - 2x5x0.5)}{40x0.5 - 5x0.5^2}$$

L_t = 38.3 m

Thus, the dimension of the proposed infiltration basin is 40 m x 40 m

Step (5) Check the requirement of water quantity. Refer Example 32.2A. The required storage for water quantity is larger than water quality. Therefore, use water quantity dimension (40 m x 64 m) to satisfy both requirements.