23 ROOF AND PROPERTY DRAINAGE

23.1 ROOF DRAINAGE SYSTEMS

Urban stormwater drainage systems operate at different scales. They can be designed and managed at the levels of:

- individual or group houses – roof drainage, property drainage
- streets and neighbourhoods - street drainage systems
- stream catchments – trunk drainage systems
- rivers and waterways – river basin management systems

Roof drainage systems are located at the top of the many branches in a large drainage system. They are generally discharged directly into the on-site detention/infiltration facilities or property drainage systems. Because the areas are usually small and there are fewer complications, roof drainage can be designed using simpler methods than those employed at larger scales.

It is recognised that many buildings in Malaysia are, and will continue to be, constructed without roof drainage systems. This practice is appropriate in some situations, such as minor buildings in rural areas. This Chapter therefore applies to those buildings where roof drainage is specified for reasons of runoff conveyance and collection to storage/retention facilities as well as for comfort and safety of occupants and the protection of the building structure.

The methods given in this section are based on the Australian/ New Zealand Standard AS/NZS 3500:3 (1998), adapted for Malaysian conditions. While the theoretical principles are generally straightforward, there is relatively little experience in specifying roof drainage systems and design methods for Malaysian conditions. It is therefore anticipated that this Chapter will be subject to review in the future as a result of further research.

23.1.1 Terminology

The meanings of the terms used in this Chapter are shown in Figure 23.1.

Eaves gutters are located on the outside of a building. Box gutters are located within the plan area of the building. Valley gutters are located between the intersecting sloping surfaces of a roof.

Property drainage refers to the systems, which transfer runoff from roofs, paved areas and other surfaces to a suitable outlet or disposal facility.

23.1.2 Design Philosophy

Roof drainage, like other parts of a drainage system, must be conceived and its various components sized, to successfully carry stormwater flows, preventing nuisance and harm. The design approach is to determine the layouts and sizes of components, and then analyse their behaviour under one or more design storms that will test the adequacy of the system. Systems should operate satisfactorily in these critical cases, and therefore under less severe conditions.

However failures can occur due to:

- very large storm events
- blockage of systems
- poor maintenance and neglect, and
- ageing of systems

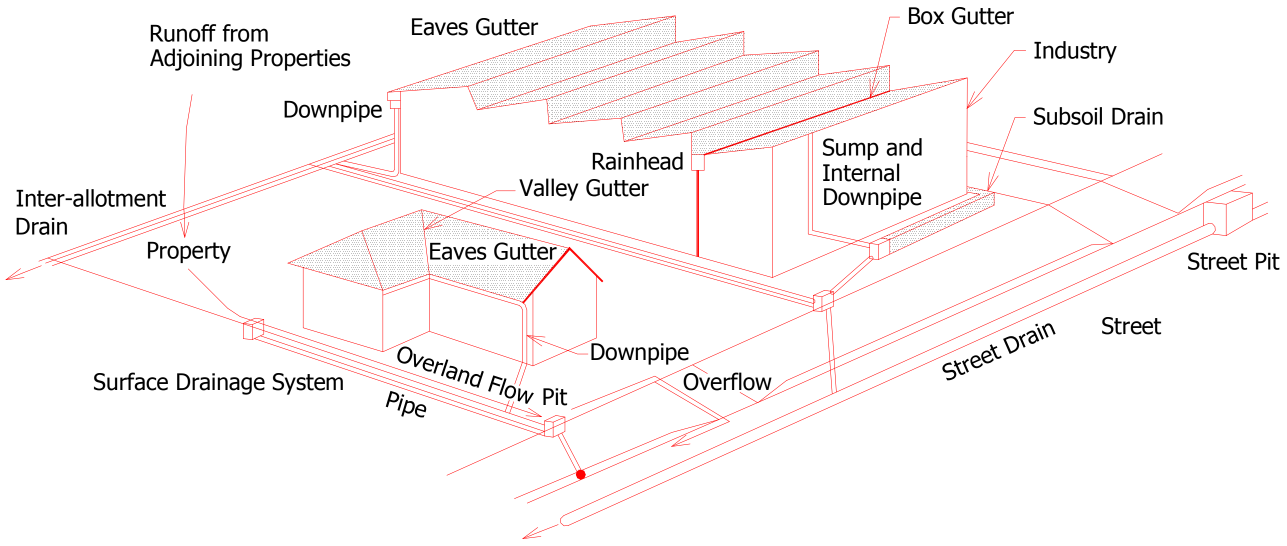


Figure 23.1 Meaning of Terms in Roof and Property Drainage

The design approach therefore also involves the management of risk, accepting that failure may occur and attempting to limit this to an acceptable frequency and magnitude. The more damaging the consequences of failure, the lower the acceptable frequency.

Property drainage systems are usually pipes and open drains. The pipes should be designed using the hydraulic design procedures in Chapter 25 and open drains should be designed using the procedures in Chapter 26.

Local authorities may place limitations on the amount of stormwater that can be drained to streets or trunk drainage systems, in order to reduce flooding. In these cases it is the responsibility of the property owner to design infiltration or on-site detention systems. The design of these systems is described in Chapters 19 and 21.

23.1.3 Standardisation

Economic advantages will result from adoption of standard sizes for gutters, downpipes, and rainheads ("rainwater goods") in Malaysia.

The preparation of suitable standards for rainwater goods is outside the scope of this Manual. However, the methods set out in this Chapter should be used when such standards are developed in the future. Sizes quoted in this Chapter are not necessarily standard sizes.

23.2 ROOF DRAINAGE DESIGN PROCEDURE

23.2.1 Introduction

The design procedure herein follows AS/NZS 3500.3.2 in recognising that wind causes the rain to slope, and because of this there is a horizontal component of rainfall. This horizontal component becomes significant on vertical walls or sloping roofs.

The direction of wind, which results in the maximum catchment area, should be selected. It is not sufficient to consider only the direction of prevailing winds.

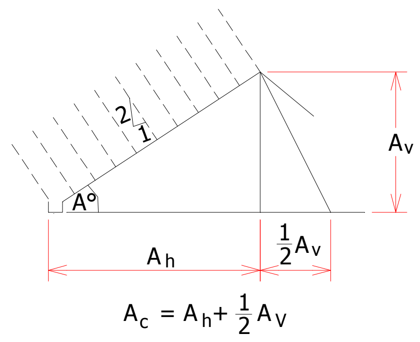
A maximum rainfall slope of 2 vertical to 1 horizontal is assumed, as used in the current British and draft European Standard.

This leads to the following formula for catchment area A_c :

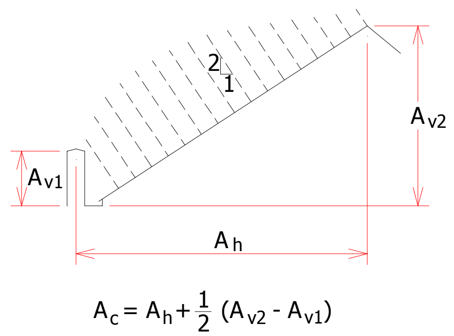
$$A_c = A_h + \frac{A_v}{2} \qquad (23.1)$$

where the meaning of terms is as shown in Figure 23.2.

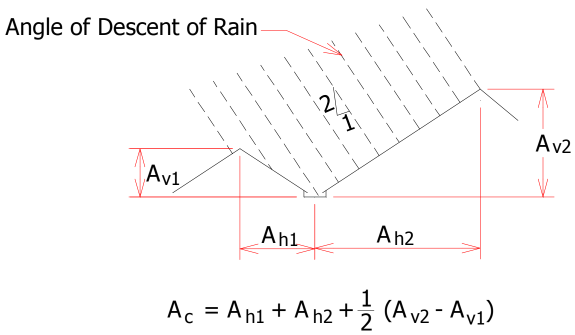
If the roof is partly shielded by another wall, the net vertical area A_v is the area seen by looking in the same direction as the wind.



(a) Single Sloping Roof Freely Exposed to the Wind



(b) Single Sloping Roof Partially Exposed to the Wind



(c) Two Adjacent Sloping Roofs

Figure 23.2 Calculation of Roof Catchment Area

23.2.2 Design Standards

Roof drainage shall use the design standards set out in Table 23.1. The critical storm duration of 5 minutes should be adopted for all roofs unless special circumstances justify a longer duration.

Table 23.1 Design Standards for Roof Drainage

	Eaves Gutters	Valley and Box Gutters
All buildings	5 minute duration, 20 year ARI *	5 minute duration, 100 year ARI

Note 1: If water can flow back into the building, then overflow measures are required

Note 2: Chapter 45 specifies a higher design standard for buildings in hillside areas

23.2.3 Rainfall Intensity

The 5 minute duration 20, 50 and 100 year ARI rainfall intensities for the particular location are obtained from the short-duration rainfall IDF method in Chapter 13. This method is based on rainfall IDF (intensity- duration-frequency) data for the particular site.

If special circumstances justify the use of a longer time of concentration, the rainfall intensity for this time of concentration shall be derived using the methods set out in Chapter 13.

The flow produced by the design rainfall shall be calculated using the Rational Formula, with C = 1.0. For roof drainage the Rational Formula can be expressed in the following form:

$$Q = \frac{I \cdot A_c}{3600} \qquad (23.2)$$

where

Q = peak flow (L/s)

I = rainfall intensity (mm/hr)

A_c = Roof catchment area draining to a downpipe (m^2)

23.2.4 Design of Eaves Gutters

For a simple sloping (gabled) roof, the eaves gutter design is straightforward. It should slope from one end to the downpipe location at the other end.

The method for the design of an eaves gutter is as follows:

- Determine the catchment area to each downpipe
- Determine the design 5 minute duration, 20 year ARI rainfall intensity
- Choose the gutter size from Design Chart 23.1.

To provide adequate fall and minimise the risk of ponding, the minimum gradient of an eaves gutter shall be 1:500.

The minimum cross-sectional size of an eaves gutter shall be 4,000 mm^2. The normal maximum size shall be 22,000 mm^2. If calculations indicate that a larger size is required, it is preferable to provide more downpipes rather than increasing the gutter size.

The required size of eaves gutter shall be determined from Design Chart 23.1. This Chart is derived from Manning's formula with 'n' = 0.016 and S = 1/500. This is a simplified method because the effect of varying flow depth is neglected. When applying the Design Chart, A_c is the catchment area draining to a single downpipe.

Downpipe size is then determined from Table 23.2 to match the eaves gutter size. Downpipes may be either rectangular or circular. Note that for a given roof catchment area, the size of downpipe will be the same irrespective of the slope of the eaves gutter.

If the listed size is not available, an alternative downpipe with equal or greater cross-sectional area than that shown may be substituted.

23.2.5 Design of Valley Gutters

Valley gutters are located between the sloping roof sections of a hipped roof (see Figure 23.1). The following points should be noted when designing systems incorporating valley gutters:

- Valley gutters should end at the high point of an eaves gutter.
- The discharge from a valley gutter does not flow equally into both eaves gutters. Therefore the designer should allow at least 20% excess capacity in the sizing of the eaves gutters.

The profile of a valley gutter is shown in Figure 23.3.

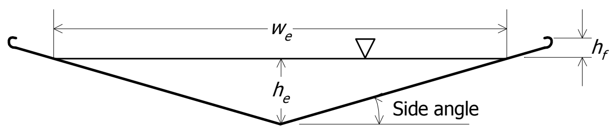


Figure 23.3 Profile of a Valley Gutter

The sizing guidelines in Table 23.3 are valid for the following conditions:

- Roof slope of not less than 12.5°
- The nominal side angle of valley gutters is 16.5°.
- The catchment area shall not exceed 20 m^2.

The method for the design of a valley gutter is as follows :

- Select the ARI
- Determine the design 5 minute duration, 20 year ARI rainfall intensity
- Choose the girth size and dimensions from Table 23.3.

Table 23.2 Required Size of Vertical Downpipe for Eaves Gutter

<table>
<tr><td>Eaves Gutter Size</td><td colspan="2">Minimum Nominal Size of Vertical Downpipe</td></tr>
<tr><td>(cross-sectional area in mm^2)</td><td>Circular (mm diameter)</td><td>Rectangular (mm)</td></tr>
<tr><td>4,000</td><td rowspan="3">75</td><td rowspan="2">65 x 50</td></tr>
<tr><td>4,200</td></tr>
<tr><td>4,600</td><td rowspan="2">75 x 50</td></tr>
<tr><td>4,800</td><td rowspan="2">85</td></tr>
<tr><td>5,900</td><td rowspan="2">100 x 50</td></tr>
<tr><td>6,400</td><td rowspan="2">90</td></tr>
<tr><td>6,600</td><td rowspan="2">75 x 70</td></tr>
<tr><td>6,700</td><td rowspan="2">100</td></tr>
<tr><td>8,200</td><td rowspan="2">100 x 75</td></tr>
<tr><td>9,600</td><td rowspan="2">125</td></tr>
<tr><td>12,800</td><td>100 x 100</td></tr>
<tr><td>16,000</td><td rowspan="2">150</td><td>125 x 100</td></tr>
<tr><td>18,400</td><td rowspan="2">150 x 100</td></tr>
<tr><td>19,200</td><td rowspan="3">Not applicable</td></tr>
<tr><td>20,000</td><td>125 x 125</td></tr>
<tr><td>22,000</td><td>150 x 125</td></tr>
</table>

(Source : based on AS/NZS 3500.3.2:1998)

Table 23.3 Minimum Dimensions for Valley Gutters (refer Figure 23.3)

Design Rainfall Intensity (mm/hr)	Minimum Dimension (mm)		
	Sheet width	Effective depth *(h_e)*	Effective width *(w_e)*
≤ 200	355	32	215
> 200 ≤ 250	375	35	234
> 250 ≤ 300	395	38	254
> 300 ≤ 350	415	40	273
> 350 ≤ 400	435	43	292
> 400	455	45	311

Notes:

1. Freeboard *(h_f)* = 15 mm
2. The sheet width from which the valley is to be formed has been calculated on the basis of h_f = 15 mm and an allowance for side rolls or bends of 25 mm.

23.2.6 Design of Box Gutters

Box gutters are located within a building. Gutters adjacent to a wall or parapet shall be designed as box gutters.

The main principle in the design of box gutters is to avoid the potential for blockages, which would prevent the free runoff of roofwater, and possibly cause water to enter the building.

- Box gutters must be straight (no bends).
- Cross-section shape must have a constant base width and vertical sides.
- Longitudinal slope must be between 1:200 and 1:40. Changes in slope are not permitted.
- The gutter must discharge directly into a rainhead or sump at the downstream end without change of direction.

Box gutters are connected to either rainheads or sumps with overflow devices.

The minimum width of box gutters for commercial or industrial construction is 300 mm. For residential construction, a minimum width of 200 mm is permitted but such gutters are more prone to blockage and should be subject to more frequent inspection and maintenance.

The method for design of a box gutter is as follows:

- Determine the catchment area draining to each downpipe (Equation 23.1)
- Determine the design 5 minute duration, 100 year ARI rainfall intensity.
- Select the width and slope of the box gutter to suit the building layout.
- Read off the minimum depth of the box gutter from Design Chart 23.2. This minimum depth must be used for the full length of the box gutter. If a sloping box gutter is built with a horizontal top edge for architectural reasons, the minimum depth requirement still applies. When applying the Design Chart, A_c is the catchment area draining to a single downpipe.

Flow conditions in a box gutter are complex, due to the varying depth of flow. Design Chart 23.2 is based on Figure I1 in AS/NZS 3500.3.2. This chart has been derived from model tests as described in Beecham, Jones and O'Loughlin (1995).

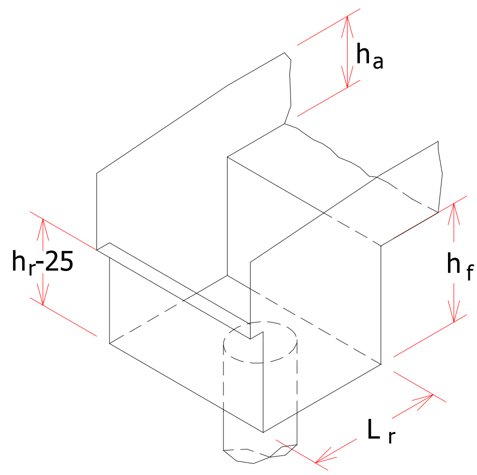
23.2.7 Rainheads and Downpipes

Box gutters shall discharge via a rainhead or sump, to a downpipe.

The required size of downpipe from a box gutter is determined from Design Chart 23.3. This graph has been adapted from AS/NZS 3500.3.2:1998. The sizing principle is to limit the maximum capacity of the downpipe in order to prevent slugs of unstable flow. The graph does not permit very deep, or very shallow rainheads. The minimum depth of water in the rainhead is limited to about half of the diameter of the downpipe. Above this depth, orifice flow conditions apply.

A standard rainhead is shown in Figure 23.4. It includes an overflow to safely discharge flow from the box gutter even if the downpipe is blocked.

The design flow of a rainhead shall not exceed 16 L/s.



Notes:

1. For $h_r \geq 1.25D_e$ or $1.25\ D_n$
2. Width of rainhead is equal to the width of box gutter
3. The rainhead to be fully seated to the box gutter and the front of the rainhead left open above the overflow

Figure 23.4 Standard Rainhead

Note that:

- The rainhead must be sealed to the box gutter.
- The depth of a rainhead must be at least 1.25 x downpipe diameter.
- There is an overflow weir at a lower level than the sole of the box gutter.
- The width of the overflow weir must be the same as the width of the box gutter, to minimise blockage.

23.2.8 Sumps

Sumps are located at the low point of a box gutter, which slopes towards the sump in both directions.

A standard sump is shown in Figure 23.5.

All sumps must be provided with an overflow to prevent overtopping of the box gutter even if the downpipe is blocked. Two types of overflow devices are permitted:

Side Overflow Device

This device is shown in Figure 23.5. This design has been in use world-wide for many years. It is only suitable for box gutters, which run parallel and adjacent to a parapet wall.

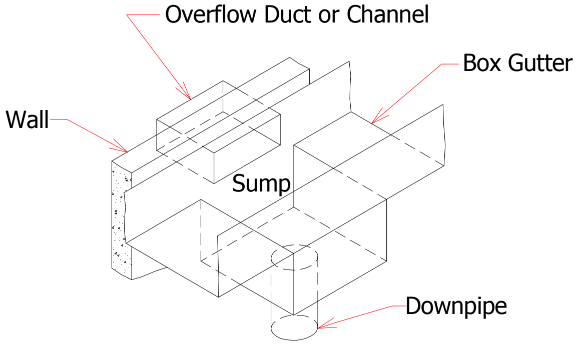


Figure 23.5 Standard Sump and Side Overflow

High Capacity Overflow Device

This device is shown in Figure 23.6. It is a new design developed in Australia, which is described in Jones and Kloti (1999).

It is anticipated that further research will be conducted into developing overflow devices suitable for Malaysian conditions.

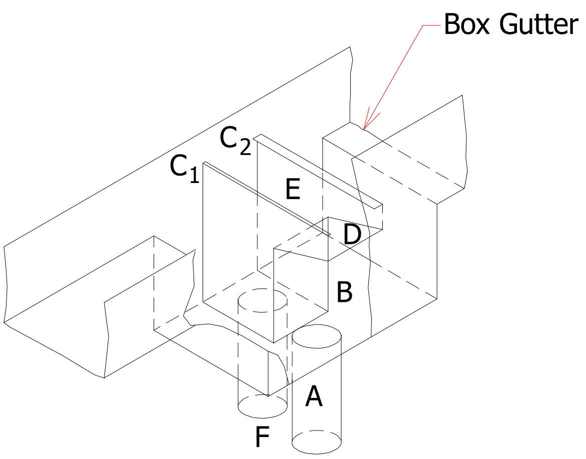


Figure 23.6 Alternative Overflow Device

23.3 RAINWATER TANKS

Rainwater tanks may be provided to collect flow from roof and gutter systems. These tanks can be used to:

- provide water supplies, and/or
- provide on-site detention storage

The design of rainwater tanks for water supply is not covered in this Manual. The design of on-site detention storage is covered in Chapter 19. Note that any tank volume provided for detention is *additional* to that set aside for water supply storage.

23.4 PROPERTY DRAINAGE

23.4.1 General

The drainage system proposed within allotments depends upon the topography, the importance of the development and the consequences of failure. The drainage systems collect water from roofs (via downpipes), surfaces of areas around buildings, and flows onto the property from adjacent allotments in major storm.

In areas with suitable soils and water table conditions, stormwater may be infiltrated directly into the soil, rather being directed to the street drainage system.

23.4.2 Design Standard

Elements in the property drainage systems shall be designed to contain flows from minor storm events of ARI not less than that specified in Table 23.4.

The property drainage systems shall be designed to ensure that overflows in a major storm event do not present a hazard to people or cause significant damage to property.

Table 23.4 Minimum Design Average Recurrence Intervals for Property Drainage

Effect of Surcharge and Overland Flow	ARI (years)
Small impact, in low density area	1
Normal impacts	2
Ponding in flat topography; or flooding of parking lots to depths greater than 150 mm	10
Impeded access to commercial and industrial building	10
Ponding against adjoining buildings; or impeded access to institutional or important buildings (e.g., hospitals, city halls, school entrances)	20

23.4.3 Drainage to the Rear of Properties

Where the natural ground level does not permit drainage by gravity to the street drain or gutter, it will be necessary to either fill the site to obtain a fall to the street, or alternatively, to provide a piped drain through an adjoining private property or properties, to discharge the runoff from the site by gravity.

Requirements for piped drainage in privately owned lots are set out in Chapter 25. Open drains shall not be permitted at the rear of private lots because they are difficult to maintain.

Any piped drain in private property, which serves an adjoining property, shall be protected by a drainage easement. Such easements shall be free of any building encroachments, including eaves footing and shall contain a single pipe only. Full details of any proposed easement is to be submitted to the local Authority for approval and this easement shall be registered prior to release of the building plans.

Service ties shall be provided on the piped drain to allow the connection of adjoining properties. The provision of service ties is described in Chapter 25.

23.5 PUMP SYSTEMS FOR PROPERTY DRAINAGE

In general, the use of pump systems for site drainage is to be avoided because of difficulties in ensuring sufficient reliability of operation. All such systems will require local Authority approval.

Pump systems are permitted for the drainage of building basement areas. Full details of the proposed installation, pump type and discharge rate and the delivery line size, must be submitted for the local Authority's approval.

23.5.1 General Requirements

Pump systems may be permitted for total site drainage with local Authority approval, only in situations where the applicant supplies positive proof that all reasonable attempts have been made to obtain an easement through an adjoining property, or implement a satisfactory alternative system and these have been unsuccessful.

Prior to occupation of the building, the applicant shall submit written evidence that a contract has been let for the regular maintenance of the pump system.

The applicant shall indemnify the local Authority from all claims for damages arising from failure of the pump system.

23.5.2 Holding Tank

A holding tank shall be provided for storing one hour’s runoff from a one hour duration storm of the recurrence interval appropriate to the development. The inlets shall be screened to prevent the entry of debris.

23.5.3 Pumps

The pump system shall consist of two (2) pumps, connected in parallel, with each pump being capable of emptying the holding tank at a rate equal to the lower of the allowable site detention discharge rate, or the rate of inflow for the 1 hour duration storm.

Pumps shall be automatically controlled by the level in the wet well. The pump control shall be set up to enable alternate pump operation at each start. In the event that a pump fails to operate when the water level in the wet well reaches the pump start level, the other pump shall be activated and a visible alarm initiated. If both pumps fail to operate, an audible alarm shall be sounded.

Additional requirements:

- Pumping equipment shall be securely mounted using corrosion-resistant fittings.
- Pumps shall have flanges or unions installed to facilitate removal for maintenance.
- Each pump shall be fitted with a gate valve and non-return valve on the delivery side of the pump.
- Pumps shall be controlled so as to limit the number of starts per hour to within the capacity of the electrical motors and equipment

23.5.4 Discharge

Discharge from a pump system shall be channelled to the open or piped street drain. Direct discharge to an open drain shall not be permitted if the pump discharge line is greater than 50mm diameter. In these cases, discharge shall be to a stilling manhole connected to the Authority's drain by a gravity pipeline designed in accordance with Chapter 25.

Prior to occupation of the site, the applicant shall submit written evidence that a contract has been let for the regular maintenance of the pump system.

The applicant shall indemnify the local Authority from all claims for damages arising from failure of the pump system.

23.6 DRAINAGE THROUGH PUBLIC RESERVES

Where a low level property adjoins a public reserve, the construction of drainage line through the reserve generally will not be permitted and alternative methods of drainage should be investigated, including:

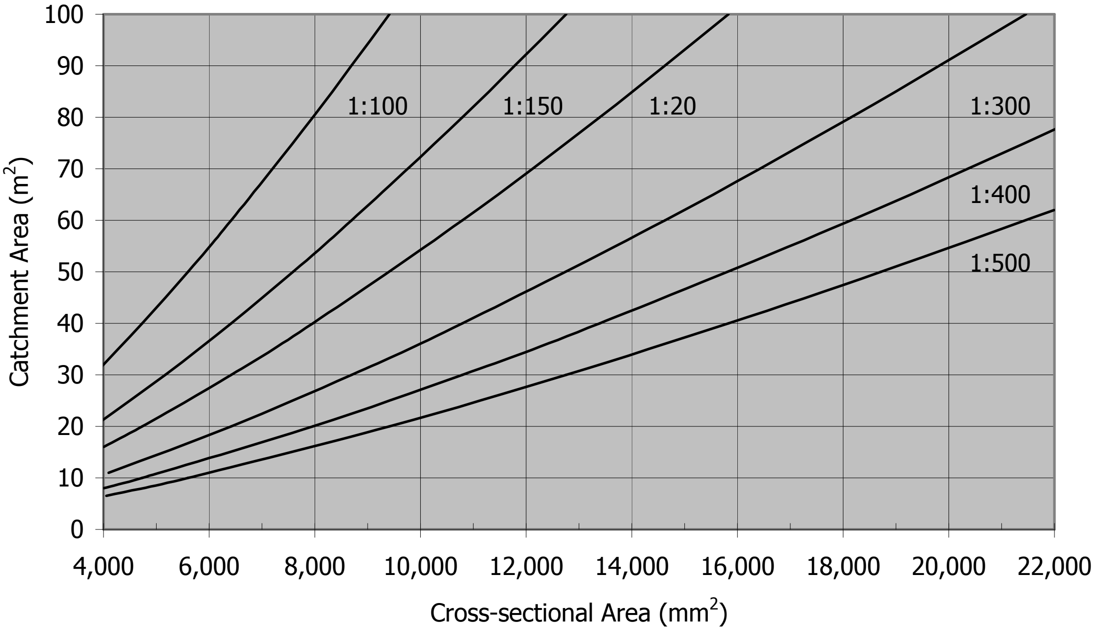
- construction of a pipeline through adjoining private property (see Section 23.4.3).
- a pump out system (see Section 23.5.1).

Construction of a drainage line through a public reserve may be permitted by the local Authority, only in situations where the applicant provides satisfactory proof that the alternatives have been investigated and found to the impractical.

Where drainage through a public reserve is permitted, the applicant is required to enter into a licence agreement with the Local Authority, subject to the payment of a one off licence fee under the respective agreement covering any installation, legal or other costs associated with the preparation and execution of the licence agreements, together with an amount considered appropriate towards the improvement of the respective reserve.

APPENDIX 23.A DESIGN CHARTS

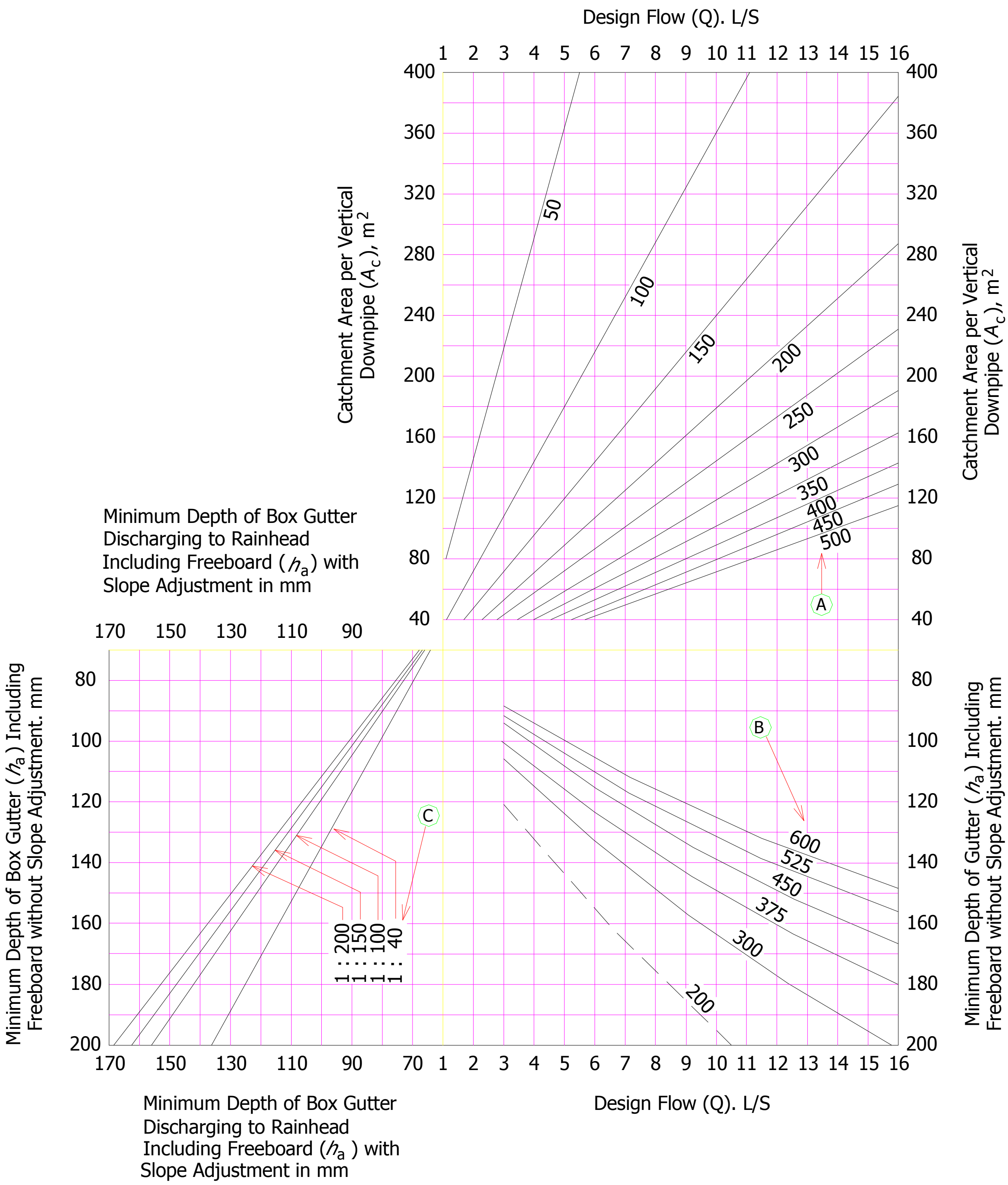
Required Cross-sectional Area of Eaves Gutter for Gradients Flatter than 1:500



NOTES:

1. Minimum gradient of eaves gutter is 1:500
2. Assumes an effective width:depth ratio of 2:1
3. Chart is applicable for rectangular or half-round cross-section shape
4. Minimum cross-sectional area = 4,000 mm^2; maximum cross-sectional area = 22,000 mm^2
5. No allowance made for freeboard, or less of waterway area due to internal brackets

Design Chart 23.1 Design Chart for Size of Eaves Gutter



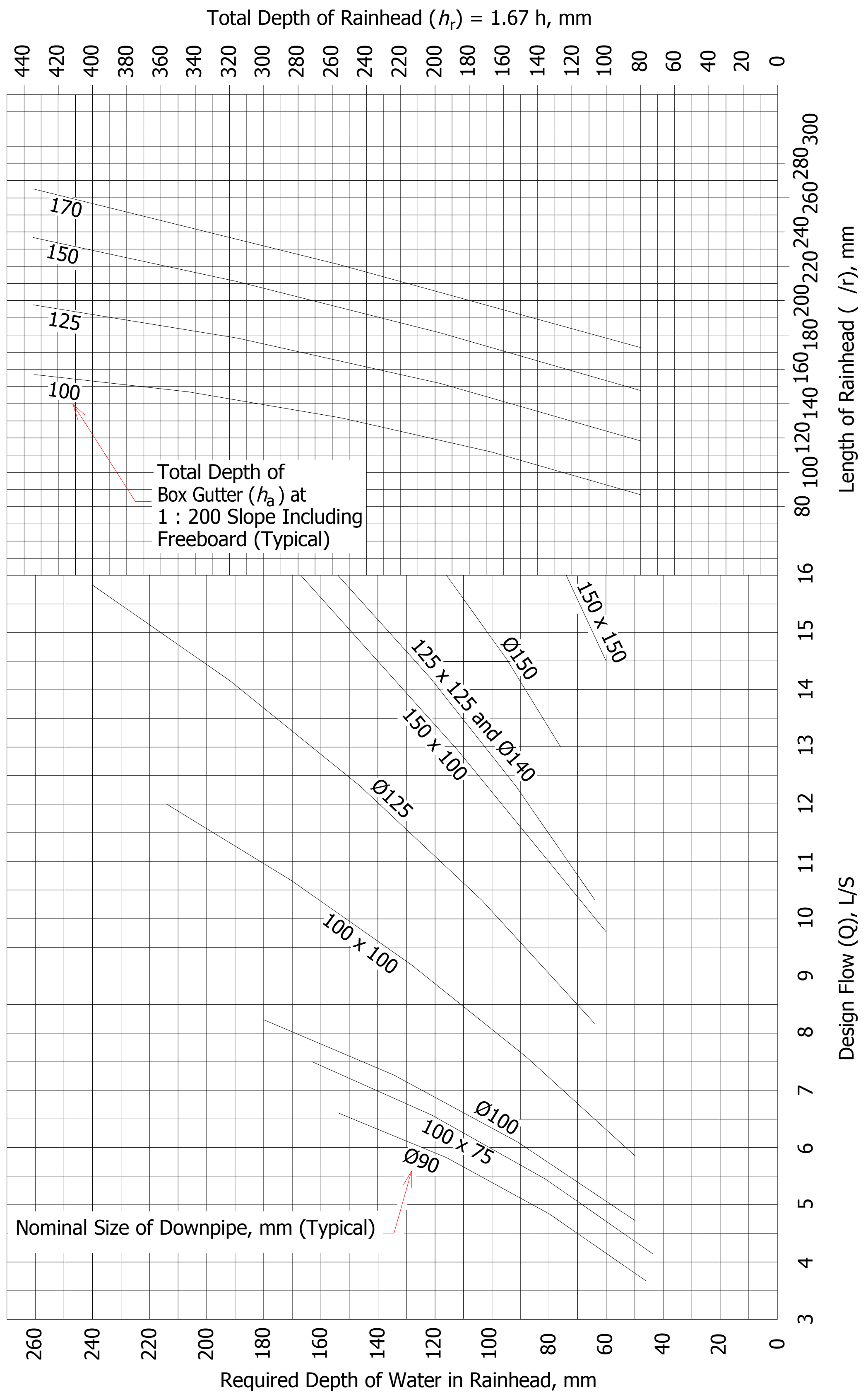
LEGEND :

- (A) = Design rainfall intensity ($^{100}I_5$) or ($^{50}I_{10}$) in mm/hr (typical)
- (B) = Width of box gutter (Wbg) in mm (typical)
- (C) = Gradient of box gutter (typical)

NOTE :

200 mm Box Gutter for Domestic Construction Only.

Design Chart 23.2 Design Chart for Size of a Freely Discharging Box Gutter (Refer to Figure 23.3 for definition of terms)



Design Chart 23.3 Design Chart for Downpipes from Box Gutters
(Refer to Figure 23.3 for definition of terms)

APPENDIX 23.B WORKED EXAMPLE

The gable roof of a house shown in Figure 23.B1 is located in Ipoh. The design rainfall intensity for 5 minute storm for 20 year ARI is 408.4 mm/hr. Determine the required size of the eaves gutters and downpipes.

(a) *Calculation of Catchment Area*

Roof A-B-C-H-A:

plan area $A_h = 13 \times 4 = 52\ m^2$

rise is 1 m. Vertical area $A_v = 1 \times 13 = 13\ m^2$

Total catchment area $= A_h + A_v/2 = 52 + (13)/2 = 58.5\ m^2$

Roof J-C-D-E-J:

plan area $A_h = 7 \times 6.5) = 45.5\ m^2$

rise is 1.75 m. Vertical area $A_v = 1.75 \times 6.5 = 11.4\ m^2$

Total catchment area $= A_h + A_v/2 = 45.5 + (11.4)/2 = 51.2\ m^2$

Roof H-J-F-G-H:

plan area $A_h = (4)(6.5) = 26\ m^2$

rise is 1 m. Vertical area $A_v = 1 \times 6.5 = 6.5\ m^2$

Total catchment area $= A_h + A_v/2 = 26 + (6.5)/2 = 29.3\ m^2$

(b) *Calculation of Gutter and Downpipe Size*

Rainfall intensity for 5 minute duration 20 year ARI = 408.4 mm/hr

Roof A-B-C-H-A:

Catchment area = 58.5 m^2

From Design Chart 23.1, required effective cross section area for gutter A-B = 18,400 mm^2

For an effective cross section area of eaves gutter = 18,400 mm^2, a 150 mm diameter downpipe is required (Table 23.2).

Roof J-C-D-E-J:

Catchment area = 51.2 m^2

From Design Chart 23.1, required effective cross section area for gutter E-D = 16,800 mm^2

Required downpipe size = 150 mm diameter (from Table 23.2)

Roof H-J-F-G-H:

Catchment area = 29.3 m^2

From Fig. 23.3, required effective cross section area for gutter F-G = 10,600 mm^2

Required downpipe size = 125 mm diameter (from Table 23.2)

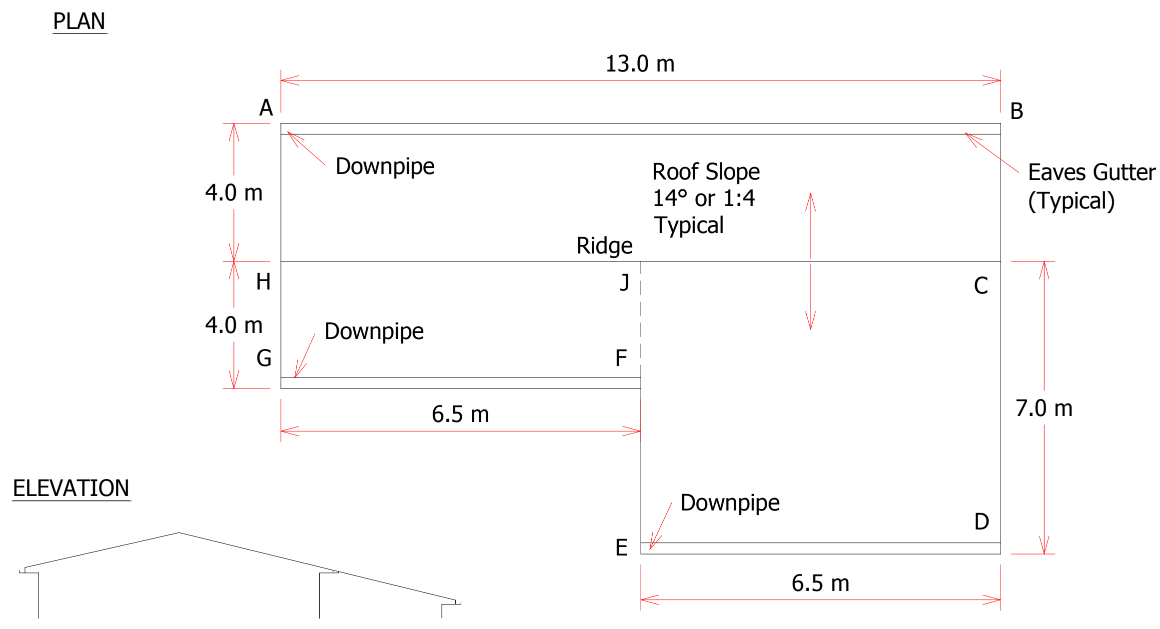


Figure 23.B1 Gable Roof of a House