CHAPTER 7

Design Example for Rainwater Harvesting System

Case Study

The example of the rainwater tank sizing is based on the proposed construction of 18 storey office including 3 storey podium and one storey car park for MITI (Ministry of International Industrial for Malaysia).

The rainwater will be collected from the roof of the (office and podium block) and from the proposed building and directed to the downpipe and rainwater tank located at ground level of the building (Figure 7.1).

Part of the collection consists of the green roof garden landscapes with the ornamental plant and trees to meet the functional objective of the building (see Appendix for the detail drawing).

The rainwater harvesting system is assumed to be used as a bathroom cistern flushing for supply up to 1,000 installation of cisterns.

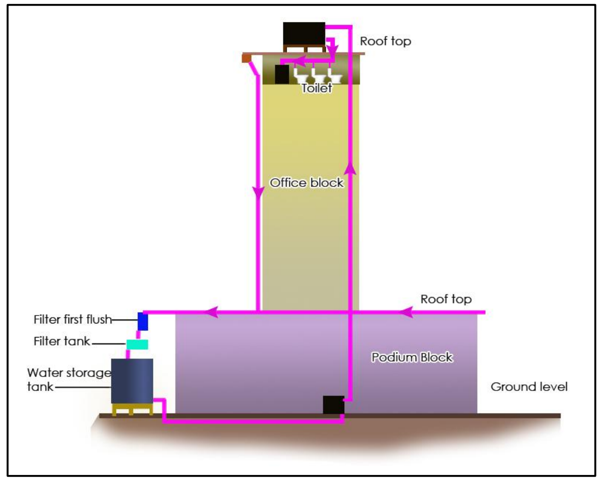

Figure 7.1 Proposed Rainwater Harvesting System

Rainwater Tank

The sizing of rainwater tank is based on the maximum volume of the water capture from the roof area to the rainwater harvesting system. The next step is to calculate the security of supply that is the size of the tank needed to ensure the volume of water collected and stored in the tank will be sufficient to meet demand throughout the year, including during the drier months or through periods of low or no rainfall. This is particularly important in the case where the tank is to represent the sole source of water supply.

There are several mathematical models available for determining the size of tank needed to provide defined security of supply. In some cases, the computer-based models are used to prepare tables of calculated tank size.

The simplest way of checking a tank size estimated to provide water throughout an average year, is to use monthly rainfall data and to assume that at the start of the wetter months the tank is empty. The following formula should then be used for each month:

$$V_t = V_{t-1} + (\text{Runoff} - \text{Demand})$$

V_t = theoretical volume of water remaining in the tank at the end of the month.

V_{t-1} = volume of water left in the tank from the previous month

Starting with the tank empty then $V_{t-1} = 0$. If, after any month, V_t exceeds the volume of the tank, the water will lost to overflow. If V_t is ever a negative figure then demand exceeds the available water. Providing the calculated annual runoff exceeds the annual water demand, V_t will only be negative if periodic overflows reduce the amount of water collected so it is less than the demand.

Tank size is not necessarily based on collecting total runoff (maximum volume of water available) from the roof area. If the water demand is less than the maximum volume of water available then some overflow might occur while demand is still met. If water demand is to be met throughout the year, the tank should be large enough so that V_t is never negative.

Calculations should be repeated using various tank sizes until V_t is ≥ 0 at the end of every month. The greater the values of V_t over the whole year, the greater the security of meeting water demand when rainfalls are below average or when dry periods are longer than normal. The greater the security, the larger the size and cost of the tank shall be.

The maximum tank size and related data are shown in Table 7.1, while the monthly catchment calculation is shown in Table 7.2

Table 7.1: Maximum Tank Size

Average monthly flushing	456,000 liters (Assumes 1000 peoples, 3.8 liter from 6/3 cistern 4 flushes per day/person)
Total annual rainfall	2520 mm
Monthly average (mm) - data from 1983-1997	Jan 107, Feb 200, Mar 266, Apr 293, May 217, Jun 153, July 150, Aug 195, Sept 237, Oct 248, Nov 235 & Dec 219.
Catchment area	6000 m²
Catchment efficiency	75%
Runoff Formula	Runoff (liters) = 0.75 (efficiency) × Rainfall × Roof Area eg. Jan runoff = 0.75 ×107 × 6000 = 481 500 liters
Tank size	750,000 liters

Table 7.2: Monthly Catchment Calculation

Month	Monthly Rainfall (mm)	Runoff (liter)	V_t (liter)
Jan	107	481 500	25 500
Feb	200	900 000	469 500
March	266	1 197 000	1 210 500
April	293	1 318 500	2 073 000
May	217	976 500	2 593 500
June	153	688 500	2 826 000
July	150	675 000	3 045 000
Aug	195	877 500	3 466 500
Sept	237	1 066 500	4 077 000
Oct	248	1 116 000	4 737 000
Nov	235	1 057 500	5 338 500
Dec	219	985 500	5 868 000

Pipe Sizing for Rainwater Installation

The conveyance system of the rainwater harvesting should be designed to ensure the plumbing installation is economic, systematic, can be maintained efficiently and safe by following the standard guidelines and the requirement of local authority

In designing for water supply installation, an assessment must first be made of the probable maximum water flow. In most buildings it seldom happens that the total numbers of appliances installed are ever in use at the same time, and therefore, for economic reasons, it is usual for a system to be designed for a peak usage which is less than the possible maximum usage.

The probable maximum demand can be assessed based on the theory of probability. This method use a *loading unit* rating which is devised for each type of appliance, based on its rate of water delivery, the time the taps are open during usage, and the simultaneous demand for the particular type of appliance.

Table 7.3 gives the loading unit rating for various appliances.

In building where high peak demands occur, a loading unit rating for such appliances is not applicable and 100% of the flow rate for these appliances is required as shown in Table 7.4. The same applies to automatic flushing cisterns for urinals.

The pipe sizing can be determined using a well known practical formula known as Thomas-Box equation given as follows:

$$q = \sqrt{\frac{d^5 \times H}{25 \times L \times 10^5}}$$

where

q = discharge through the pipe (liter/s)
d = diameter of pipe (mm)
H = head of water (m)
L = total length of pipe (m)

Table 7.3: Loading Unit Rating for Various Applications

	Loading Unit Rating
Dwelling and flats	
W.C. flushing cistern	2
Wash basin	1 1/2
Bath	10
Sink	3-5
Offices	
W.C. flushing cistern	2
Wash basin (distributed use)	1 1/2
Wash basin (concentrated use)	3
School and industrial Buildings	
W.C. flushing cistern	2
Wash basin	3
Shower (with nozzle)	3
Public bath	22

Table 7.4: Recommended Minimum Flow Rate at Various Appliances

Type of appliance	Rate of flow (liter/s)
W.C. flushing cistern	0.12
Wash basin	0.15
Wash basin with spray taps	0.04
Bath (private)	0.30
Bath (public)	0.60
Shower (with nozzle)	0.12
Sink with 13 mm taps	0.20
Sink with 19 mm taps	0.30
Sink with 25 mm taps	0.60

Effective Length of Pipe

The diameter of the pipe necessary to give a required flow rate will depend upon the head of water available, the smoothness of the internal bore of the pipe and the effective length of the pipe.

An allowance for the frictional resistance set up by fittings such as elbows, tees, taps and valves must be added to the actual length of the pipe. Table 7.5 gives the allowance for fittings expressed in equivalent pipe lengths.

In calculating the diameter of a pipe to supply individual fittings, the loss of head through the draw-off tap should also be taken into account. Table 7.6 gives the allowances for draw-off taps expressed in equivalent pipe lengths.

Table 7.5: Frictional Resistance of Fittings Expressed in Equivalent Pipe Length

Nominal outside diameter (mm)	Meter run of pipe		
	Elbow	Bend	Tee
15	0.5	0.4	1.2
20	0.6	0.5	1.4
25	0.7	0.6	1.8
32	1.0	0.7	2.3
40	1.2	1.0	2.7
50	1.4	1.2	3.4
65	1.7	1.3	4.2
80	2.0	1.6	5.3
100	2.7	2.0	6.8

Table 7.6: Frictional Resistance of Draw-off Taps Expressed as Equivalent Pipe Lengths

Fitting (BS 1010)	Discharge rate tap fully open (liter/s)	Equivalent length of pipe of same diameter as tap (m)	
		Copper	Galvanised steel
15 mm diameter bib-tap or pillar tap	0.20	2.70	4.00
20 mm diameter bib-tap or pillar tap	0.30	8.50	5.75
25 mm diameter bib-tap or pillar tap	0.60	20.00	13.00

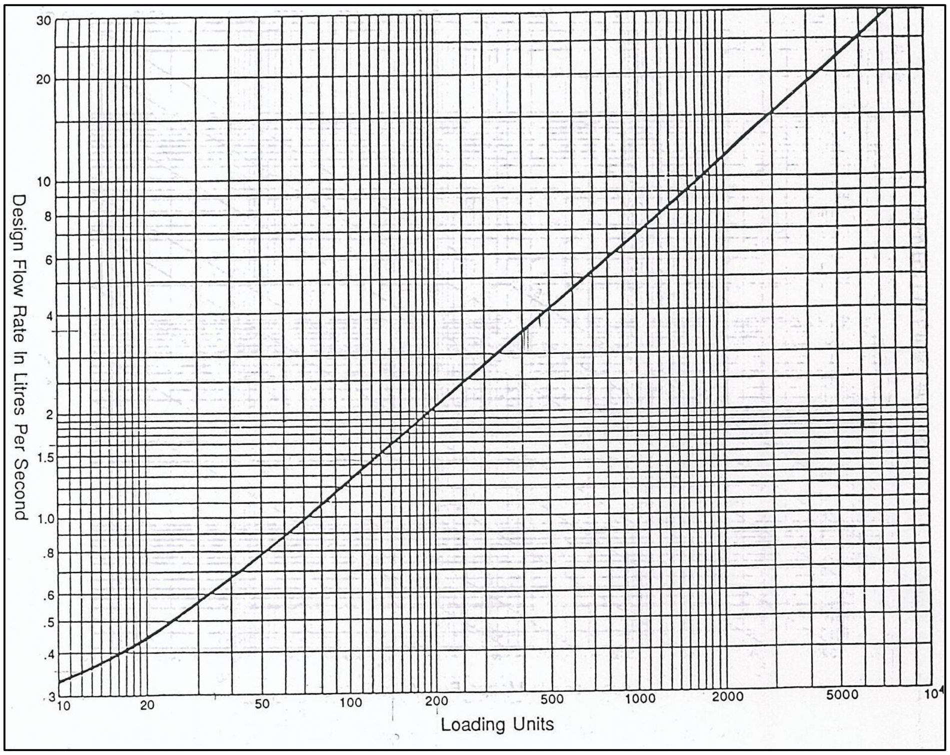

Figure 7.2: Loading Units

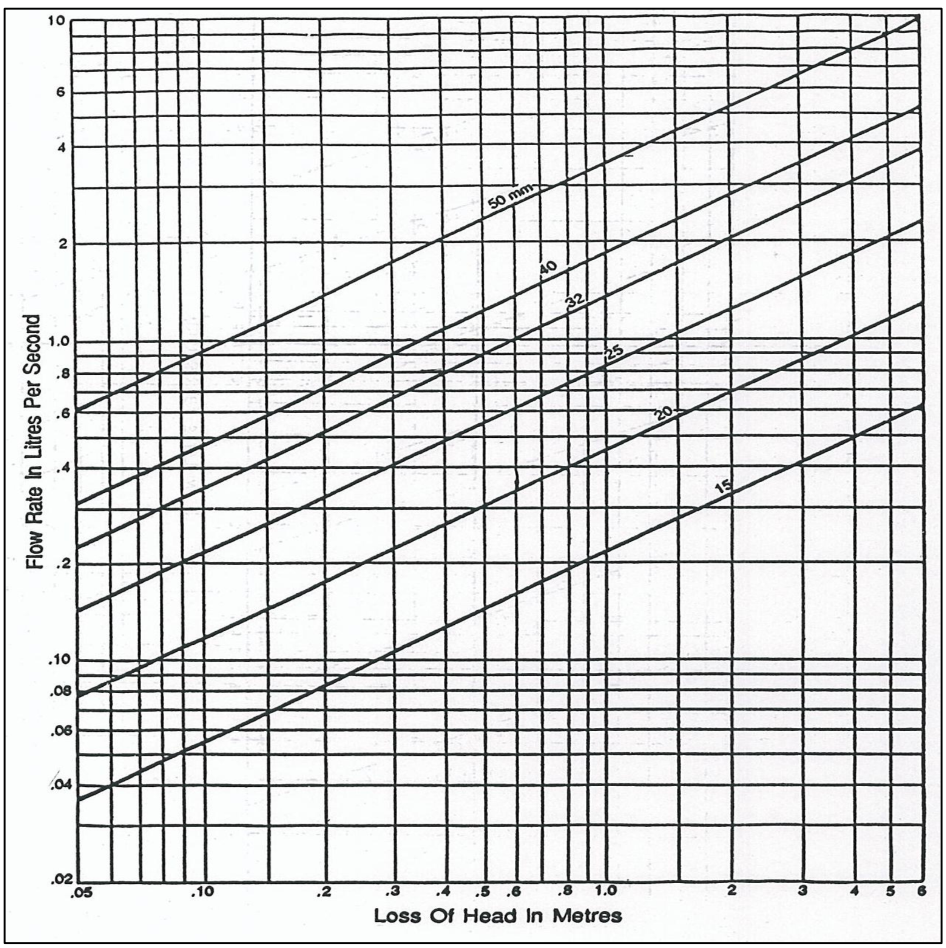

Figure 7.3: Head Loss through Stop Valve

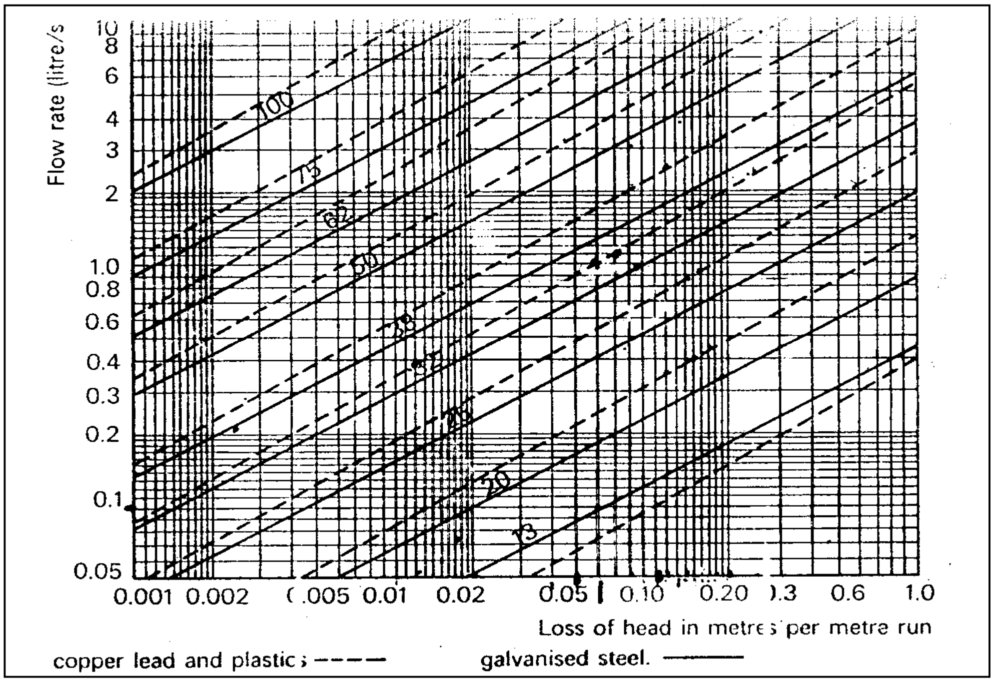

Figure 7.4: Pipe Sizing Chart

Pipe Sizing Example

The calculation of main pipe size for rainwater tank serving a typical bathroom of a commercial building, the appliances in the bathroom consist of 5 W.C. flushing cisterns, 10 wash basins and 5 showers with nozzle. The layout of the system is shown in Figure 7.5.

The calculation of loading rating per unit appliance from Table 7.3.

W.C. flushing system (WC)	= 5 units
Wash basin (WB)	= 10 units
Shower (SR)	= 5 units

The calculation of total loading.

5 WC × 2	= 10 units
10 WB × 1.5	= 15 units
5 SR × 3	= 15 units
Total	= 40 units

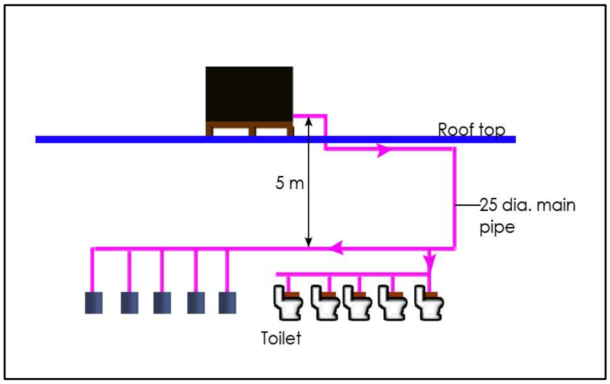

Figure 7.5: Example layout of the Plumbing System Serving a Bathroom

The flow rate for 40 units loading is 0.70 liter/s using relationship between design flow rate and loading unit shown in Figure 7.2.

The calculation of head loss due to frictional resistance for elbow and tee in equivalent pipe length from Table 7.5.

Elbow = 0.7 meter run of pipe

Tee = 1.8 meter run of pipe

The calculation of the effective length of the main pipe serving the appliances in the bathroom. Assuming the system used 25 mm (O.D) galvanized steel pipe.

actual length of the main pipe = 15 meters

effective length = actual length + equivalent length

equivalent length = 4 elbows + 1 tee

equivalent length = $(0.7 \times 4) + (1.8 \times 1)$
= 4.6 meters

effective length = 15 + 4.6
= 19.6 meter

The head loss in 25 mm copper pipe due to frictional resistance obtained from Figure 7.4 is 0.10. The head loss due to fitting of stop valve is equivalent to 0.6 (Figure 7.3). Hence, the total head loss can be calculated as follows:

Total head loss = $(19.6 \times 0.1) + 0.6$

Total head loss = 2.56 meter

The available head is 5 meter, therefore the residual head at appliances distribution point is:

Residual head = 5 – 2.56
= 2.44 meter – the system is adequate.

The calculation of the pipe size using Thomas-Box equation:

Effective length = 19.6

Design pipe flow = 0.70 liter/s

Head = 2.44 m

Therefore

$$d = \sqrt[5]{\frac{0.70^2 \times 25 \times 19.6 \times 10^5}{2.44}} = 25.04mm$$

The pipe size used 25 mm is acceptable.