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CBD 156

Drainage Around Buildings

Originally published 1973

G.P. Williams

Please note

Good drainage around buildings will prevent wet basements, frost heaving problems, and the build-up of hydrostatic pressure on basement floors, banks and retaining walls. A well-designed land drainage system can convert useless, poorly drained land to valuable building sites or permit construction to be carried on during extended periods of wet weather, Good drainage practice can help prevent flooding and erosion and improve the general attractiveness of a site.

Despite these obvious advantages, good drainage is frequently neglected as it is not considered important enough to warrant the same detailed planning as other aspects of building practice. Consequently, many problems that could be prevented by adequate planning of drainage system continue throughout the lifetime of buildings.

It is the purpose of this Digest to outline in general the principles of good drainage practice for the non-specialist. Numerous texts on general hydrology, groundwater and the design of hydraulic structures are available for those interested in pursuing the subject in detail.

Surface Drainage

Estimating Surface Runoff

A surface drainage system should be designed to handle the maximum rate of surface runoff from rain or snow-melt likely to occur at a site The area to be drained, slope, vegetation, and soil type must all be considered. In obtaining design values for surface runoff various methods are available for making the necessary calculations for different terrain and climatic conditions, but they are usually only used when surface run off might be a critical factor, for example in the design of a major culvert. There is little published information on the amount of runoff that can be expected from the relatively small watersheds associated with most building sites.

The most common procedure for determining runoff from rain is the "Rational Method" based on the empirical formula $Q=CIA$, where Q is the rate of runoff in cubic feet per second; C a coefficient of runoff; I the intensity of rainfall in inches per hour; and A the drainage area in acres. Values of C for different surface conditions and slopes are available from handbooks. The rainfall intensity, I, in the formula depends on the design interval chosen (maximum rate of rainfall over a given number of years). For most urban areas in Canada quite high rates of rainfall can be expected for short periods. The maximum 5-min rate of rainfall for a 10-year period ranges from about 0.5 to 0.6 in. for 5 min for Eastern Canada (6.0 to 7.2 in./hr). The rate of runoff also depends on the concentration time, the period required for water from the most remote part of the watershed to reach the location where runoff is being estimated. The concentration time varies with the slope and shape of the watershed; for small watersheds under 5 acres it is usually less than 10 to 15 min. High-intensity, short-duration rainfalls and short concentration times mean that relatively high rates of surface runoff can be expected to occur on small watersheds.

The Rational Method was used to calculate some design values (Figure 1) for maximum runoff from small watersheds and different slope and surface conditions to illustrate the relative amounts of runoff that can be expected. The large decrease in runoff once lawns have been established is evident as is the effect of reducing slopes on reducing peak runoff rates. Reducing the slope and establishing a vegetative cover not only decreases peak runoff but also decreases soil erosion.

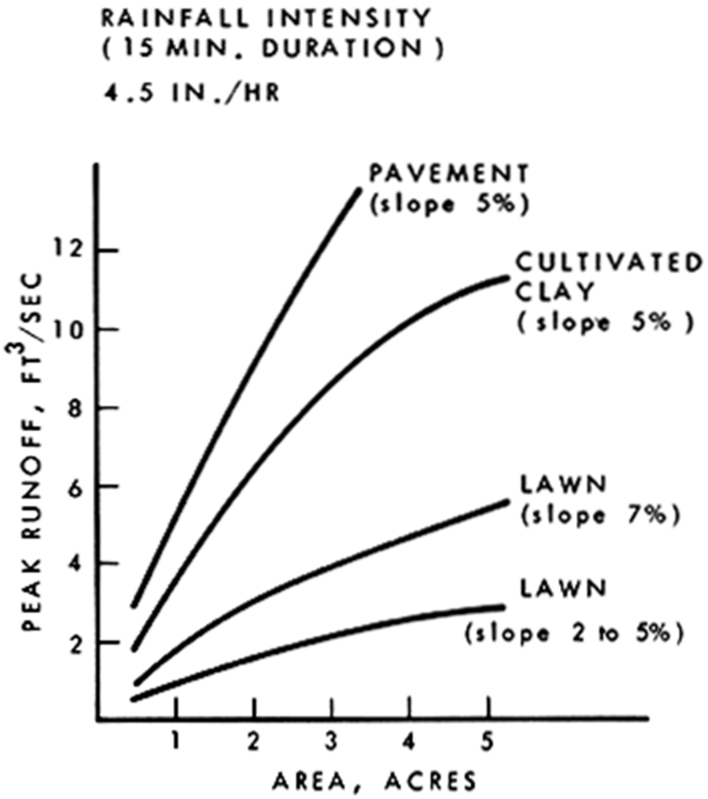

Figure 1. Estimated peak runoff from small watersheds.

The problem of estimating peak runoff from snow-melt is more complex than that of estimating runoff from rainfall. Snow-melt runoff depends on whether or not the ground is frozen, the rate of melting, the amount of snowcover on the ground and the intensity of spring rainfall on a melting snowcover. In general, culverts or ditches designed to carry maximum runoff from rain will also be able to handle snow-melt runoff, provided the culverts or ditches do not become blocked by ice or snow.

Culverts, Ditches and Grading

Once maximum discharge or design surface runoff has been estimated, the size of ditch or culvert needed to handle the flow can be determined. Table I gives approximate culvert and ditch capacities for surface runoff from small watersheds.

Table I

Flow, cfs	Culvert Diameter, in.	Depth of Water in Ditch*, in.

2.5	12	8
5.0	15	12
7.5	18	14
10.0	24	16

* Grade 0.25 ft in 100 ft; 2-ft bottom; 1½: 1 side slope

In general, culverts and ditches should be larger than needed in order to avoid blockage by snow and ice or unexpected sediment and debris. A minimum slope of about 2 ft in 100 ft is recommended for culverts, which should be laid on a solid earth base so that they do not settle when fill is placed on top. Entrances to and exits from culverts should have a good slope to prevent ponding and should be protected by rockfill to prevent erosion. A desirable slope for a ditch is about ¼ to ½ ft in 100 ft. Ditches should be kept free of vegetation and weeds because these substantially reduce flow capacity. Erosion of silt or clay ditches with steep slopes can be prevented by the construction of small check dams. If steep slopes cannot be avoided the ditch should be paved, covered with rock or stones, or sodded.

Control of surface runoff by temporary culverts, ditches and proper grading is especially important during the construction period when there is no vegetation to reduce surface runoff or prevent erosion. Only the areas going into immediate construction should be graded if construction is delayed at a site that has been cleared, temporary cover crops can be seeded or temporary straw mulches used to prevent erosion of the steeper slope. The proper location of access and work roads can also reduce erosion and flooding. Temporary ditches or diversions can be used to divert surface runoff away from unfinished foundations and other sites where flooding would delay construction work unnecessarily. Temporary bench terraces constructed across steep, uncovered slopes can also be effective in reducing erosion and flooding.

In planning the final grading of a site it is important to know the minimum slope that will prevent soft spots or unsightly puddles from forming. A minimum grade of about 0.5 to 1.0 ft in 100 ft should be sufficient for sodded or gravelled areas. Once an area has been sodded or paved quite steep slopes can be tolerated. Generally, the maximum slope is determined by such considerations as erosion, the steepest grade recommended for power lawn mowers, the problem of icy driveways or walks, and the problems of establishing suitable vegetative cover.

Subsurface Drainage

Infiltration, Permeability, Water Table

Rain and snow-melt water that does not appear as surface runoff infiltrates the soil. The rate of infiltration depends on soil type, initial moisture content, surface slope, frost in the soil, and rainfall characteristics. Infiltration rates are highly variable, ranging from as much as 10 to 12 in. per day for coarse-grained soils to less than 0.05 in. per day for heavy clays. Once the rain or snow-melt has penetrated the soil it encounters varying degrees of resistance to flow, depending on the type of soil it must go through. Coarse gravels allow water to flow rapidly and in large quantities; tight clays are so impervious that rates of flow are almost infinitesimal. The "permeability" of gravel is about 1,000 ft per day in contrast with permeabilities of less than 0.001 ft per day for tight clays. Areas with soils having high infiltration rates and high permeability are sometimes used as "soakaways" to absorb surplus storm runoff which would otherwise flood downstream sections of an urban watershed.

Some of the water infiltrating and moving in soil is held by soil particles, but most of it eventually reaches the water table below which the soil is saturated. In general, the water table follows the natural contours of the land, and its depth from the surface varies with the type of soil and amount of rainfall. During wet periods the water table will be close to the surface; during extended dry periods it may be many feet beneath.

Moisture conditions in the soil and the depth to the water table are usually changed drastically by the construction of buildings. During construction, excavations act as a sump for the collection of surface runoff. Infiltration and permeability rates are changed by the movement and compaction of soil by equipment, by service trenches that act as subsurface drainage channels, and by drainage tiles around foundations, which tend to keep the water table below previous levels. In some areas where drainage tile around buildings is not considered a necessity, regular watering of lawns and high runoff from roof areas have substantially raised the depth of the natural water table.

Quite frequently compaction of soil during construction or the occurrence of natural layers of clay lead to what is known as a "perched" water table. This condition arises when a compacted clay layer creates an impervious layer above more pervious material. Water will collect or pond above the clay layer, creating a poorly drained area.

Tile Drainage

Tile drains around the perimeter of footings of foundations are recommended for any site where the water table can be expected to extend above the top of the footing. Tiles are laid with a slight grade towards the storm sewer or, in areas without sewage systems, towards a sump pump inlet in the basement. In some cities without separate storm sewers the tiles are connected directly to the sanitary sewers.

Various types of tile are used for drainage around building foundations. These include clay, porous concrete, perforated corrugated steel, or bell-and-spigot concrete. Use of perforated, corrugated plastic drainage tubing is increasing. Clay tiles, which are commonly used in Canada, are laid with a small gap (about 3/8 in.) between to allow soil water to drain into them.

For most situations with conventional housing, a 4-in. diameter tile will easily handle the water flowing through the soil and into the tile. Although the quantity flowing in foundation tile is small, the combined flow from many buildings can impose an undesirable load where tile is connected directly to a sewage system not designed to handle this additional flow. This overloading of the system sometimes results in back-up of sewage into basements.

The main problem with building tile is to prevent blockage by soil washing into it. Blockage frequently occurs as a result of poor construction practice, for example, from laying broken or poorly aligned tile or from allowing silt or clay deposits to wash into the tile before backfilling takes place. The filter that is placed around tile after it has been laid at the perimeter of a building is of special importance. It must satisfy two conflicting requirements: the pore spaces in the filter must be small enough to prevent fine soil particles from being washed through them, yet large enough to permit water to move through the filter, thus preventing a build-up of the water table around the foundation. The ideal way to achieve this is to place about 12 in. of crushed rock around the tile and cover it with a finer-grained pervious material, such as coarse sand, to keep small particles from washing into the gravel. The coarse sand backfill should extend from the tile to the surface soil around the house to allow surface water to drain freely to the tile. Roof drains should be directed away from the foundation to prevent excessive drainage to the tile through the backfill and filter.

Even small amounts of silt or clay mixed with the sand or gravel can drastically reduce the effectiveness of the filter. Table II illustrates the comparative flow through different materials placed around 100 ft of 4-in. tile under a high hydraulic gradient.

Table II

Material	**Permeability, k, ft/day**	**Flow gpm**
Crushed stone ¼ to 3/8 in.	30,000	45
Clean pea gravel	1,000	10

Fine sand	10	1/10
Silt clay	1/1000	1/100,000

Drainage of a building foundation and site where septic tanks and sump pumps are used poses special problems because the effluent from a tile bed will sometimes drain into the foundation tile. Such systems require careful design and an understanding of the factors that control soil water movement. The quality of water flowing from foundation tile where septic tanks are used is often quite poor, in contrast with that flowing from foundation tile at sites without septic tanks.

Other Subsurface Drainage Problems

Good subsurface drainage is needed for crawl spaces to prevent wet conditions that can lead to deterioration of building materials. Frost heaving of unheated porches or garages, steps, walks and driveways can also be prevented or kept to a minimum by using permeable subgrade material (**CBD 26**). The swelling and shrinking of clays, leading to foundation settlement (**CBD 148**), is related to the drainage problem around buildings.

Subsurface drainage with buried tile is sometimes required in low lying areas to make sites suitable for building purposes and is usually necessary along filled-in gulleys. The considerable information available on depth and spacing of agricultural drainage tile can be drawn upon for the proper design of such drainage systems. The type of soil determines the feasibility of using buried drainage tile. In pervious soils, such as sand or gravel, tile drainage lines may be placed as far apart as 50 or 70 ft; at the other extreme, in some impervious clays they must be placed so close together as to make their use impractical. Tile drainage of soils with a high peat content can lead to severe settlement problems unless adequate allowance is made for soil consolidation.

The most common cause of failure of retaining walls is inadequate drainage. It is not always appreciated that retaining walls or basement walls without adequate drainage are subject to substantial hydrostatic pressures, sufficient to cause collapse if they are not designed to withstand such pressures. For example, a 4-ft wall with saturated-soil backfill will have a hydrostatic pressure of about 250 lb/sq ft at its base. It is therefore important to backfill the retaining wall (and basement wall) with suitable pervious material and provide tiles with adequate filters to drain water from the base. Weepholes in the retaining wall are not as satisfactory as tiles because they tend to become blocked with fine-grained soil.

New methods of ensuring adequate drainage along the outside of basement walls being developed in Sweden and Norway include: corrugated slabs of asbestos cement placed on the outside of the basement wall; plastic panels with knobs or ridges to ensure clearance between the panels and the foundation wall; and mineral wool or glass wool insulation on the outside foundation wall.

The last mentioned method not only provides drainage along the outside wall but also provides thermal insulation and consequently creates a higher temperature on the inside of the wall.

Concluding Remarks

Surface and subsurface drainage systems around buildings are as important as most of the other aspects of building design and thus should receive the same attention. Adequate drainage will prevent erosion and flooding problems during construction and problems such as wet basements after buildings are completed. Good surface drainage can be achieved relatively simply by means of culverts and ditches of sufficient size, proper grading, and well planned ditch systems and diversions. Adequate subsurface drainage around foundations, retaining walls, excavations, and under pavements can be achieved by careful placement of drainage tile and use of suitable filters and permeable backfill material. For any unusual drainage condition a careful site survey and design of a drainage system by a qualified engineer is a sound investment. The benefits from good drainage around buildings will, in most cases, more than justify the relatively small cost associated with planning, designing and constructing a proper system.