Stormwater Network Code in Lebanon

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ACKNOWLEDGEMENT

To begin with, we dedicate this project and these efforts to our beloved country Lebanon.

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ABSTRACT

The main aim of our project is to create a clear and well-organized code for the storm water networks in Lebanon. This project is not intended only to reduce the efforts required for networks establishment, but to increase their efficiency, make water deliverable and avoid the problems of flood.

For this idea, we have been selected for a research grant by HawkaMaa – EU.

On the hand, we will make a complete detailed code for the storm water in Lebanon. This project will contribute in decreasing the waste of water since we do not have until nowadays a clear standard to be followed in Lebanon concerning this topic.

On the other hand, we will present an advocacy plan to convince the stakeholders and our allies to be part in this idea.

CHAPTER I: INTRODUCTION

Lebanon is a small country with a land area of slightly over 10452 km2. Beirut (the capital), Tripoli (in the north), Saida and Tyre (in the south), and Zahle and Baalbek (in the east) are the major cities. Lebanon's mountainous landscape is divided by the Beqaa Valley, a vast agricultural area, and consists of two parallel mountain ranges running north to south.

In December 2016, the resident population of Lebanon was estimated to be around 5.9 million, with 3.3 million estimated persons in need, comprising 1.5 million vulnerable Lebanese, 1.5 million displaced Syrians, and 320,174 Palestinian refugees, according to the Lebanon Crisis Response Plan (LCRP 2017-2020).

As we know, Lebanon is a country rich in water resources, but this situation will not last long due to the lacking behavior of the authority, the fast growing population, the low awareness of most of the people and the drastic climate changes due to the global warming.

For the purpose to proceed, we had to find the answers of these questions:

Why should we collect the storm water in Lebanon?

How to implement a storm water network in Lebanon? What are the standards required related to the site plan, existing facilities?

What are the proper operations and maintenance of all temporary and permanent stormwater management facilities?

This project will affect all the residents of Lebanon and especially those who cannot satisfy their needs for water (drinking and washing) or consume polluted water. But mainly it is directed for civil engineers to open new horizons for them in their country and design all stormwater networks based on a unique code applied all over Lebanon.

CHAPTER II: SYSTEM PLANNING

Designing storm drainage systems is essential to creating effective roadway and transportation networks. In order to prevent flooding of the roadway surface during design flood events and to minimize potential environmental effects from storm water runoff associated with highways, drainage design for highway facilities must work to maintain consistency and minimize interference with existing drainage structures. Storm drainage system planning and implementation must start at the early planning stages of projects in order to achieve these objectives.

The effective creation of a final storm drainage design depends on system planning before design work begins. A final system design that smoothly flows across the project's preliminary and final design stages is the outcome of effective system planning.

2.1 Objectives

Surface drainage must be adequately provided for in stormwater collecting systems. Surface drainage has a close relationship to traffic safety. Hydroplaning dangers are reduced to a minimum when runoff is removed quickly from the pavement.

Stormwater conveyance systems, such as storm drain pipes, ditches and channels, pumps, etc., are intended to transport design flows from intake sites to the discharge point efficiently without surcharging inlets or otherwise resulting in surface flooding.

2.2 Design Approach

Storm water system design is a process that changes as the overall roadway design evolves. Collected data, agency cooperation, preliminary development, concept improvement and design, and final design documentation are the major components of the process.

2.3 Data Requirements

Storm water system design necessitates the collection of some fundamental data, including the following:

- Topographic characteristics, watershed borders, current drainage patterns, and ground cover are identified during watershed mapping.

- Land use mapping identifies current and anticipated future land usage.
- Soil types and hydrologic soil groups are identified on soil maps.
- Flooding patterns and high water mark elevations
- Existing drainage facility descriptions, including size, shape, material, invert information, age, condition, and so on.
- Existing drainage system design and performance data.

2.4 Preliminary Design

1. *Base Map*

The first stage in developing a concept storm water plan is to create a project base map. The watershed areas, land use and cover types, soil types, current drainage patterns, and other topographic characteristics should all be identified on the base map. This fundamental data is then complemented with buried utility locations (and elevations, if available), a preliminary road profile, and the positions of existing and planned structures.

2. *Major and Minor Systems*

Major and minor storm water systems are both taken into account when designing a full storm water system. The parts that were historically relating to the "storm drainage system" constitute the minor system, also known as the "Convenience" system. Curbs, gutters, ditches, inlets, access holes, pipes, other conduits, open channels, pumps, detention basins, water quality control facilities, etc. are some examples of these components. The minor system is typically intended to transport storm event runoff with a 10-year frequency.

When storm water flows surpass the minor system's capacity, the major system offers overland relief. This often happens during less common storm occurrences, including the 25-, 50-, and 100-year storms. The main system is made up of paths that are created allowing the runoff to flow to receiving channels like streams, creeks, or rivers that are either natural or man-made.

The primary system has not received as much attention as the smaller system components in storm drainage design initiatives. Even while the minor system continues to receive greater attention throughout the design process, neglecting the secondary functionality of the major storm drainage system is no longer acceptable.

3. Concept Plan

A conceptual stormwater plan may be created once the basic base map has been finished and the major and minor system components have been identified. The following initial steps should be taken before developing this approach, taking into account both minor and major systems:

- Identify and arrange inlets
- Find the primary outfall
- Find storm mains and other transportation components
- Specify the detention plan and the storage areas.
- Describe your facility locations and water quality control approach.
- Describe the principal system's components.

The designer will be able to go on with the with many of stormwater design calculations, modifications, and improvements with the help of this drawing or schematic.

2.5 System Components

Storm water Collection

The minor storm drainage system, which is supported by the use of roadside and median ditches, gutters, and drainage inlets, is responsible for collecting stormwater.

- *Roadside and median ditches*

Runoff is captured and transported to a suitable storm drain via roadside and median ditches. These ditches should be positioned and formed such that they do not provide a traffic hazards, and they should have sufficient capacity for the designed runoff.

- *Curb and Gutter*

Pavement runoff is captured by gutters, which then transport it down the road shoulder to a suitable storm drain intake. When runoff from the pavement surface threatens to erode fill slopes or when topographic restrictions prevent the creation of roadside ditches, curbs are often constructed in conjunction with gutters.

- *Inlets*

Storm surface water enters storm drains through inlets, which are the receptors for surface water gathered in ditches and gutters. Storm drain inlets are proportioned and placed along the shoulder of the road to prevent surface water from spreading onto the traffic lanes. As used here, the term "inlets" includes all varieties of inlets, including grate inlets, curb inlets, slotted inlets, etc.

Locations for drainage inlets are frequently chosen based on the geometry of the highway as well as the goal of limiting the spread of water onto the surface. To stop water from pouring onto the main road, inlets are often installed at low areas in the gutter grade, junctions, crosswalks, cross-slope reversals, and on side streets.

Storm water Conveyance

When stormwater reaches the primary system, it is transported through the right-of-way and along storm drains connected by access holes or other access structures to the discharge site.

- *Storm Drains*

Storm drains are the part of the storm drainage system that collect runoff from inlets and carry it to a location where it is released into a channel, water body, or other piped system. Storm drains can have an open channel or a closed conduit, and they are made up of pipes or conveyance channels that connect two or more inlets.

- *Inlets, junction boxes, and access holes*

Inlets, junction boxes, and access holes act as alignment base stations and access structures for stormwater systems. Storm drain deflection and access structure spacing are important design factors for these structures.

- *Storm pump stations*

Storm drainage systems must include stormwater pump stations in regions where gravity drainage is impractical or not financially feasible. In order to drain recessed portions of roads, stormwater pump stations are frequently needed.

Storm water Discharge Controls

Controls on stormwater discharge are frequently needed to prevent the consequences that runoff amount and/or quality could have.

- *Detention and Retention Facilities*

Facilities for detention and retention are used to limit the amount of runoff that is released to receiving waterways.

- *Water Quality Controls*

The quality of storm water flows from highway storm water systems is regulated by water quality regulations.

- *Flood Water Relief*

The major system performs the purpose of providing flood water relief. Streets, surface swales, ditches, streams, and/or other flow conduits frequently provide this role by acting as a release mechanism and flow channel for flood waters.

CHAPTER III: HYDROLOGY

The most significant variables that might impact the amount of flood flow include rainfall, snowfall, temperature, wind, hail, and evaporation.

3.1 Rainfall

One of the most prevalent variables in many equations created to estimate runoff, particularly peak discharges, is rainfall.

A hyetograph is a diagram that displays how rainfall quantities change over time. The time component is often represented on the horizontal axis, while the intensity of the rainfall is typically plotted on the vertical axis.

There is no surface runoff when the intensity of the rainfall is lower than the soil's capacity for infiltration. Surface runoff will quickly rise with an increase in rainfall intensity after the infiltration capacity is reached. Due of the storage-induced lag effect, the increase in stream flow does not occur at the same speed as the rise in rainfall overflow.

The following quantitative rainfall factors may be taken into account when estimating flood runoff:

- mean annual precipitation,
- mean seasonal precipitation,
- t-hour (t-h) rainfall intensity of T years of return period,
- mean annual number of thunderstorm days,
- mean seasonal number of thunderstorm days,
- direction of storms,
- antecedent precipitation index,
- storm duration, and
- total storm rainfall.

3.2 Snow

Runoff is typically delayed by snow. Low-peak runoff occurs from a sluggish snowmelt. Rainfall after snowfall, especially in the presence of rising ambient temperatures, can result in runoff peaks that are substantially higher than those that would result from rainfall alone. The extent of snowmelt floods is directly proportional to the drainage area.

The mean annual snowfall, water equivalent of snow before the flood season, and t-h snowmelt rate of T years of return period are some of the snow characteristics that might be taken into account when estimating the runoff.

3.3 Temperature, Wind and Evaporation

Although temperature may not have a direct impact on the amount of flood flow, it does because meteorological changes are linked to differences in atmospheric temperature.

Without air movement, there would be no major moisture transfer, making wind a key player in the hydrologic cycle. Wind directly influences the rates of precipitation, snowmelt, reservoir evaporation, and many other hydrologic processes. The primary cause of winds is horizontal pressure differences.

The process of evaporation involves returning precipitation that has reached the earth's surface to the atmosphere as vapor. Total evaporation, also known as evapotranspiration, is the sum of all evaporation from water, snow, and soil surfaces, as well as evaporation of precipitation that was intercepted and transpiration from plants.

3.4 Infiltration

Infiltration is the process through which precipitation is quantitatively abstracted before it becomes runoff. However, it might be referred to as the phenomena of water penetrating from the ground's surface into the nearby soil for the sake of highway hydrology. Actual infiltration and percolation—the flow of water through the soil—are closely connected processes, with the lesser of the two controlling how much rainfall is actually absorbed by infiltration. As the rain continues, infiltration frequently starts out quickly and falls steadily or exponentially to a much lower rate. The "infiltration capacity" of a soil refers to the highest rate at which it can absorb water in a specific circumstance.

CHAPTER IV: METHODOLOGY

An overview of popular hydrologic techniques and approaches for designing urban storm water network is given in this section.

4.1 Rational Method

The Rational formula, which is offered as one of the most often used formula for calculating peak flow from small regions, is given by the equation below:

$$Q = \frac{CIA}{K_u}$$

Where:

Q: flow (m^3/s)

C: Dimensionless, runoff coefficient

I: Rainfall Intensity (mm/hr)

A: Area (m^2)

K_u: units' conversion factor equal to 360

In general, the minimum design storm frequency to be used is **10 years**.

The following are the implicit assumptions in the Rational formula:

- When the whole watershed is contributing to the flow, peak flow occurs.
- The drainage region has the same amount of rainfall.
- Over a period of time equal to the time of concentration, t c, the intensity of the rain is constant. The concentration time is the amount of time needed for water to go from the place in the basin that is hydraulically farthest from the location of interest.
- Coefficient of runoff is the same for all storms of all recurrence probabilities;
- Frequency of the calculated peak flow is the same as that of the rainfall intensity, i.e., the 10-year rainfall intensity is assumed to cause the 10-year peak flow.

The Rational formula should only be used for drainage areas smaller than 80 ha due to these underlying assumptions.

4.1.1 Runoff Coefficient C

The ground cover and a variety of other hydrologic abstractions influence the runoff coefficient, C. It connects the projected peak discharge to a maximum theoretical runoff of 100%. The table below provides typical values for C. If the basin has several types of land cover or other abstractions in varied proportions, a composite coefficient can be determined using areal weighing as follows:

$$C = \frac{\sum C_x A_x}{\sum A_x}$$

Where:

x: subscript designating values for area with consistent cover land.

Table 1: Runoff Coefficients.

Type of Drainage Area	Runoff Coefficient, C*
Business:	
Downtown areas	0.70 - 0.95
Neighborhood areas	0.50 - 0.70
Residential:	
Single-family areas	0.30 - 0.50
Multi-units detached	0.40 - 0.60
Multi-units attached	0.60 - 0.75
Suburban	0.25 - 0.40
Apartment dwelling areas	0.50 - 0.70
Industrial:	
Light areas	0.50 - 0.80
Heavy areas	0.60 - 0.90

Parks cemeteries	0.10 - 0.25
Playgrounds	0.20 - 0.40
Railroad yard areas	0.20 - 0.40
Unimproved areas	0.10 - 0.30
Lawns:	
Sandy soil, flat, 2%	0.05 - 0.10
Sandy soil, average 2 7%	0.10 - 0.15
Sandy soil, steep, 7%	0.15 - 0.20
Heavy soil. flat 2%	0.13 - 0.17
Heavy soil, average, 2 7%	0.18 - 0.22
Heavy soil, steep, 7%	0.25 - 0.35
Streets	
Asphaltic	0.70 - 0.95
Concrete	0.80 - 0.95
Brick	0.70 - 0.85
Drives and walks	0.75 - 0.85
Roofs	0.75 - 0.95
Higher values are usually appropriate for steeply sloped areas and longer return periods because infiltration and other losses have proportionally smaller effects on runoff in these cases.	

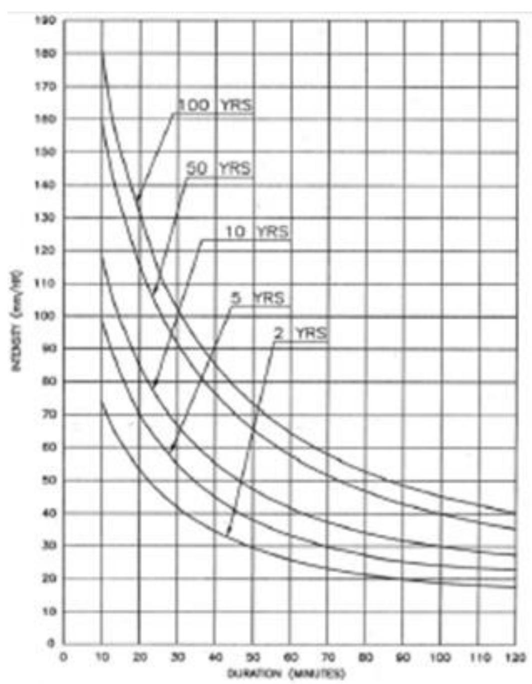
4.1.2 Rainfall Intensity

The amount of rain that falls in a certain time interval equated to its equivalent in millimeters per hour. To apply the Rational technique, rainfall intensity, duration, and frequency curves are required. Since in Lebanon, IDF curves are not available, they must be developed.

Table 2: IDF curves in Beirut.

	2 y	5 y	10 y	50 y	100 y
10 min	74.13	98.65	118.37	159.31	181.02
20 min	53.33	70	84.9	115.38	131.22
30 min	41.89	55.01	66.81	91.6	102.23
60 min	25.94	33.31	41.69	57.86	64.54
90 min	20	25.37	31.68	43	48.76
120 min	17.78	23	27.42	35.34	40.3

Table 3: Rainfall intensity duration curves in Beirut.



4.1.3 Time of Concentration

The term "time of concentration" is generally defined as "the time required for runoff to travel from the most remote point in the contributing watershed (point from which the travel time of flow is greatest) to the point of interest."

It has been suggested to apply the Kirpich equation, which is often used to determine time of concentration:

$$t_c = \frac{0.0078 \times (3.28L)^{0.77}}{S^{0.385}}$$

Where:

t_c = time of concentration, min

L= length of travel,

S= slope, m/m.

4.2 Appurtenances

4.2.1 Curb and Gutter

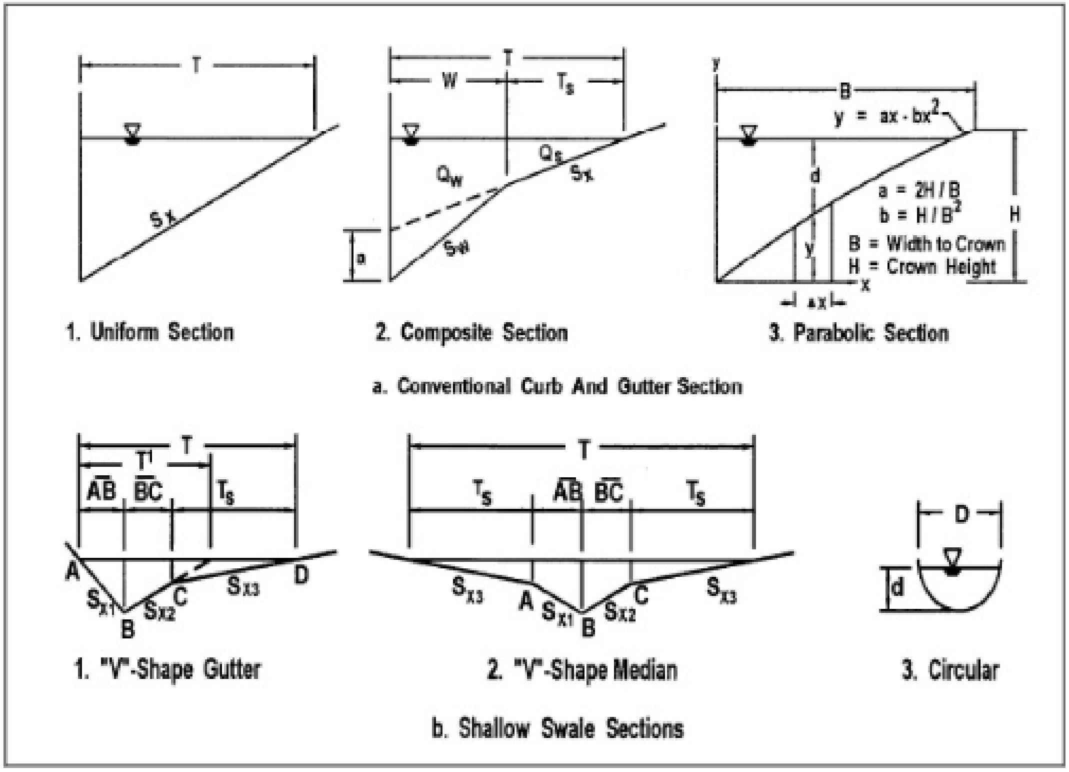


Figure 1: Typical gutter sections.

Gutters that are constructed in conjunction with curbs range in size from 0.3 to 1.0 meters. Gutter cross slopes may be created with a higher cross slope, typically 80 mm per meter steeper than the shoulder or parking lane, or they may be the same as that of the pavement.

For low-speed highways, curbs are often used along the outside edge of the pavement, and occasionally next to the shoulders for moderate- to high-speed facilities. They accomplish the following goals:

- Ensure pavement delineation
- Prevent flooding on fill slopes
- Keep surface runoff inside the route and away from neighboring properties
- Enable the orderly development of land next to the roadway

Curb and gutter construction creates a triangle-shaped channel that may carry runoff at or below the design flow without affecting traffic. The delivered water surface spreads or widens as a design flow occurs. Parking lanes, shoulders, and some of the traveled surface are all included in the water's spread beyond the gutter's width.

The hydraulic engineer is concerned about spread in curb and gutter flow. To determine the amount of the water on the road, the spread, T, is measured perpendicular to the curb face.

The Manning's equation is integrated for a width increment over the segment to determine gutter flow. The result is as follows:

$$T = \left(\frac{Qn}{0.397 \times S_x^{5/3} \times S_L^{1/2}} \right)^{3/8}$$

Where:

n = Manning's coefficient

Q = Flow rate (m^3/s)

T = Width of flow (spread) (m)

S_x = Cross slope (m/m)

S_L= Longitudinal slope (m/m)

Spread on the pavement and flow depth at the curb are often used as criteria for spacing pavement drainage inlets.

$d = T\ S_x$

Where d: depth of flow (m)

Table 4: Manning's n for street and pavement gutters.

Type of Gutter or Pavement	Manning's n
Concrete gutter troweled finish	0.012
Asphalt Pavement:	
Smooth texture	0.013
Rough texture	0.016
Concrete gutter-asphalt pavement:	
Smooth	0.013
Rough	0.015
Concrete pavement:	
Float finish	0.014
Broom finish	0.016
For gutters with small slopes, where sediment may accumulate, increase above values of "n" by	0.002

A tiny circular or V-shaped piece of a swale may be used to transport runoff off the pavement in areas where curbs are not required for traffic management.

As an example, it could be necessary to regulate pavement runoff on fills in order to prevent erosion of the embankment. Small swale sections could have enough strength to transport the flow to a spot where it can be intercepted.

4.2.2 Inlets

Where gutter capacity requirements are violated, an inlet is necessary at the top of the gutter section. To reach this point, the intake is moved, modifying the drainage area in the process, until the tributary flow reaches the gutter capacity. The location of the point at which the combined flow from the new contributing region and the bypassing flow exceeds the gutter capacity determines the spacing between subsequent inlets. Where the roadway cross slope starts to super elevate, inlets are also necessary. These inlets are designed to lessen the traffic hazards caused by street oncoming vehicles.

Runoff is collected and discharged into an underground storm drainage system via storm drain inlets. Inlets are often found in roadside and median ditches, paved medians, and gutter section. The following four sorts of inlets can be used:

- Grate inlets
- Curb-opening inlets
- Slotted inlets
- Combination inlets

Grate inlets function well across a variety of gutter grades as a group. In general, grate inlets lose capacity as the gradient rises, although less so than curb opening inlets. The main benefit of grate inlets is that they may be positioned where the water is flowing—along the road. Their main drawback is that floating garbage or other material can block them. Grates with potential for involvement by out-of-control vehicles should be preferred for safety reasons. Grates should also be bicycle-safe where there is bicycle traffic.

Curb-opening inlets work best in sags, with flows that frequently convey a lot of floating debris, and on flatter slopes. As the gutter gradient steepens, the interception capacity of curb-opening inlets reduces. Therefore, it is advised to use curb-opening inlets in sags and on gradients lower than 3%. They are, of course, also safe for bicycles.

Combination inlets offer the benefits of both grate and curb opening inlets. The benefits of both grate and curb-opening inlets are combined to provide a high capacity inlet.

When it is preferred to stop sheet flow before it enters a stretch of highway, slotted drain inlets might be employed. Their capacity to intercept flow over a large length is their main benefit. Slotted inlets are not advised for use in settings where there may be considerable sediment or debris loads because they are highly susceptible to blockage by sediments and debris.

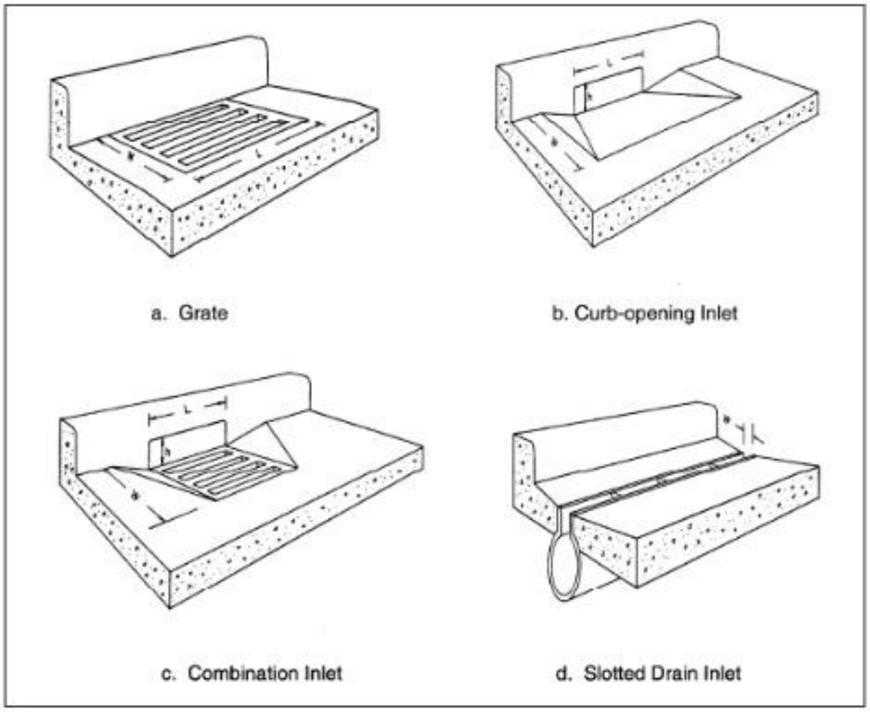


Figure 2: Classes of storm drain inlets.

4.2.3 Manholes

A manhole's principal purpose is to offer easy access to the storm drainage system for maintenance and inspection. Manholes may also reduce the pressure and act as flow junctions, which are additional uses for them in storm drainage systems. Pre-cast and cast-in-place concrete are the two materials that are most frequently used for access hole construction. Pre-cast concrete manhole sections are often used in Lebanon since they are readily available and reasonably priced.

Storm drain maintenance requirements have led to the development of access hole placement and spacing standards. Manholes should be placed at least where the following points are:

- Where pipe diameters vary
- Where an alignment change takes place
- Where a grade change occurs
- Where two or more storm drains intersect

The maximum spacing between two manholes are proportional to the size of pipes used. The table below represent the maximum spacing.

Table 5: Access hole spacing criteria.

Pipe Size mm (in)	Suggested Maximum Spacing m (ft)
300 - 600 (12 - 24)	100 (300)
700 - 900 (27 - 36)	125 (400)
1000 - 1400 (42 - 54)	150 (500)
1500 and up (60 and up)	300 (1000)

The internal size of the bottom chamber is large enough to execute inspection and cleaning operations without trouble, and the majority of access holes are circular. A minimum inside diameter of 1.2 m has been adopted widely with 1.5 m diameter access hole being used for larger diameter storm drains.

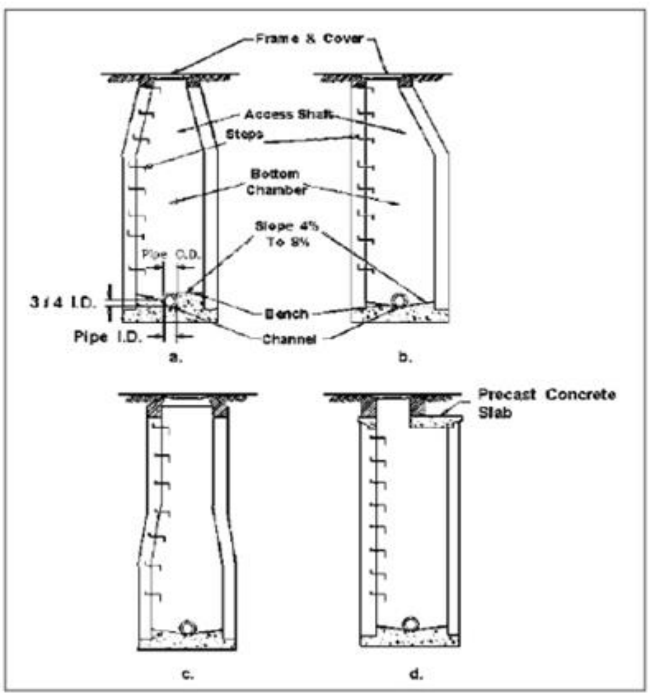


Figure 3: Typical access hole configurations.

Manhole frames and covers are made to maintain opening provisions while resisting improper opening, give a suitable fit between the cover and the frame, and provide sufficient strength to withstand superimposed loads (primarily from children).

The storm drain profile and surface topography will determine the depth needed for a manhole. The depths of typical manholes range from 1.5 to 4.0 m. It is advised that the access hole diameter match the depth for deeper penetrations. 1.2 to 1.5 meters wide is the range for access holes.

The insulation of rainwater manholes is important to prevent the infiltration of groundwater or surface water into the manhole, which can cause problems such as overflow, flooding, and contamination. There are several methods of insulating rainwater manholes, including:

- Waterproofing coatings: A waterproofing coating is applied to the surface of the manhole walls and floor to prevent the ingress of water. The coatings can be made of various materials such as cementitious, epoxy, or polyurethane.
- Sealing joints: The joints between the manhole walls and floor are sealed with a flexible sealant to prevent water from entering the manhole.
- Installation of a waterproof liner: A waterproof liner made of materials such as PVC or HDPE can be installed inside the manhole to prevent water infiltration.
- Grouting: A grout material is injected into the voids between the manhole walls and the surrounding soil to create a watertight barrier.
- Installation of a prefabricated manhole: A prefabricated manhole made of materials such as concrete or fiberglass can be installed to provide a completely waterproof structure.

The choice of insulation method depends on factors such as the type of soil, the depth of the manhole, the water table level, and the local regulations.

The concrete used for the manhole should have a minimum compressive strength of 25 MPa. The manhole should be reinforced with steel bars to increase its strength and durability.

The size and spacing of the reinforcement bars will depend on the size of the manhole, the anticipated loads, and the local regulations. Typically, the reinforcement bars will be placed in both the walls and the base of the manhole to ensure that it can withstand the anticipated loads.

In general, the reinforcement bars should have a minimum yield strength of 400 MPa and be placed at a spacing that is no greater than 150mm. The bars should also be positioned to ensure that they are adequately covered by the concrete to prevent corrosion.

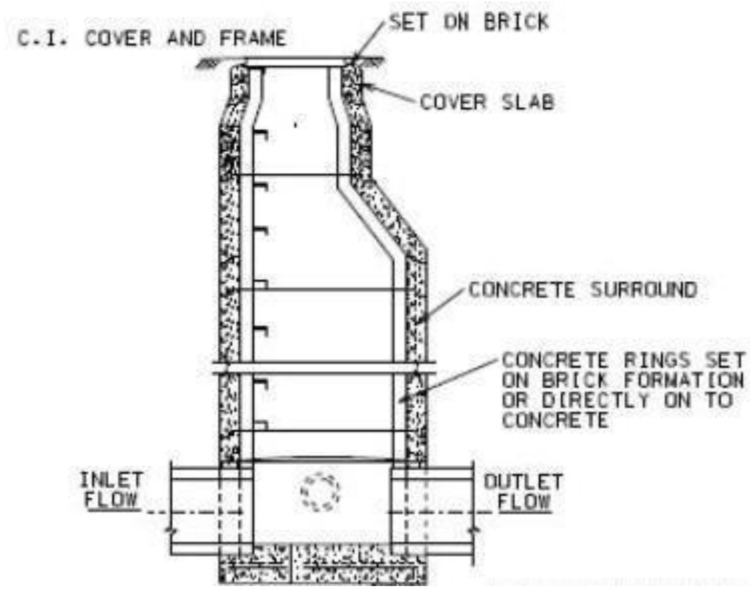


Figure 4: Precast Concrete Manhole.

Making a connection within a manhole between the inlet and outlet pipes in a stormwater collection system requires careful planning and proper installation techniques to ensure a watertight and secure connection.

A hole should be cut in the manhole wall or base at the connection point. The size of the hole should be slightly larger than the diameter of the pipe to allow for proper installation. A flexible connector, such as a rubber seal or PVC adapter, should be installed in the hole to create a watertight seal between the inlet and outlet pipes. The connector should be properly sized and installed to ensure a snug fit between the pipes and the manhole. The connector should be secured to the inlet and outlet pipes and the manhole using clamps or other fasteners. The clamps should be tightened to ensure a tight seal and prevent movement of the connector. The connection should be tested for leaks by filling the manhole with water and monitoring the inlet and outlet pipes for any signs of water infiltration. Once the connection is properly installed and tested, the manhole should be backfilled and compacted to ensure proper support and stability.

Figure 5: Connection within manhole.

4.2.4 Pipes

The section of the highway stormwater system that accepts surface water through inlets and transports it through conduits to an outfall is known as a storm pipe. It is made up of various pipe or conduit lengths and diameters joined by auxiliary components. The storm conduit is most frequently a circular pipe; however other enclosed conduit designs, such a box, are also possible.

The design approaches described here includes continuous, uniform flow inside each segment of a storm drain. This implies that it is expected that the discharge and flow depth are independent of both time and distance in each section. Additionally, because storm drain pipes are frequently prismatic, the average velocity along a segment is thought to be constant.

The minimum design velocity for piped drainage has been limited to 0.75 m/s. Maximum velocity shall not exceed 5 m/s.

For circular pipes flowing full, velocity and flow are estimated using Manning's formula as follows:

$$V = \frac{0.397}{n} D^{2/3} S^{1/2}$$

$$Q = \frac{0.312}{n} D^{8/3} S^{1/2}$$

Where:

n= Manning’s roughness coefficient

S= Friction slope, (m/m)

V= Velocity stipulated (m/s)

Q= flow in pipe (m^3/s)

D= Diameter of the pipe (m)

Table 6: Typical range of Manning's coefficient (n) for channels and pipes.

Conduit Material	Manning's n•
Closed Conduits	
Concrete pipe	0.010 - 0.015
CMP	0.011 - 0.037
Plastic pipe (smooth)	0.009 - 0.015
Plastic pipe (corrugated)	0.018 - 0.025
Pavement/gutter sections	0.012 - 0.016
Small Open Channels	
Concrete	0.011 - 0.015
Rubble or riprap	0.020 - 0.035
Vegetation	0.020 - 0.150
Bare Soil	0.016 - 0.025
Rock Cut	0.025 - 0.045
Natural channels (minor streams, top width at flood stage <30 m (100 ft))	
Fairly regular section	0.025 - 0.050
Irregular section with pools	0.040 - 0.150
•Lower values are usually for well-constructed and maintained (smoother) pipes and channels	

The pipe material used in a stormwater system can be affected by traffic, particularly if the pipes are located in areas with heavy vehicular traffic or where the ground is subject to settlement or movement. The type of pipe material used in a stormwater system can affect its resistance to traffic loads.

In addition, the depth of the pipe installation can also affect its resistance to traffic loads. Pipes that are installed at shallow depths may be more susceptible to damage from traffic loads and settlement than pipes that are installed at deeper depths.

To minimize the effects of traffic on stormwater pipes, it is important to carefully consider the type and size of pipe material used, as well as the depth of installation and the surrounding soil conditions. It may also be necessary to reinforce the pipes with additional materials, such as steel or concrete.

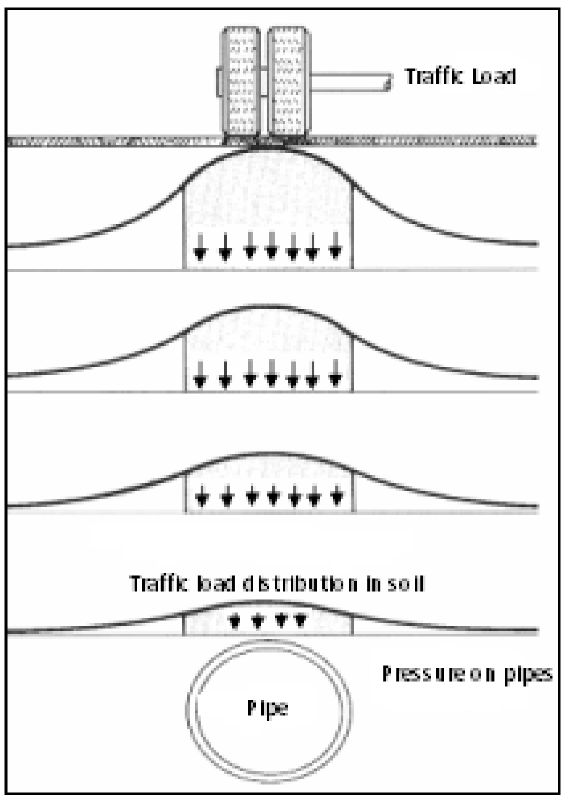


Figure 6: Traffic effect.

Table 7: Proportion of (long) superficial loads pipes in trenches.

Ratio of depth to width	Sand and topsoil	Saturated topsoil	Wet loamy soil	Saturated loamy soil
0.0	1.00	1.00	1.00	1.00
0.5	0.85	0.86	0.88	0.89
1.0	0.72	0.75	0.77	0.80
1.5	0.61	0.64	0.67	0.72
2.0	0.52	0.55	0.59	0.64
3.0	0.37	0.41	0.45	0.51
4.0	0.27	0.31	0.35	0.41
5.0	0.19	0.23	0.27	0.33
6.0	0.14	0.17	0.20	0.26
8.0	0.07	0.09	0.12	0.17
10.0	0.04	0.05	0.07	0.11

Table 8: Proportion of (short) superficial loads pipes in trenches.

Ratio of depth to width	Sand and topsoil	Saturated topsoil	Wet loamy soil	Saturated loamy soil
0.0	1.00	1.00	1.00	1.00
0.5	0.77	0.78	0.79	0.81
1.0	0.59	0.61	0.63	0.66
1.5	0.46	0.48	0.51	0.54
2.0	0.35	0.38	0.40	0.44
2.5	0.27	0.29	0.32	0.35
3.0	0.21	0.23	0.25	0.29
4.0	0.12	0.14	0.16	0.19
5.0	0.07	0.09	0.10	0.13
6.0	0.04	0.05	0.06	0.08
8.0	0.02	0.02	0.03	0.04
10.0	0.01	0.01	0.01	0.02

Table 9: Minimum crushing strength of clay pipe (ASTM).

Nominal size (mm)	Extra strength clay pipe, kgf/linear (m)	Standard strength clay pipe, kgf/linear (m)
100	2980	1790
150	2980	1790
200	3270	2080
250	3570	2380
305	3870	2680
380	4320	2980
460	4910	3270
530	5730	3570
610	6550	3870
690	6990	4170
760	7440	4910
840	8190	5360
915	8930	5960

Table 10: Physical and dimensional requirements for non-reinforced concrete pipes (ASTM).

Internal diameter, (mm)	Class l		Class 2		Class 3	
	Minimum thickness of wall, (mm)	Minimum strength, kN/linear m, three-edge bearing	Minimum thickness of wall, (mm)	Minimum strength, kN/linear m, three-edge bearing	Minimum thickness of wall, (mm)	M inimum strength, kN/linear m, three-edge bearing
100	15.9	21.9	19.0	29.2	22.2	35.0
150	15.9	21.9	19.0	29.2	25.4	35.0
200	19.0	21.9	22.2	29.2	28.6	35.0
250	22.2	23.3	25.4	29.2	3l.8	35.0
310	25.4	26.3	34.9	32.8	44.5	37.9
380	3l.8	29.2	4 1.3	37.9	47.6	42.2
460	38.I	32 I	50.8	43.8	57.2	48.l
530	44.5	35.0	57.2	48.1	69 9	56.2
610	54.0	37.9	76.2	52.5	95.3	64.2

Table 11: Supporting strength of concrete pipe.

	Standard strength Concrete sewer pipe, C 14 Safety factor = 1.5				Extra strength Concrete sewer pipe, C 14 Safety factor = 1.5			
Bedding class	D	C	B	A	D	C	B	A
Load factor	1.1	1.5	1.9	3.0	1.1	1.5	1.9	3.0
Internal diameter of pipe, (mm)	Supporting strength, (kN/m)							
150	11.68	16.06	20.44	32.12	21.90	29.20	36.50	58.40
200	13. 14	18.98	23.36	37.96	21.90	29.20	36.50	58.40
250	14.60	20.44	26.28	40.88	21.90	29.20	36.50	58.40
310	16.06	21.90	27.74	43.80	23.36	32. 12	40.88	65.70
380	17.52	24.82	32.12	51.I0	29.20	40.88	51.10	80.30
460	20.44	29.20	36.50	58.40	35.04	48. 18	61.32	96.36
530	23.36	32. 12	40.88	64.24	40.88	55.48	71.54	113.88
610	42.82	35.04	43.80	70.08	42.34	58.40	74.46	116.80

Table 12: Design loads for reinforced concrete pipe (ASTM).

Design load, *(N/m* per mm diameter)		
Class	To produce a 0.25 mm crack	Ultimate
I	38.3	57.4
II	47.9	72
III	64.6	95.8
IV	95.8	144.0
V	144.0	180.0

Stormwater pipelines generally do not require pressure breakers as they are typically designed to operate under gravity flow conditions. Unlike pressurized systems, such as water supply or irrigation systems, stormwater systems do not rely on pressure to move water through the pipes. Instead, stormwater systems rely on the natural slope of the land and the pipe to facilitate the movement of water.

However, there are some instances where a pressure breaker may be required in a stormwater system. For example, if the stormwater pipeline discharges into a water body that is at a higher elevation than the pipeline, a pressure breaker may be required to prevent backflow from the water body into the pipeline during high water events.

4.2.5 Outfall

Every storm drain has an exit where the storm drainage system's flow is released. A natural river or stream, an existing storm drainage system, or a canal that is either already in place or is being considered for the purpose of diverting storm water away from the roadway can all serve as the discharge point. The outfall is where the process to determine the energy grade line through a storm water system begins. As a result, taking outfall circumstances into account is crucial for storm drain design.

Outfall design must take a number of factors into careful account. These include the planned storm drain outlet's flow line or invert (inner bottom) elevation, tail water levels, the requirement for energy dissipation, and the outlet structure's orientation.

The projected outlet's flow line or invert elevation has to be on par with or higher than the outfall's flow line.

Care must be used while determining the tail water depth or elevation in the storm pipe outfall. At the system outfall with the tail water elevation, the hydraulic grade line for a storm water system is assessed. For the majority of design applications, the tail water will either be above the outlet's crown or may be regarded as being between the crown and the outlet's critical depth.

It could be necessary to use energy dissipation to secure the storm drain exit. The outfall bed and banks must often be protected at the outlet to avoid erosion.

Draining stormwater into natural springs can have several risks and negative impacts on the environment and human health. Some of these risks include:

- Contamination: Stormwater runoff can carry pollutants such as oil, pesticides, and other chemicals that can contaminate natural springs. These pollutants can harm aquatic life and make the water unsafe for human consumption.
- Erosion: Excessive stormwater runoff can cause erosion and sedimentation, which can alter the physical characteristics of the spring, including its flow rate and temperature. This can have negative impacts on aquatic life and the surrounding ecosystem.
- Flooding: Large volumes of stormwater runoff can overwhelm natural springs, leading to flooding and property damage.
- Spread of disease: Stormwater runoff can contain harmful bacteria, viruses, and other pathogens that can spread disease if they contaminate natural springs that are used for drinking or recreational purposes.

Loss of biodiversity: Natural springs are often important habitats for a variety of plant and animal species. Draining stormwater into these areas can alter the natural balance and biodiversity of the ecosystem.

Stormwater can be collected in large quantities in Lebanon, particularly during the rainy season. However, the amount of stormwater that can be collected and the methods used to collect it may vary depending on the specific location and local conditions.

The proper method of draining stormwater into the sea involves a combination of proper design, construction, and maintenance of the stormwater drainage system to ensure that the discharge is safe and environmentally sound.

There have been various tests conducted on the quality of rainwater in Lebanon. However, the results of these tests can vary depending on the location and specific conditions at the time of testing.

In general, rainwater in Lebanon can be contaminated with various pollutants, including sediment, bacteria, heavy metals, and chemicals from industrial and agricultural activities, as well as from urban runoff. The level of contamination can be influenced by various factors, such as the location of the rain gauge, the time of year, and the intensity of rainfall.

In recent years, there has been an increased focus on monitoring and improving the quality of rainwater in Lebanon. This includes the implementation of various stormwater management strategies, such as the construction of green infrastructure, the use of permeable pavements, and the installation of stormwater treatment systems.

Stormwater should be treated to remove pollutants, sediment, and other contaminants before it is discharged into the sea. This can be accomplished through various methods such as sedimentation, filtration, and biological treatment. The stormwater drainage system should be designed to handle the expected volume of stormwater runoff during heavy rain events. The capacity of the system should be sufficient to prevent flooding and ensure that the outfall does not become overwhelmed during heavy rain events.Moreover, regular monitoring of the quality of the discharged stormwater is essential to ensure that it meets the required environmental standards. This can include testing for pollutants such as oil, chemicals, and bacteria.

CHAPTER V: OPEN CHANNEL FLOW

The following sections provide concise summaries of various significant open channel flow principles and relationships.

Open channel flow is based on the fundamental principle of energy conservation. The sum of the potential energy head (elevation), pressure head, and kinetic energy head is used to represent the total energy at a certain place in an open channel (velocity head).

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + H_L$$

Where:

Z = Elevation above a given datum (m)

P: Pressure (Pa)

V = Mean velocity (m/s)

g = Gravitational acceleration, 9.81 (m/s^2)

H_L: Head Losses (m)

5.1. Design

The force of gravity causes water to flow in an open channel. The friction between the water and the channel barrier resists flow. There are no accelerations, streamlines are parallel and straight, and the pressure distribution is hydrostatic in steady, uniform flow.

The easiest flow condition to understand is this one, but it doesn't happen very often in reality. For many applications, however, the flow is essentially constant and variations in breadth, depth, or direction (which cause non uniform flow) are so little that the flow may be regarded as uniform. The Manning's equation is the formula that is most frequently used to solve situations with steady, uniform flow:

$$V = \frac{1}{n} R^{2/3} S^{1/2}$$

$$Q = \frac{A}{n} R^{2/3} S^{1/2}$$

Where:

n= Manning’s roughness coefficient

S= Friction slope, (m/m)

V= Velocity stipulated (m/s)

Q= flow in pipe (m^3/s)

D= Diameter of the pipe (m)

In the case of open channel, the quantity of flow can vary considerably, with virtually no flow in the dry season to maximum flow at the peak of a storm. a maximum velocity of 6 m/s is allowed in concrete channels although higher velocities may be tolerated. A minimum velocity of 0.6m/s is sought to achieve self-cleaning of the pipe and prevent deposition and settling of fine material.

Table 13: Typical channel lining Manning's roughness coefficients.

Lining Category	**Lining Type**	Manning's n		
		Maximum	**Typical**	**Minimum**
Rigid	Concrete	0.015	0.013	0.011
	Grouted Riprap	0.040	0.030	0.028
	Stone Masonry	0.042	0.032	0.030
	Soil Element	0.025	0.022	0.020
	Asphalt	0.018	0.016	0.016
Unlined	Bare Soil	0.025	0.020	0.016
	Rock Cut	0.045	0.035	0.025
RECP	Open-weave textile	0.028	0.025	0.022
	Erosion control blanket	0.045	0.035	0.028
	Turf reinforcement mat	0.036	0.030	0.024

5.2. Channel Geometry

Most storm water drainage ditches around highways have a trapezoidal form. The graphic below shows many popular forms along with calculations for calculating channel characteristics. To provide the required flow area, the channel depth, bottom width, and top width must be chosen. For triangular or trapezoidal channels, the side slopes should typically be 1V:3H or less and should not be more than the angle of repose of the soil and/or lining material.

Channel side slopes should be 1V:4H or less steep in situations where traffic safety may be an issue.

To ensure stability, channel gradients higher than 2% may need the use of flexible linings. With the exception of certain grasses, the majority of flexible lining materials are appropriate for covering channel gradients of up to 10%. The maximum depth allowable in open channel is 1 m.

Due to conditions like overtopping, freeze-thaw cycles, swelling, and high soil pore water pressure, rigid linings like concrete pavement are vulnerable to collapse from structural instability.

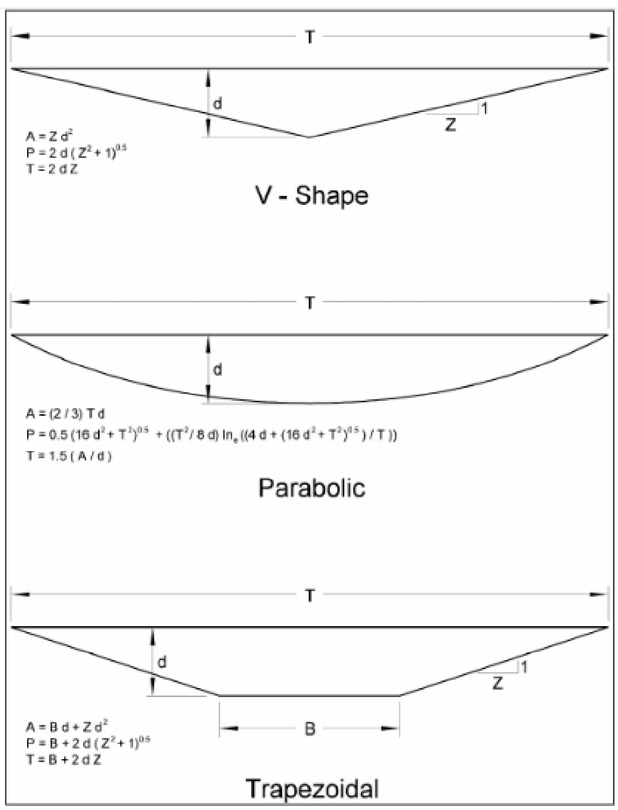


Figure 7: Channel geometries.

Open channel flow, which refers to the flow of water in an open channel, can be used in stormwater systems to convey stormwater runoff to a downstream location. However, there are several limitations to using open channel flow in stormwater systems:

- Limited capacity: Open channels have a limited capacity for carrying stormwater, which means that they may not be able to handle large storm events, leading to flooding and property damage.
- Maintenance requirements: Open channels require regular maintenance to remove debris and sediment buildup, which can reduce their capacity and cause blockages.
- Public safety concerns: Open channels can pose safety risks to the public, particularly children who may be tempted to play in them. In addition, open channels can attract litter and illegal dumping, which can create health hazards.
- Land use restrictions: Open channels require a significant amount of space, which may not be feasible in areas with limited available land.
- Aesthetics: Open channels can be unattractive and may have a negative impact on the surrounding environment, including property values.

The topography of an area plays an important role in determining the geometry of an open channel in a stormwater system. The geometry of the channel, in turn, affects the channel's capacity to convey stormwater runoff. The slope of the terrain is a key factor in determining the shape of the open channel. In general, steeper slopes require narrower channels with steeper side slopes to maintain stability and prevent erosion. On flatter terrain, wider channels with flatter side slopes can be used to convey stormwater runoff.

The topography also influences the alignment of the open channel. In areas with uneven terrain, the channel may need to follow the natural contours of the land to maintain a consistent slope and avoid steep drops or rises. In areas with more uniform terrain, the channel may be aligned in a straighter path. In addition to the slope and alignment, the geometry of the open channel can be influenced by other factors, such as the expected flow rate of stormwater runoff and the available space for the channel. Design standards and guidelines may also dictate the minimum and maximum dimensions of the channel based on the expected flow rate and other factors.

The suitability of open channel flow versus gutters and pipes for stormwater management in Lebanon depends on several factors, including the topography of the area, the expected flow rate of stormwater runoff, and available space for stormwater infrastructure.

In general, open channel flow may be suitable in areas with sloped terrain and a relatively low flow rate of stormwater runoff. These areas may include rural or suburban areas with natural drainage patterns, such as small streams or swales, where an open channel can be used to convey stormwater runoff to a downstream location. In some cases, green infrastructure features such as vegetated swales or infiltration basins can be incorporated into the open channel design to further manage stormwater runoff.

However, in areas with more urbanized or developed land uses, such as commercial or industrial areas, gutters and pipes may be more suitable for managing stormwater runoff. This is because these areas typically have a higher flow rate of runoff and limited available space for stormwater infrastructure. In these areas, underground pipes may be necessary to convey stormwater runoff to a downstream location and prevent flooding and property damage.

Grating covers are often used on open channels in stormwater systems to provide several benefits, including:

- Safety: Grating covers can prevent people and animals from accidentally falling into the open channel, which can be dangerous, especially during periods of heavy rain and fast-flowing water.
- Debris control: Grating covers can help prevent leaves, branches, trash, and other debris from entering the open channel, which can reduce the risk of blockages and flooding.
- Aesthetics: Grating covers can provide a more attractive appearance to the open channel and prevent the accumulation of debris and sediment on the channel bottom.

Grating covers may be necessary in areas with high foot traffic, such as urban parks or commercial areas, where safety is a primary concern. They may also be used in areas with high levels of debris or where the open channel is used for aesthetic purposes.

5.3. Freeboard

The vertical distance from the water's surface to the canal's top is known as the freeboard of a channel. The impact of the channel bank overflow determines how important this element is.

The freeboard should be at least high enough to prevent waves, extreme height changes, and surface-level changes from overflowing the edges. 150 mm of freeboard is typically thought to be sufficient in a permanent roadside or median channel. Freeboard is not required for temporary channels. To account for the significant changes in flow brought on by waves, splashing, and surging, a steep gradient channel should have a freeboard height equal to the flow depth.

CHAPTER VI: MAINTENANCE

The owner (government, municipality, citizen …) is in charge of performing the maintenance and is required to keep an accurate log of all preventative and corrective maintenance for the structural stormwater system measures included in the development's design. This log must include a record of all inspections and copy of all work orders relating to maintenance. At least once a year, the owner must assess the maintenance plan's efficacy and make any necessary adjustments.

6.1. Preventive Maintenance

Debris and sediment are anticipated to be taken in by and/or accumulated in the conveyance systems, including inlets, manholes, and pipes, as well as the proposed underground detention facilities and manufactured treatment devices. These systems must be checked for clogging and sediment buildup at least twice a year, as well as for the removal of trash and other debris. Cleaning may be necessary to prevent the loss of discharge capacity storage volume.

Refer to the suggested inspection schedules for the manufactured water quality treatment devices and underground detention facilities from the manufacturer as these are subject to change. When the systems are sufficiently dry and all runoff has been drained from the pipe networks, sediment removal should begin. Debris, trash, sediment, and other waste materials should be disposed of properly, in accordance with all applicable local, state, and federal waste regulations, and at appropriate disposal/recycling sites.

At least once a year, all structural components must be examined for signs of wear, deterioration, and cracking, subsidence, and breaching. The surrounding and above-lying materials must be examined for any signs of deterioration or potential failure. Whenever the systems are cleaned and at least twice a year after that, structural components must be inspected.

According to the manufacturer's instructions and maintenance schedule, the manufactured water quality treatment device and filter media components must be examined, maintained, and replaced as needed.

The manufacturer's recommendations and recommended maintenance schedule should be followed when inspecting, maintaining, and replacing the underground detention systems as necessary.

At least twice a year, as well as immediately following each significant rain event, riprap aprons must be checked for erosion or displaced rock.

The conveyance systems' regular maintenance may require the assistance of two people. Shovels, lighting equipment, a wheelbarrow or truck for hauling away debris, a jet vacuum vehicle, and other standard equipment may be used for the maintenance tasks.

All maintenance tasks and inspections must be logged and documented. All records and logs must be kept for future analysis.

6.2. Corrective Maintenance

Corrective maintenance is necessary to fix issues or malfunctions, return the stormwater system to its intended operations, and ensure its safety. It may be necessary in an emergency or on an irregular basis.

Sediment, debris, and trash that endangers a stormwater facility's ability to discharge water and store it should be removed right away and properly disposed of as soon as possible.

It is necessary to have the necessary tools and personnel on hand to complete the removal work quickly. Debris, trash, sediments, and other waste materials should be disposed of properly, in accordance with all applicable local, state, and federal waste regulations, and at suitable disposal/recycling sites. The removal of waste, debris, and sediment should not be delayed because there is no disposal site available. In the interim, until a permitted disposal site is available, temporary storage must be used.

Inlet structures and pipes that have sustained structural damage must be quickly fixed. To complete these repairs quickly, it is necessary to have the necessary tools, supplies, and personnel on hand. The extent of the damage and how it affects the facility's operations and safety will determine how quickly repairs need to be made. Only professionals with the necessary training should analyze structural damage and design and carry out structural repairs.

Any structural damage to the underground detention system vault chambers, as well as any structural damage to precast manufactured water quality treatment devices, must be repaired right away in accordance with the manufacturer's instructions and should only be handled by qualified personnel.

The riprap aprons' missing or relocated rocks must be quickly replaced in order to stop erosion.

Every corrective maintenance procedure must be logged and documented. All records and logs must be kept for potential future review.

Chapter VII: Advocacy Plan

7.1. Message

A clear and organized code is needed to the storm water networks in Lebanon to reduce the efforts required for network establishment, increase their efficiency, make water deliverable, and avoid the problems of floods.

7.2. Target

The main target in our mission is the ministry of water and energy in Lebanon in line with the order of engineers, since the code we are working on will be a necessity in each building project before giving the acceptance to start the construction.

Additionally our allies will be the international community, because they refund the Lebanese government through NGOs to apply this code in the public sector and public facilities.

7.3. Tools

In order to go further in this project, and to obtain the maximum advantages, a campaign could be conducted on site or through social media by municipalities and NGOs to support and spread the importance of this project, also they can offer rewards for people who establish the code requirements.

Campaigns should also mention the importance of green roofs, treatment, and rainwater harvesting so that the Lebanese people can sell their water excess to the authority who can sell it to neighboring countries (Jordan, Egypt, Syria …) or exchange it with them for fuel.

CHAPTER VIII: CONCLUSION

This project is a step forward to upgrading the Lebanese WASH sector and making huge progress economically and environmentally. This is why we need to expand its implementation to get maximum efficiency.

To conclude, all these efforts will lead to nothing without people's awareness; this is why we have to use the means of social media, seminars and campaigns in order to spread information about the importance of water.

Last, we thank again the community, and every person exercising efforts in the WASH sector, because together we can make an impact.

We can be the change makers…

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