City of Sunnyvale

# Storm Drain Systems

# Design Standards

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and
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# 1.0 STORM DRAIN SYSTEMS – DESIGN CRITERIA

## 1.1 GENERAL

A. All storm drain systems shall conform to the most recent edition of the City of Sunnyvale standards. If the standard that is sought does not appear in this Manual, then the following standards shall be utilized in the order listed:

1. State of California Department of Health Services
2. City of Sunnyvale Municipal Code
3. City of Sunnyvale Standard Details
4. City of Sunnyvale Consolidated General Plan
5. Standard Specifications for Public Works Construction (SSPWC or "Greenbook"), latest Edition
6. Santa Clara County Drainage Design Manual
7. All other applicable local state and federal guidelines

**Exceptions to this and all other guidelines appearing in this manual may be allowed only upon the approval of the City.**

## 1.2 HYDRAULIC CAPACITY

A. When storm drains are part of drainage systems that serve one (1) square mile (640 acres) of tributary area or less, the required design storm events shall be 10 year for site lateral design and main line pipe, 25 year for curb to curb, 100 year for R-O-W to R-O-W. The pipe shall convey the design flow with the hydraulic grade line (HGL) maintaining a minimum freeboard of one (1) ft below the ground surface or gutter flow line during the design event.

B. At a minimum, main line storm drains within the public right-of-way shall not be less than 15 inches in diameter. The cross-sectional area of the pipe shall not decrease when proceeding down gradient within the storm drain system. Diversion of drainage is not allowed (i.e., the discharge point and all inlets of a storm drain system shall be within the same watershed).

C. This Manual references its design criteria and procedures to storm drain pipe with a circular cross-section. These criteria and procedures can be adapted to other cross-section shapes (e.g., arches, other non-circular or non-rectangular shapes) with due care. It is important to note that cross-section shapes must be compared using their section factor ($AR^{2/3}$), and not simply on the basis of cross-sectional area and perimeter.

## 1.3 MANNING ROUGNESS COEFFICIENT

A. The following table provides Manning Roughness Coefficients for typical average pavement and gutters:

Concrete Gutter........................................................................ 0.015
Concrete Pavement

| | |
|---|---|
| Float Finish | 0.014 |
| Broom Finish | 0.016 |
| Concrete Gutter with Asphalt Pavement | |
| Smooth Finish | 0.013 |
| Rough Texture | 0.015 |
| Asphalt Pavement | |
| Smooth Finish | 0.013 |
| Rough Texture | 0.016 |

## 1.4 ALIGNMENT AND CURVATURE

A. Horizontal Alignment:

1. Storm drains shall adhere to a straight alignment within the same run of pipe (i.e., from one clean-out, inlet, or other drainage structure to another), or follow the alignment of overlying streets whenever reasonable. Where practical, storm drains shall run perpendicular to the slope contours in cases where the slope is 20 percent or steeper. Storm drains shall not be placed within a slope parallel to slope contours in cases where the slope is 20 percent or steeper.
2. The horizontal alignment of a storm drain system shall maintain a minimum horizontal clearance from potable water mains and sanitary sewer lines. The distance between the outside diameter of a storm drain and the outside diameter of other wet utilities shall not be less than five (5) feet without prior approval by the City.
3. When designing the junction of two (2) storm drain pipes, priority shall be given to the larger of the connecting storm drains. Flow from the lateral (i.e., the smaller storm drain pipe) shall not oppose the flow in the main. line, without prior approval from the City. Specifically, when the angle of confluence ($\varphi$) is measured from the centerline of the main line, the angle of confluence shall be less than or equal to 90 degrees at all times. Figure 2-1 illustrates the definition of angle of confluence used. The angle of confluence shall be further limited to 60 degrees in cases where:

    a. The lateral is 36 inches in diameter or larger;
    b. The lateral flow is greater than or equal to 10 percent of the main-line flow;

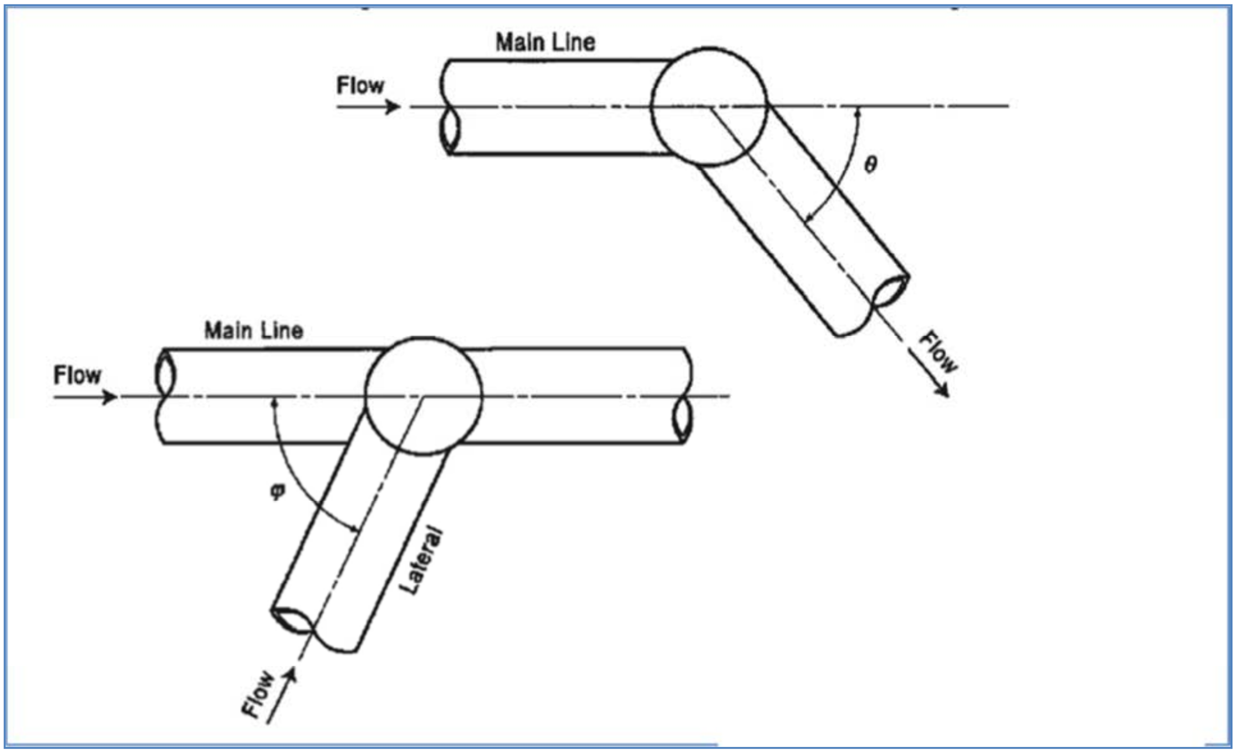


**Figure 2-1** Definition Sketch for Angle of Deflection ($\theta$), Angle of Confluence (φ), and Bend Radius (Δ)

B. Vertical Alignment:

1. The vertical alignment of storm drain systems shall:
   a. Minimize conflicts with other underground utilities; and
   b. Minimize potential buoyancy problems (in cases where a groundwater table is present).
2. The minimum grade of storm drain pipe shall be 0.5 percent. The City may approve flatter grades where no other practical solution is available.
3. The maximum soil cover above a storm drain facility depends on storm drain material type and strength, size of the pipe, cover material, bedding conditions, and traffic loading. The designer shall confirm that the design strength of the pipe shall be adequate for the soil loading conditions. When there is more than 15 feet of soil cover, special design conditions may apply and approval by the City shall be required.
4. Best design practice for the vertical alignment within cleanouts, junction structures, or equivalent drainage structures is to provide a minimum of 0.1 foot of fall across the structure. When increasing the pipe diameter in the downgrade direction, the standard practice is to match the crowns (soffits) of the incoming and outgoing storm drain pipes when possible. The designer may vary from this practice in consultation with the City.

## 1.5 REQUIRED MAINTENANCE EASEMENT WIDTHS

A. Table 2-3 lists the minimum easement width required for underground storm drainage facilities. These minimum easement widths assume conventional storm drain installation with a cover of up to 15 feet. Storm drains with cover between 15 feet and 25 feet shall require an additional two (2) feet of easement width for every foot of cover over 15 feet. Storm drains with cover deeper than 25 feet or other special conditions may warrant additional easement width, and require City consultation and approval.

**Table 2-3 Minimum Underground Storm Drainage Facility Easement Width**

| Pipe Diameter or Equivalent | Easement Widths |
|---|---|
| <60” | 15’ |
| 84” | 20’ |
| 108” | 25’ |
| >108” | 30’ |

B. Storm drains and easements shall be placed on one (1) side of lot ownership lines in new development. In existing developments, storm drains easements shall follow lot ownership lines to the maximum extent practical.

C. It is preferred that storm drain easements be established exclusively for storm drainage facilities. Joint use easements with other wet utilities (i.e., potable water and sanitary sewer) shall be permitted when circumstances warrant, so long as the facilities within the joint-use easement maintain the minimum separation between wet utilities as outlined in Section 2.4.

D. All storm drain easements shall have physical access from the public right-of-way. In cases where such access requires a road (e.g., a steep slope or grade differential), the access easement shall be a minimum of 15 feet wide. The access road shall be a minimum of 12 feet wide, with a 15 percent maximum grade.

E. Strom drain easements shall be created by the developer. Securing of the easements shall be determined on a case by case basis by the City. Easements shall be dedicated to the City and maintained by the Property Owner.

F. All storm drains not located within the public right-of-way shall be provided with a minimum 15-foot wide storm drain easement (see Table 2-3). All easements shall at all times be easily accessible to the City’s maintenance equipment with all-weather access roadways. The access road shall be three (3) inches of asphalt concrete over six (6) inches of aggregate base. No trees or structures or building overhang are allowed within the City easements. When easements are located on private properties, the property owner shall keep the easement free and clear of weeds and debris. An access road may be required for trucks and as approved by the City.

## 1.6 DEEP-COVER PIPES AND CULVERTS

A. When pipe is under cover of 25 feet or more, the storm drain shall be over-sized by six (6) inches, or one size, in order to provide for future interior repairs or re-lining.

## 1.7 WATER TIGHT JOINTS

A. Water-tight joints shall be specified in prescribed locations and situations:

1. Where the Hydraulic Grade Line (HGL) shall exceed the inside crown (soffit) of the pipe by more than five (5) feet for more than 40 feet of pipe length for the design storm.
2. Where the pre-project geologic investigation (i.e., soils report) indicates that groundwater levels might exceed the pipe invert elevation.

## 1.8 PIPE ABRASION

A. In cases where a storm drain pipe is expected to carry a large amount of debris or abrasive sediment material, it shall have measures to provide sufficient design life for the facility. The pipe material shall dictate the type and degree of protection required. When protection is warranted, the invert of the pipe (i.e., the bottom 90 degrees of the pipe) shall be protected on all straight-aways, and the invert and walls (i.e., the lower 180 degrees of the pipe) shall be protected on all curves.

## 1.9 STORM DRAINS AND LATERALS

A. Approved material for storm drain mains is RCP class IV. For laterals RCP class III or IV, or SDR-26 PVC. The specified material shall be approved by the City, and have a minimum design life of 60 years.

B. The selection of pipe material shall consider factors such as strength of the pipe under maximum or minimum cover, bedding and backfill conditions, anticipated loading, length of sections, ease of installation, corrosive action of surrounding soils, expected deflection, and cost of maintenance.

C. Storm drains shall be reinforced concrete pipe and shall be Class III or better with a minimum ‘B’ wall thickness conforming to ASTM C76 and shall have rubber gasketed joints conforming to the requirements of ASTM Designation C443.

D. Vertically and horizontally curved pipe alignments shall not be used.

E. The minimum inside diameter for storm drain mains shall be 15-inches.

F. Minimum cover over storm drain mains shall be 2 ½ feet to street subgrade.

G. Maximum depth to invert shall be 30 feet.

H. The minimum vertical pipe crossing clearance shall be one (1) foot as measured from the outside walls of the pipes.

I. All laterals installed in existing streets shall have profiles locating utility crossings.

J. All storm drainage laterals shall be minimum 12-inch.

K. Where applicable, laterals shall be stubbed and plugged at the property line for future development. The invert elevation at the property line shall be shown on the plans.

L. Pipes abandoned in place shall be filled with sand slurry and plugged at ends.

M. Private inlets with rim elevations lower than street grades must utilize a privately maintained, owned, and operated flapgate or other back flow protection device located on private property.

N. Public systems shall not connect low laying areas by an adverse grade pipe.

O. Install three (3) inch minimum width green color coded (per USA Mark Out System) detectable tape marked "SEWER" in 1-1/2 inch black letters shall be placed on the compacted and graded bedding material within one foot above and centered over the sewer main prior to backfilling the trench.

**1.10 MANHOLES, INLETS, BASINS, PUMPS, OUTFALLS AND GUTTERS**

A. Manhole spacing shall be 450 feet maximum except when the storm main size equals or exceeds 60 inches in diameter in which case spacing shall be subject to approval by the of City.

B. Manholes shall be used at:

1. All connections of laterals from storm water inlets located in public right-of-way.
2. All changes in direction.
3. All changes of pipe size.
4. At all intersections of mains.
5. Where one lateral serves multiple lots.
6. At the interface of public and private systems, located on private property.

C. Storm water inlet spacing shall not exceed 600 feet maximum.

D. Flat grate inlets shall not be used in lieu of hooded type inlets where and curb and gutter exists.

E. Minimum gutter grade, curb returns and cul-de-sac bulbs shall be 0.5 percent.

F. Maximum sag created within the public street system shall not exceed the depth at which ponding water extends beyond the right-of-way. If there is a series of sags, a minimum positive slope of 0.05 percent shall be required from the downstream release point to successive low points upstream.

G. Finished floor of structures (including garages) opposite downhill runs, such as downhill “T” intersections, shall be elevated to EGL of overland flow plus one (1) foot freeboard. This is a minimum requirement only.

H. Gutter flow on public streets shall not be diverted into private streets or property.

I. Interior of Manholes: Coat entire interior of new and retrofitted manholes with Sewpercoat, Mainstay or Sancon calcium aluminate cementitious mortar.

## 1.11 PRIVATE CONNECTIONS TO THE PUBLIC DRAINAGE SYSTEM

A. All storm drain connections shall be subject to approval of the City and shall be in accordance with applicable standards and specifications. Permits shall be required.

B. Storm drain laterals from private properties shall not be connected to public storm water inlets.

C. Cross connections between sanitary and storm systems are prohibited.

## 1.12 BASIC DESIGN PROCEDURE

A. Storm drain capacity analysis shall account for changes in flow conditions (open channel versus pressure flow) in the hydraulic grade line (HGL) calculations. Figure 2-2 provides a definition sketch for storm drain hydraulic computations.

B. The procedure for storm drain design proceeds as follows:

1. Size storm drain system on a preliminary basis assuming uniform, steady flow conditions for the peak design discharge.
2. Check the initial pipe sizes using the energy equation, accounting for all head losses.
3. Adjust the pipe size and vertical alignment as necessary to provide minimum HGL freeboard

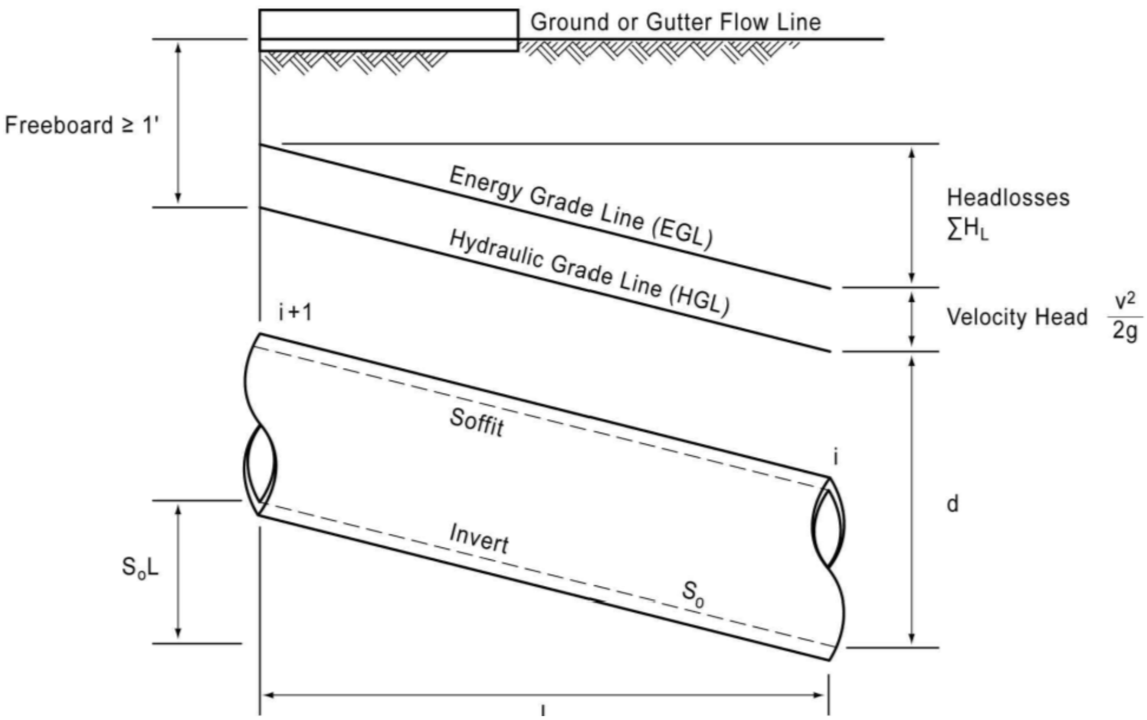


**Figure 2-2** Definition Sketch for Storm Drain Hydraulic Calculations

## 1.13 STORM DRAIN ANALYSIS – UNIFORM FLOW

A. When a storm drain is not flowing full, the storm drain operates as an open channel and the hydraulic properties can be calculated using open channel techniques. The flow is a pipe operating as an open channel can evaluated numerically using the Manning Equation:

$$Q = \frac{1.49}{n} AR^{2/3} S_f^{1/2} \qquad (2\text{-}1)$$

where ...

| | | |
|---|---|---|
| $Q$ | = | flow rate ($ft^3/s$); |
| $n$ | = | Manning roughness coefficient (no dimension); |
| $A$ | = | flow area ($ft^2$); |
| $R$ | = | hydraulic radius (ft); and |
| $S_f$ | = | friction slope, typically assumed to be equivalent to longitudinal slope of storm drain $(S_o)$ (ft/ft) |

B. During full-flow conditions, the flow area and hydraulic radius for a circular pipe diameter (D) can be simplified to the following relationships:

$$A = Afull = \frac{\Pi D^2}{4}$$

$$R = Rfull = \frac{\Pi D^2}{4}$$

C. The pipe diameter is specified as the next standard pipe size larger than the minimum required. An analogous procedure can be followed for alterative pipe shapes.

## 1.14 STORM DRAIN ANALYSIS – PRESSURE FLOW

A. When a storm drain is flowing under a pressure flow condition, the friction slope ($S_f$) and longitudinal slope of the storm drain ($S_0$) may not be equivalent. Therefore, the energy and hydraulic grade lines cannot be calculated using the uniform Flow Equation. The capacity calculations generally proceed upstream from the storm drain outlet, accounting for all energy losses through each pipe run and drainage structure. These losses are added to the EGL and accumulate to the upstream end of the storm drain. The HGL is then determined by subtracting the velocity head, (Hv) from the EGL at each change in the EGL slope.

## 1.15 STORM DRAIN ANALYSIS – HGL CALCULATIONS

A. The designer shall check the available energy at all junctions and transitions to determine whether the flow in the storm drain shall be pressurized due to backwater effects, even when the design flow is less than the full flow capacity of the storm drain.

B. To calculate the Energy Grade Line (EGL) for a storm drain system, divide the system into “runs” of pipe between structures (clean-outs, inlets, junctions, or other structures) or change in grade. The slope of the pipe shall be constant within each run. Starting with the downstream control elevation ($EGL_i$) for the most downstream run of pipe, first calculate the friction losses and bend losses through the pipe and then the losses across the upstream drainage structure. The EGL at the upstream end of the run ($EGL_{i+1}$) shall be the sum of the downstream control elevation, friction losses, and structure losses, and shall be the downstream control elevation for the next run of pipe:

$$EGL_{i+1} = EGL_i + (\sum H_L)_{PIPE} + (\sum H_L)_{STRUCTURES}$$

C. Figure 2-2 illustrates the components used in the energy grade line and head loss calculations. The hydraulic grade line (HGL) is then calculated by subcontracting the velocity head (v2/2g) from the energy grade line:

$$HGL_i = EGL_i — (vi^2/2g)$$

D. EGL elevations must always decrease in the downstream direction, and must always increase in the upstream direction. On the other hand, HGL elevations may increase or decrease at the structure locations regardless of the direction considered. For instance, the HGL shall increase in the downstream direction within a pipe when there is a hydraulic jump.

### 1.16 DOWNSTREAM CONTROL (TAILWATER) ELEVATION

A. The hydraulic analysis of a storm drain system typically begins at the downstream outfall. The controlling water surface elevation at the point of discharge is commonly referred to as the tailwater. At the outfall, one of several conditions shall be encountered: another closed pipe; outfall to a drainage channel, storage facility, reservoir, lake, or detention facility; a free outfall; or a tidally influenced outfall.

B. For free outfalls, the initial water surface elevation (tailwater) shall be assumed to be equivalent to the soffit elevation. For outfalls into other drainage facilities, a drainage channel, reservoir, or detention facility, the initial water surface elevation shall be set at the 100-year water surface elevation calculated for the channel or described on the appropriate Flood Insurance Rate Map (FIRM) at the location of the outfall. In cases where the storm drain outfall condition is tidally influenced, it is usually sufficient to use the historic high tide elevation as the tailwater elevation. In cases where storm surge is a concern or for other situations with unusual tailwater conditions, the appropriate design outfall tailwater elevation shall be chosen in consultation with the City.

**END OF STORM DRAIN SYSTEMS – DESIGN CRITERIA**