9.0 Introduction

This chapter summarizes design criteria and evaluation methods for storm sewer systems in the City of Centennial. The review of all planning submittals will be based on the criteria presented herein.

9.0.1 **Stormwater Quality Considerations**. Traditionally, urban development has relied on storm sewer systems in the upper portions of watersheds. As storm sewers pick up more drainage area, they increase in size; when they become large, criteria requires a switch from storm sewers to open channels. Major drainageways (streams draining 130-acres or more) have been defined based on the amount of area that could reasonable be served with storm sewers before an open channel becomes necessary.

Today, with the emphasis on runoff reduction and water quality enhancement, stormwater management practices are turning to concepts that retain or create a surface drainage network extending upstream of major drainageways. To promote infiltration, attenuation of runoff, and water quality enhancement, properly designed drainageways and swales can extend upstream to the point where few, if any, storm sewers are necessary. When planning a new project, consideration is to be given to the use of grass swales and drainageways to reduce the extent of storm sewers, especially direct connections of paved areas to storm sewers. This concept, termed “minimizing directly connected impervious areas”, is discussed in more detail in Chapter 14, Stormwater Quality.

Replacing inlets and storm sewers with grass swales and drainageways will not be feasible everywhere and storm sewers will continue to be an integral part of many drainage systems. The storm sewer criteria in this chapter are identified to guide the design of these systems.

9.1 Design Storms for Sizing Storm Sewers

Two design storms shall be considered for sizing storm sewers: the minor (5-year) storm and the major (100-year) storm. In each case, storm sewers are to be sized to carry the portion of the runoff that cannot be conveyed on the surface, as dictated by the available capacity in streets and swales.

9.1.1 **Minor Event Storm Sewer Design.** At a minimum, storm sewers are to be sized to pick up any minor storm runoff that exceeds the minor event (5-year) capacity of the street or roadside swales (discussed in Chapter 7, Street Drainage). Inlets shall be located at these points to intercept excess minor event flow and direct it to the storm sewer. The storm sewer shall be sized to convey the minor storm in a “just full” condition, generally without surcharging the pipelines. Section 9.8 provides additional information on hydraulic design methods for the minor storm.

9.1.2 **Major Event Storm Sewer Design.** There are conditions when the storm sewer system needs to be sized to convey flows greater than the minor storm runoff (and as much as the major storm runoff), including the following:

1. Locations where the street capacity for the major storm is exceeded.
2. Locations where major storm flows can split off in an undesirable direction (i.e. flow splits at intersections).
3. Locations where the storm sewer system is accepting flow from an upstream storm sewer system or branch that is designed for the major storm.
4. Regional storm sewers designed for the major storm.
5. Locations where storm sewers must convey undetained flows to a regional detention pond.

If a storm sewer is to be designed to carry major storm flows, the inlets to the storm sewer shall be designed accordingly. The major storm event hydraulic grade line is allowed to rise above the top of the storm sewer pipe and surcharge the system. The major event hydraulic grade line elevation shall be a minimum of 1.0 foot below all manhole lid, inlet grate and inlet curb opening elevations. In no case shall the surcharge create system velocities in excess of the maximum outlined in Section 9.8.1

The major storm event hydraulic grade line must also be analyzed for storm sewer systems designed to convey the minor storm event runoff. Since the flow depth in the street during the major storm will typically be greater than the minor storm, inlets may intercept additional runoff and the flow in the storm sewer will be greater than during the minor storm event. Any surcharge created by conveyance of the additional runoff is subject to the limits outlined above. Section 9.8 provides additional information on hydraulic design methods for the major storm.

9.2 Storm Sewer Pipe Material and Size

9.2.1 Storm Sewer Pipe Material. All storm sewers located within City rights-of-way, public easements or in private streets shall be constructed with reinforced concrete pipe (RCP). Urban Drainage and Flood Control District has performed an extensive evaluation of the performance of various types of storm sewer pipe materials and this information is presented in the *UDFCD Update to Storm Sewer Pipe Material Technical Memorandum* dated March 1998, herein referred to as the *UDFCD Pipe Memo.* SEMSWA has considered the *UDFCD Pipe Memo,* other pertinent data, and its experience with the installation and maintenance of storm sewers within the City and has determined RCP to be the appropriate pipe material for use in SEMSWA's stormwater management systems. Circular pipe is the most cost effective option for reinforced concrete, but elliptical pipe may be a more appropriate option in areas where available cover is limited or there are utility conflicts.

Alternate pipe materials may be used for private storm sewers with SEMSWA approval prior to submittal of drainage reports or construction drawings for SEMSWA review. A private storm sewer system is defined as a system that conveys runoff generated by one subdivided lot or parcel. When a storm sewer system conveys runoff from two or more subdivided lot or parcels, it is considered a "public" system. The alternate pipe material that is proposed must conform to the requirements set forth in the *UDFCD Pipe Memo*, however, SEMSWA will recognize changes in applicable standards and specifications since that document was published. For instance, AASHTO M294 – Type S – Corrugated Polyethylene Pipe is applicable for pipe diameters from 12-inches to 60-inches. Trench details, installation specifications, minimum cover or fill height limits, and construction testing requirements for alternate pipe materials shall be consistent with those recommended by the manufacturer/supplier or as determined by SEMSWA.

Outlets into detention or water quality ponds and connections to the public storm sewer system must be constructed with RCP. This typically requires a change in pipe material at the privately owned structure (i.e. manhole or inlet) immediately upstream from the connection to the public storm sewer or the pond outfall.

9.2.2 Minimum Pipe Size. The minimum allowable pipe size for storm sewers located within City right-of-way and public easements is presented in Table 9-1.

TABLE 9-1
MINIMUM STORM SEWER PIPE DIAMETERS

Type	Pipe Diameter
Main Trunk	18-inch
Lateral from Inlet	18-inch
Outlet from Detention Pond	18-inch

9.2.3 Driveway Culverts. See Section 11.4 of Chapter 11, Culverts and Bridges, for SEMSWA criteria on driveway culverts.

9.3 Other Design Considerations

9.3.1 RCP Pipe Class, Fill Height, and Installation Trench. The minimum class of reinforced concrete pipe shall be Class III, however, the depth of cover, live load, and field conditions may require structurally stronger pipe. SEMSWA's trench installation requirements, trench installation details, and allowable fill heights are shown on the SEMSWA Pipe Trench Standard Detail which can be found on SEMSWA's website at www.semswa.org. It is the responsibility of the design engineer to develop and submit alternate trench and installation details when project specific conditions or loadings require modification to the standard installation. Alternate designs shall follow ASTM C1479.

9.3.2 Storm Sewer Joints. All storm sewer installations within public and private roadways and public easements shall be constructed with water-tight joints, using rubber gaskets. ASTM Standard C443 covers flexible watertight joints for circular concrete storm sewer and culvert pipe and precast manhole sections using rubber gaskets for sealing the joints.

9.3.3 Trash Racks. Trash/safety racks shall not be used at storm sewer outlets.

9.3.4 Conduit Outlet Structures. See Chapter 10, Conduit Outlet Structures, for discussion regarding conduit outlet structures at storm sewer outfalls.

9.4 Easements and Maintenance

9.4.1 Storm Sewer Easements. Drainage easements are required in order to ensure the proper construction and maintenance of storm sewers and related facilities. Easements shall be provided for all storm sewer systems that convey or impact the public storm drainage system. Refer to Chapter 3, Stormwater Management and Development for further discussion regarding storm sewer easements.

9.4.2 Minimum Acceptable Storm Sewer Easements. Table 9-2 presents the minimum acceptable easement requirements for storm sewer systems. The design of the storm sewer shall include the easement width that is necessary to ensure that adequate space is provided for the access, construction and maintenance of the facility.

TABLE 9-2
MINIMUM ACCEPTABLE STORM SEWER EASEMENT WIDTHS

Pipe Size	Easement Width
Less than 36-inch diameter	20 feet*
36-inch diameter and larger	25 feet*

*Or as required in order to meet Occupational Safety and Health Administration (OSHA) and/or construction requirements.

The pipe shall be constructed at one-third of the easement width to allow for stockpiling of material on one side of the storm sewer trench. The minimum widths provided in Table 9-2 assume a shallow pipe depth. Deeper pipes are required to be constructed in accordance with OSHA requirements, and appropriate easements are required to allow for construction and potential future repair or replacement. Easements to provide access to the storm sewer, outlet, and other appurtenances are required if not accessible from a public right of way.

9.4.3 Allowable Landscaping and Surface Treatment in Storm Sewer Easements. Although storm sewer systems are designed to have a significant service life, it is recognized that there are circumstances that may require the storm sewer to be accessed for inspection, maintenance, repair or replacement. Storm sewer easements also convey above ground flows in the event the storm sewer or inlet becomes clogged or full. It is therefore necessary to limit uses on the surface of the easement to ensure that the above ground conveyance is not obstructed, and to allow maintenance access to the storm sewer if necessary. Minor landscaping including, rock, shrubs etc. may be appropriate where it can be demonstrated that the function of the easement is not compromised by the presence of the materials. Pavement over a storm sewer easement is allowable, providing that the property owner assumes responsibility for replacement in the event it is necessary to remove it to access the pipe. Improvements that are not allowed on storm sewer easements include structures of any kind, retaining walls, permanent fencing, trees, and others if determined by SEMSWA to be a problem and/or costly to replace. Surface treatments within drainage easements shall be shown on the drainage plan and final development plan, and accepted by SEMSWA.

9.5 Storm Sewer Vertical Alignment

9.5.1 Minimum Cover. All storm sewers shall be constructed so that the minimum cover is maintained to withstand AASHTO HS-20 loading on the pipe. The minimum cover depends upon the pipe size, type and class, and soil bedding condition, but shall be not less than 12-inches at any point along the pipe.

There are numerous factors that ultimately affect the depth of cover over a pipe and in most cases it is likely that the cover will have to be greater than the minimum allowed due to other design considerations and factors. Some of the other factors that affect the depth of the pipe are hydraulic grade line elevations, inlet depths, adjacent utilities or utility crossings, including water and sewer services lines along residential streets, and connections to existing storm sewer systems.

9.5.2 Minimum Cover in Roadways. A minimum cover of 30-inches shall be required in roadways, unless it is demonstrated by the design engineer that less cover is needed given the pavement design and soils reports. The roadway subgrade, which supports the pavement section is typically plowed to a certain depth, moisture treated and compacted prior to the placement of the sub-base, base course, and surfacing. There are also instances where the subgrade material must be excavated and replaced or treated to a certain depth to mitigate swelling soils. These efforts can impact the storm sewer system if it has not been designed with adequate depth. The design engineer shall use the best information available, including pavement design or soils reports (if available) to ensure that storm sewer pipes have adequate depth.

9.5.3 Utility Clearance. For all storm sewer crossings at water and/or sanitary sewer lines, the appropriate agency (i.e. water and sanitation district) shall be contacted to determine the agency's requirements for the crossing.

SEMSWA requires a minimum vertical clearance of 18-inches between a storm sewer and a water main, above or below (all clearances are defined as outside-of-pipe to outside-of-pipe). Additional requirements may be required by the specific utility provider.

The minimum vertical clearance between a storm sewer and a sanitary sewer, above or below, shall also be 18-inches. In addition, whenever a sanitary sewer main lies above a storm sewer the sanitary sewer shall have an impervious encasement for a minimum of 10-feet on each side of the storm sewer. Additional requirements may be required by the specific utility provider.

If 18-inches of clearance from the storm sewer cannot be maintained, additional measures will be required to address potential concerns associated with minimum separation. Additional measures may include concrete cradles for additional structural support, encasement, or other improvements as needed to address potential impacts to either pipe system.

9.6 Horizontal Alignment

9.6.1 Storm Sewer Alignment. The storm sewer alignment between drainage structures (inlets or manholes) shall be straight. If a change of alignment is necessary, a manhole shall be used. Curvilinear alignment for storm sewers is NOT allowed in the City.

9.6.2 Utility Clearance. For all storm sewer pipes constructed within a utility corridor (i.e. roadway), the appropriate agency (i.e. water and sanitation district) shall be contacted to determine the agency's requirements for horizontal clearance between the utilities.

SEMSWA requires a minimum clearance of 10-feet between a storm sewer and a water line or sanitary sewer line. The 10-feet of clearance shall occur from the outer diameter of the storm sewer pipe to the outer diameter of the water or sewer pipe. The design engineer shall give careful consideration to the required horizontal clearance and the potential impacts to the existing utility construction trench and bedding material. The required horizontal clearance may be reduced, at the approval of SEMSWA, if the vertical elevations of the pipes provide adequate clearance to prevent impacts to the existing and proposed construction trench.

9.7 Manholes

9.7.1 Required Locations. Manholes are required along straight segments of pipe in order to provide maintenance access. Manholes are also required whenever there is a change in size, direction, or grade of a storm sewer pipe. A manhole shall also be constructed when there is a junction of two or more sewer pipes. The maximum spacing between manholes for various pipe sizes shall be as shown in Table 9-3.

TABLE 9-3
MAXIMUM MANHOLE SPACING

Pipe Diameter	Maximum Distance Between Manholes
18-inch to 36-inch	400 feet
Greater than 36-inch	500 feet

9.7.2 Manhole Types and Minimum Sizes. The required manhole type and size is dependent on the diameter of the largest pipe entering or exiting the manhole and the horizontal and vertical alignments of all pipes entering or exiting the manhole. Table 9-4 presents general guidance regarding acceptable manhole types and minimum diameters, based on the diameter of the storm sewer pipe.

TABLE 9-4
MANHOLE SIZE BASED ON PIPE DIAMETER*

Pipe Diameter	Minimum Manhole Diameter	Acceptable Manhole Types
42” or less	5'	Cast-in-place Slab Base
48 ”- 54”	6’	Cast-in-place Slab Base
60”	7’	Box Base, Denver Type “P”
72” – 78”	8’	Box Base, Denver Type “P”, T-Base
78” – 96”	5’ (Riser)	Box Base, T-Base
Larger than 96”	5’ (Riser)	T-Base

*Table is based on pipes with a straight through alignment (no horizontal alignment change from the upstream to the downstream pipe) or changes in alignment accommodated in the standard design for large pipe manhole structures.

Table 9-4 provides general guidance and in many cases, it is likely that the minimum diameter of manhole size will need to be increased to account for more significant changes in pipe alignment or multiple incoming pipes. There must be a minimum of 12-inches clearance from the outside of pipes adjacent to each other. This 12-inch dimension must be measured on the inside wall of the manhole. Pipes shall not be allowed to enter or exit a manhole through the corner of the manhole structure. It is the responsibility of the design engineer to determine the required manhole size to achieve adequate space between the pipes entering or exiting the manhole structure. This same analysis and dimension check must be performed when an inlet is used as a junction structure. In those cases where modifications to standard manhole construction details are required or where special junction structure designs are required, additional construction details must be developed and included in the construction drawing set.

9.7.3 Large Pipe Manhole Structures. A manhole with a large diameter or a special junction structure may be required, depending on the degree of horizontal bend, the use of large pipes, or the presence of multiple laterals into a manhole. There are a number of different options available for these special cases:

1. Box Base Manhole. It is appropriate to use this manhole for large pipe diameters with a horizontal alignment change of less than 45 degrees. The Box Base Manhole shall be constructed per SEMSWA's Standard Detail (located on the SEMSWA website).
2. T-Base Manhole. This manhole is acceptable for 72-inch diameter pipes and larger when there is no horizontal or vertical alignment change at the structure. The T-Base manhole shall be constructed per SEMSWA's Standard Detail. Horizontal or vertical alignment changes using a three piece elbow or bend in conjunction with a T-Base may be considered through the variance process for very large pipes where the base structure for a Box Base or Type P manhole would be excessively large.
3. Type "P" Manhole. This manhole is appropriate for 30 degree and 45 degree deflections (horizontal alignment changes) where the use of a box base manhole would result in excessive dimensions. The Type "P" Manhole shall be constructed per SEMSWA's Standard Detail.
4. Special Junction Structures. Special junction structures may have to be designed when pipe sizes and alignment changes exceed those that can be accommodated by standard manhole types.

9.7.4 Steps and Platforms. Steps are required in all manholes exceeding 3.5 feet in height and shall be in accordance with AASHTO M 199. The Occupational Health and Safety Administration has specific standards for fixed ladders used to ascend heights exceeding 20-feet. Cages and/or landing platforms may be required to satisfy these requirements in excessively deep manhole structures. It is the design engineer's responsibility to ensure that the appropriate measures are designed and construction details are developed and included in the construction drawings, as needed to comply with the Occupational Health and Safety Administration standards. When landing platforms are proposed, considerations shall be given to the potential maintenance activities and the expected loadings on the platform.

9.7.5 Drop Manholes. The drop within a manhole from the upstream to downstream pipe invert should normally not exceed 1-foot. There are cases when a drop larger than 1-foot may be necessary (to avoid a utility conflict, reduce the slope of the downstream pipe, or to account for the energy losses in the manhole). Drops that exceed 1-foot will be evaluated on a case-by-case basis, and additional analysis may be required. The details referenced in Section 9.7.3 for the Box Base and Type P manholes do not accommodate a significant elevation difference between the pipes entering and exiting the manhole, therefore use of these manholes would require a special design.

9.7.6 Energy Dissipation in Manholes for Small Storm Drainage Outfalls. Small storm drainage outfalls are defined as outfall systems that have a design flow rate of 20 cubic feet per second or less at the outlet point into a drainageway or detention pond. Small storm drainage outfall systems are commonly proposed to drain cul-de-sacs or other small tributary areas. In many cases, a relatively steep slope is required for the pipe to outlet into an adjacent drainageway or detention pond. In the design of these systems, manholes will be allowed to have drops to a maximum of 4.5-feet in order to provide energy dissipation within the system. In order for a manhole to qualify as an energy dissipation structure upstream of the storm sewer outlet, the minor storm flow must have sufficient velocity to impact the opposite side of the manhole. These minimum velocities based on the drop height, are provided in Figure 9-1. The information provided in Figure 9-1 is based on the use of a 4-foot manhole (inside diameter). The use of a 4-foot manhole is acceptable and required when proposed for the purposes of energy dissipation in the small outfall systems.

9.7.7 Manhole Shaping. All manholes shall be constructed with fill concrete to the top of the highest crown of the highest top of pipe entering or exiting the manhole. The shaping shall match the pipe section below pipe springline and consist of vertical walls above pipe springline. This shaping significantly reduces manhole losses. The appropriate loss coefficient can be determined using Figure ST-8 and Table ST-9 of the UDFCD Manual for full shaping. SEMSWA's Standard Details for storm sewer manholes (located on the SEMSWA website) provide construction details for channelization in slab base and box base manholes.

9.7.8 Other Design Considerations. The following design criteria shall be met:

- The elevation of the pipe crowns shall be matched when the downstream pipe is larger than the upstream pipe. This will minimize the backwater effects on the upstream pipe.
- The invert of a manhole shall be constructed with a slope between the upstream and downstream pipes. The slope shall be the average of the upstream and downstream pipe slopes or based on a fall of 0.1-foot minimum through the manhole.
- It is critical that gutter pans, curb heads, and any other problematic locations be avoided when determining the horizontal placement of manholes.

9.8 Hydraulic Design

Once the layout of the storm sewer system is determined, the peak flows in the system must be calculated followed by a hydraulic analysis to determine pipe capacity and size. The pipe size shall not decrease moving downstream (even if the capacity is available due to increased slope, etc.) in order to reduce clogging potential.

9.8.1 Allowable Storm Sewer Velocity and Slope. The allowable storm sewer velocity is dependent on many factors, including the type of pipe, the acceptable water level during the pipe design life, proposed flow conditions (open channel versus pressure flows), and the type and quality of construction of joints, manholes, and junctions.

1. <u>Maximum velocity.</u> In consideration of the above factors, the maximum velocity in all storm sewers shall be limited to 18-fps.
2. <u>Minimum velocity.</u> The need to maintain a self-cleaning storm sewer system is recognized as a goal to minimize the costs for maintenance of storm sewer

facilities. Sediment deposits, once established, are difficult to remove - even with pressure cleaning equipment. However, the infrequency of storm runoff also possesses a problem in obtaining flows large enough to maintain the self-cleaning quality of the design. Thus, a balance must be drawn between obtaining a self-cleaning system and constructing a reasonably sized and sloped storm sewer. A minimum velocity of 4-feet per second is required when the storm sewer conveys runoff from frequently occurring events. Assuming that the pipe has been designed to flow near full, a flow depth equal to 25-percent of the pipe diameter and the corresponding flow rate shall be used to check the minimum velocity. If the pipe is not designed to flow near full, a flow depth equal to 25-percent of the design flow rate depth and the corresponding flow rate shall be used to check the minimum velocity.

3. Minimum slope. In general, the minimum allowable pipe slope ensures that the minimum velocity is achieved in those cases where the pipe is designed to flow near full. In addition, storm sewers generally are not practicably constructed at slopes less than 0.50-percent and it is difficult to maintain a smooth even invert. The minimum allowable longitudinal slope shall be 0.005 ft/ft (1/2-percent) for pipes 30-inch in diameter and greater. The minimum allowable longitudinal slope shall be 0.01 ft/ft (1-percent for pipes smaller than 30-inches in diameter).

9.8.2 Hydraulic Evaluation of Storm Sewers in the Minor Storm Event. In the minor storm event, inlets are placed along the roadway where the flow in the roadway exceeds the minor event capacity of the street as defined in Chapter 7, Street Drainage. These inlets intercept flow, as determined by the procedures in Chapter 8, Inlets, and convey it to a storm sewer which must be sized to convey the intercepted flow. The following process outlines the steps taken to determine the appropriate size of storm sewer pipe for laterals and main lines.

1. Step 1 Hydrology. The most common method used to determine the peak flow within a storm sewer is the Rational Method. Chapter 6 of this Manual provides detailed information on Rational Method calculations. In order to determine the peak flow within a storm sewer at various locations along the system, the total drainage area tributary to the storm sewer must be divided into sub-basins. Typically the design point of these sub-basins is located at proposed inlet locations along the system. Determining inlet locations and/or design points for the minor event is an iterative process since the placement of an inlet depends upon the minor event capacity of the street. In order to check the capacity of the street (see Chapter 7), a flow rate at the location to be checked must be calculated. Once the design points (inlet locations) have been determined, the inlet interception shall be determined per Chapter 8. This inlet interception flow rate is used to determine the size of the pipe exiting the inlet.

   For a storm drainage system which consists of a main line with multiple laterals tributary to the main line, a time of concentration (t_c) comparison shall be completed. Form SF-3 in Chapter 6, Hydrology, is a useful tool for completing this analysis. Each lateral must be analyzed using the t_c value at the local design point or inlet from the tributary sub-basin. The storm sewer main line usually has multiple tributary laterals; therefore the t_c in the main line is equivalent to the travel time from the most remote point in the major basin to the specific point of interest. This travel time is a combination of the t_c to the inlet where the flow was intercepted and the travel time from the inlet to the specific location being analyzed.

2. Step 2 Pipe Capacity. The storm sewer system shall not be surcharged in the minor storm event. A storm sewer is considered surcharged when the depth of flow or hydraulic grade line in the storm sewer is greater than 80-percent of the pipe's inside diameter.

   For the minor storm event, a storm sewer is not flowing full, therefore the sewer acts like an open channel and the hydraulic properties can be calculated using Manning's Equation. For calculations performed for SEMSWA , the Manning's roughness coefficient (n) is assumed to be constant for all depths of pipe flow. For concrete pipe, the Manning's roughness coefficient to be used for all storm sewer designs and analyses shall be 0.013 for new pipe and 0.015 for old pipe. Based on the flow in the pipe as determined by Step 1, Manning's Equation should be solved for the pipe diameter. Once the pipe diameter is calculated, the next larger pipe size available should be specified (i.e. if Manning's equation results in a diameter of 22-inch, then 24-inch should be specified). See Section 4.4 of the UDFCD Manual for additional information on Manning's equation and storm sewer sizing calculations.

3. Step 3 Hydraulic Grade Line. For partial flow conditions, the hydraulic grade line is equal to the water surface in the pipe. Hydraulic grade line calculations must be performed to account for energy losses and to ensure that the system is not surcharged during the minor storm event. There may be some special cases where the proposed storm sewer pipe is connected to an existing storm pipe (or a detention pond). If this existing pipe is surcharged, then the proposed system will receive backwater from the downstream pipe. In this situation, the minor event hydraulic grade line must be calculated to determine the impacts on the hydraulic grade line through the upstream portions of the system. Further discussion on hydraulic grade line calculations can be found in Section 9.8.3.

9.8.3 Hydraulic Evaluation of Storm Sewers in the Major Storm Event. The storm sewer system layout determined for the minor event analysis must also be evaluated for the major storm event. If necessary, additional inlets must be placed along the roadway when the flow in the roadway exceeds the major storm event capacity of the street as defined in Chapter 7. The interception rates for all of the inlets shall then be calculated for the major storm event, based on the procedures in Chapter 8.

1. Step 1 Hydrology. As described in Section 9.8.2, typically the design points of sub-basins along a storm sewer system are located at proposed inlet locations. Determining inlet locations and/or design points is an iterative

process since the placement of an inlet depends upon the minor and major event capacity of the street. In order to check the capacity of the street (see Chapter 7), a flow rate at the location to be checked must be calculated. Once the design points (inlet locations) have been determined, the inlet interception shall be determined per Chapter 8.

As described in Section 9.8.2, a time of concentration comparison shall be completed for the major storm event using Form SF-3 from Chapter 6. Each lateral must be analyzed using the t_c value at the local design point or inlet from the tributary sub-basin. The storm sewer main line usually has multiple tributary laterals; therefore the t_c in the main line is equivalent to the travel time from the most remote point in the major basin to the specific point of interest. This travel time is a combination of the t_c to the inlet where the flow was intercepted and the travel time from the inlet to the specific location being analyzed.

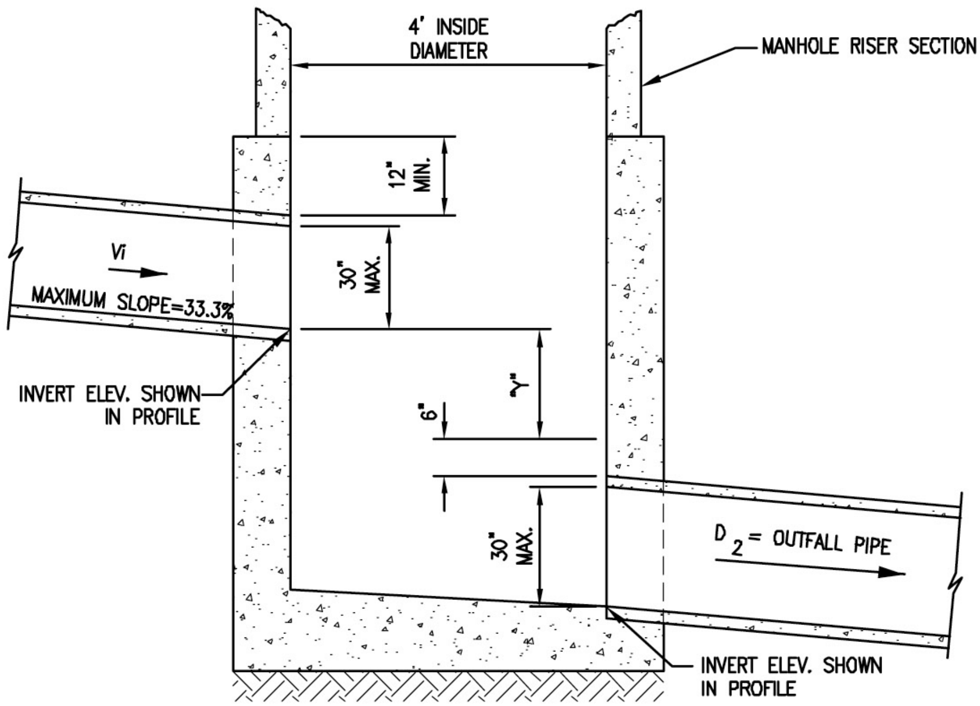
2. Step 2 Pipe Capacity. In the major storm event it is acceptable to have a surcharge in the system. Therefore Manning's equation is not applicable for those pipes which are under pressure flow conditions. There may be cases where the major storm event does not result in a surcharge of the system. In these pipes the capacity can be calculated using Manning's equation as described in Section 9.8.2.

3. Step 3 Hydraulic and Energy Grade Lines. Hydraulic grade line calculations for the storm sewer system shall be provided for the major storm event. The major storm hydraulic grade line must be a minimum of 1-foot below the final grade along the storm sewer system. When a storm sewer is flowing under a pressure flow condition, the energy and hydraulic grade lines shall be calculated using the pressure-momentum theory. The capacity calculations generally proceed from the storm sewer outlet upstream, accounting for all energy losses. These losses are added to the energy grade line and accumulate to the upstream end of the storm sewer. The hydraulic grade line is then determined by subtracting the velocity head from the energy grade line at each change in the energy grade line slope. Refer to Section 4.4 of the UDFCD Manual as a guideline for completing hydraulic grade line and energy grade line calculations. The procedure described in the UDFCD Manual is based on the FHWA HEC-22 publication. All of the losses through a storm sewer system at bends, junctions, transitions, entrances, and exits are based upon coefficients recommended in the UDFCD Manual.

9.8.4 Computer Programs. It is recommended that a computer program be used for the design or as a calculation "check" of a storm sewer system. NeoUDSewer is the software created to supplement the UDFCD Manual and is an approved computer program for storm sewer analysis in the City. NeoUDSewer is a powerful tool which can calculate rainfall and runoff using the Rational Method and then size a circular storm sewer based on Manning's equation. Example 6.13 in the Streets/Inlets/Storm Sewers chapter of the UDFCD Manual is an example of sample project input and the resulting output from NeoUDSewer.

If an alternate computer program (i.e. StormCAD) is used, a calibration model based on Example 6.13 in the UDFCD Manual must be completed and provided to SEMSWA. This calibration model is generated by completing an analysis of Example 6.13 with the alternate computer model. The results of this alternate model must be comparable to the results from the NeoUDSewer analysis. It is not necessary to calibrate the hydrologic analysis as shown in Example 6.13, rather the design engineer may input the peak flow directly to obtain a comparison of the resulting hydraulic and energy grade lines through the example system. The goal of this model calibration is to verify that the loss coefficients and other system assumptions used in the alternate computer program are equivalent to the methodology applied by NeoUDSewer, which is accepted by SEMSWA.

FIGURE 9-1
ENERGY DISSIPATION IN MANHOLES FOR SMALL STORM DRAINAGE OUTFALLS



DROP MANHOLE SECTION

MAX. "Y" DIMENSION

D_2=	18"	21"	24"	27"	30"
	2.50'	2.25'	2.00'	1.75'	1.5'

"Y" DIMENSION	MIN. VELOCITY (Vi) (fps)
0.50'	23.0
0.75'	19.0
1.00'	16.0
1.25'	14.0
1.50'	13.0
1.75'	12.0
2.00'	11.0
2.25'	10.5
2.50'	10.0