10.0 Storm Sewer Systems

10.1 Introduction

A storm sewer system consists of a system of inlets, pipes, manholes, junctions, cleanouts, outlets, and other appurtenant structures that collect and convey minor storm runoff. Storm sewer systems must be conservatively designed to function with a level of reliability that maximizes safety and minimizes the inconveniences of inadequate control for frequent storm events.

10.2 Classifications

Pipe conveyance systems are hydraulically classified by type of flow condition. Storm sewer systems are typically designed for gravity flow and operate, under design conditions, as partial flow conduits with a free water surface. Storm sewer systems are less typically designed to operate as full flow conduits under pressurized flow conditions. Operational flow conditions are not restricted to design assumptions. For instance, gravity storm sewers may convey pressurized flow during major storm events and pressurized storm sewers may function as gravity flow conduits during low-flow events.

10.3 Design Criteria

The hydraulic analysis and design of storm sewer systems shall be in accordance with the criteria presented in the Streets/Inlets/Storm Sewer Chapter, Volume 1 of the Urban Drainage and Flood Control District (UDFCD) Drainage Criteria Manual. Detailed design criteria and design procedures specific for the City of Greenwood Village (Village) are highlighted in the following Sections.

The design policy of the Village is to provide guidelines that are consistent with regional stormwater drainage policy. These guidelines are intended to serve as a minimum standard and not intended to replace site-specific analysis and design requirements of individual projects.

Software packages for analysis and design shall be applied in accordance with the criteria presented in Chapter 17.0.

10.3.1 Design Storm Frequency

A storm sewer system is required when the allowable street capacity is exceeded by runoff from the design storm. The design storm recurrence interval is given in Table 8-1 as a function of street classification.

The design of the storm sewer system shall include appropriate capacity modifications at all

locations where deviation from the design storm is required, for example, at sump inlets with no alternative drainage outlet for the major storm. The design of the storm sewer system shall include hydraulic analysis of both the minor and the major storm events.

10.3.2 Construction Materials

Pipe materials acceptable for use in storm sewer construction include the following:

1) Reinforced concrete pipe (RCP), in accordance with the criteria specified in ASTM C-76, C-506, C-507, with Class II pipe being the minimum acceptable standard;
2) Corrugated polyvinyl chloride (PVC) pipe, in accordance with the criteria specified in ASTM D-3034 and ASTM F-679; and
3) Corrugated dual wall high-density polyethylene pipe (HDPE), in accordance with the criteria specified in ASTM D-1248.

In areas of high abrasion potential and under collectors and arterials, the Village may limit acceptable pipe materials only to RCP. The use of other storm sewer materials shall require approval of the City Manager or designee.

10.3.3 Vertical Alignment

Manholes are required at all locations of hydraulic discontinuity, including junctions and changes in pipe size or alignment. The maximum spacing between manholes shall be in accordance with criteria presented in Table 10-1.

Table 10-1: Maximum Manhole Spacing

Vertical Dimension of Pipe (in)	Maximum Allowable Distance Between Manholes and/or Cleanouts
36 and smaller	400 feet
42 and larger	500 feet

The storm sewer grade shall be sufficient to provide minimum cover required for H-20 loading conditions as specified in the American Association of State Highway and Transportation Officials (AASHTO) “Standard Specifications for Highway Bridges”. The minimum cover shall not be less than one foot at any point along the pipe.

10.3.4 Horizontal Alignment

Storm sewer alignment between manholes shall be straight, except when approved in writing by the City Manager or designee. Storm sewers may be constructed with curvilinear alignment using the pulled-joints, pipe bends, or radius pipe. The maximum allowable joint pull shall be ¾

inch. The radius requirements for pipe bends shall be in accordance with the manufacturer's specifications.

10.3.5 Pipe Diameter

The minimum allowable pipe size for storm sewers is dependent upon maintenance considerations. The length of the storm sewer also affects maintenance. The minimum pipe size for storm sewers is given in Table 10-2.

Table 10-2: Minimum Storm Sewer Size

Vertical Dimension of Pipe (in)	Minimum Equivalent Pipe Diameter	Minimum Cross-Sectional Area
Main Trunk	18 in	1.77 ft^2
Lateral from Inlet	15 in	1.23 ft^2

Private systems that serve a single family residential lot or business can reduce the minimum allowable pipe size to 12 inches.

10.3.6 Storm Sewer Outlets

Selection of an outfall location is an important and sometimes critical design issue. Isolated sites or other project constraints may require design and construction of an intermediate surface water drainage facility to convey site runoff to an acceptable outfall, or existing outfalls may require substantial improvements to convey the increased flows from the developed site. Erosion control requirements may vary from rock-lined protection to stilling basins, depending on the magnitude of the discharges, the extent of the existing surrounding development, and the relationship of site hydraulics relative to receiving water hydraulics.

All storm sewer outlets that discharge into open channels shall be constructed with a headwall and wingwalls or a flared-end section. Erosion protection shall be provided at the outlet in accordance with the criteria presented in Chapter 12.0.

10.3.7 Hydraulic Design Criteria

The hydraulic analysis shall include calculation of the hydraulic and energy grade line to ensure that the storm sewer system is capable of conveying the design discharge without surcharge for the minor storm. The hydraulic grade lines must be at least 6 inches below the top of any storm sewer structures or the ground surface during the major storm. The energy grade line for the design discharge shall be at or below final grade during the major storm.

Total hydraulic losses, including friction losses and form losses due to expansions, contractions, bends, and junctions, shall be computed in accordance with the criteria presented in the UDFCD Drainage Criteria Manual or manufacturer's criteria. Use of other hydraulic loss criteria shall

require approval by the City Manager or designee.

10.4 Design Procedures

Design of many storm sewer systems can be adequately addressed by manual application of the computational procedures described herein. The Village, however, recognizes the efficiency of using computerized applications, including spreadsheets and other technical software, to design larger and more complicated systems.

Storm sewer systems can be sized using the Rational Method as presented in the Streets/Inlets/ Storm Sewer Chapter, Volume 1 of the UDFCD Drainage Criteria Manual. The Colorado Urban Hydrograph Procedure (CUHP) and Urban Drainage and Storm Water Management (UDSWM) model may also be used for basins larger than 10 acres.

10.4.1 Gravity Flow Design

The design of a gravity flow storm sewer system shall be in accordance with the criteria presented in the UDFCD Drainage Criteria Manual. Storm sewers not flowing full are hydraulically equivalent to open channels and are analyzed using the Manning equation for uniform open channel flow.

The computation of hydraulic properties for conduits under partial flow conditions is arithmetically complex. Pipe manufacturers have, therefore, condensed the computation into charts for convenience of application. The full flow capacity of the storm sewer is computed using the Manning Equation. The partial flow values are estimated from the charts. The applicant shall consult the manufacturer for partial flow charts pertaining to other pipe flow geometries.

10.4.2 Pressurized Flow Design

The design of a pressurized storm sewer system shall be in accordance with the criteria presented in UDFCD Drainage Criteria Manual.

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