CHAPTER 4

SEWER MAIN DESIGN

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4.1 Introduction

A. Responsibility of the Designer

This chapter addresses the selection and use of design criteria and practices applicable to the design of sewer system projects in St. Mary's County. The subject matter discussed includes the layout of piping systems, the selection and employment of pipeline materials and the use of appurtenances. While the requirements described for the various aspects of design will include and cover the majority of conditions encountered, there is no intention to relieve the Designer of responsibility to recognize when conditions are not favorable for the application of standards. In the preparation of the contract documents, the Designer shall take into account such matters as environmental impact, maintenance of pedestrian and vehicular traffic, maintenance of existing and proposed utility services, constructability, and system maintenance and shall produce the overall most cost-effective design. The Designer must be continually alert to conditions that cannot be satisfied by the application of these standard criteria.

B. Limitation of Topics Presented in Design Manual

It is not possible to include in this manual all features of design and drafting, which are necessary to accomplish the development of construction documents for all projects. The topics addressed are limited to those that will help the Designer perform most tasks in an efficient manner and comply with Commission practice. Although it is the Designer's responsibility to exercise professional judgment in the acceptance or use of the standards or features of design included herein, the Designer shall recognize that they are given to assist in the development of the project in the manner preferred by the Commission. Deviations from the design standards must be brought to the attention of the Chief Engineer. Waivers from the design manual must be justified to the Chief Engineer, in writing, from an engineering evaluation standpoint that includes consideration of life cycle costs and ease of maintenance. Approval or denial of the waiver requests will be by return letter signed by the Chief Engineer.

4.2 Design Criteria

A. General

The sizing of major components of the Commission sewer collection and conveyance system such as major pumping stations, force mains and interceptor sewers are generally the responsibility of the Metropolitan Commission.

B. Developer Projects

Prior to commencing any work, the Designer is encouraged to schedule a pre-design meeting with the Chief Engineer to discuss any topics which are particularly important in the development of the Engineering Report and subsequent design of the project. Pertinent topics may include any of the following:

1. Preliminary or prior reports prepared by the Commission, if applicable
2. Sizing of major system components
3. Applicable plumbing codes
4. Route selection and location of pipe in public right-of-way
5. Pipe materials and appurtenances
6. Design criteria to be used
7. Design constraints due to anticipated interaction with existing utilities
8. Soil conditions that may affect infiltration and inflow in pipes and appurtenances
9. Bedding requirements
10. Special topographic conditions affecting design such as slopes, streams, floodplain and stream crossings
11. Special permitting issues created by the presence of wetlands, rare and endangered species, historical and/or archaeological artifacts
12. Easement requirements
13. Conditions affecting traffic maintenance and control
14. Requirements for new or upgraded telemetry systems

For projects which require minor extensions of the public water and sewer systems, the pre-design meeting may take the form of a preliminary water and sewer plan showing the general layout of the utilities in relation to the proposed development. The plan shall be accompanied by a letter report, which shall include general information about the project, design criteria used, alternatives investigated and the cost estimates for all alternatives. The plan shall be submitted after the sketch plan for the development has been approved by the Planning Commission.

Developer Projects involving more than 25 EDU's will be required to submit a comprehensive utility plan along with the engineering report unless waived by the Chief Engineer. The comprehensive utility plan shall be signed and sealed by a professional engineer registered in the State of Maryland.

If the construction of the utilities within a development is to be phased, the Designer shall provide a phasing plan showing the phasing and timing of the construction of the utilities. The phasing plan shall be signed and sealed by a professional engineer registered in the State of Maryland. The phasing plan must be approved by the LUGM office.

During each phase of the development, the public water and sewer systems must be able to support the design flow requirements noted in the Design Manual. The Designer shall provide calculations for each phase of the development. For sewer systems, all downstream facilities must be sized to support the flows from each phase of the development. All improvements to collector sewers, interceptor sewers, wastewater pumping stations, force mains, and treatment facilities required to convey and treat wastewater from that phase must be in service prior to any units from that phase connecting to the public sewer system.

Three copies of the comprehensive utility plan, phasing plan and engineering report shall be provided to the Chief Engineer. The comprehensive utility plan and phasing plan shall have standard Commission water and sewer title blocks with approval signature lines.

Following approval, the comprehensive utility plan and phasing plan cannot be revised without the authorization of the Chief Engineer. Revisions to the comprehensive utility plan and phasing plan will require a reevaluation by the Designer of the design flows and the ability of the proposed water and sewer systems to meet Design Manual requirements. Changes to the comprehensive utility plan and phasing plan shall be noted in the revision blocks.

C. Capital Projects

In accordance with the scope of services, the Designer is encouraged to schedule a pre-design meeting with the Chief Engineer to discuss any topics which are particularly important in the development of the Engineering Report and subsequent design of the project. Pertinent topics may include any of the following:

1. Preliminary or prior reports prepared by the Commission, if applicable
2. Development of population projections and wastewater flows
3. Sizing of major system components
4. Applicable plumbing codes
5. Limit of project and future extension, if planned

6. Route selection and location of pipe in public right-of-way
7. Pipe materials and appurtenances
8. Design criteria to be used
9. Both design constraints due to and anticipated interaction with existing utilities
10. Soil conditions that may affect infiltration and inflow in pipes and appurtenances
11. Bedding requirements
12. Special topographic conditions affecting design such as slopes, streams, floodplain and stream crossings
13. Special permitting issues created by the presence of wetlands, rare and endangered species, historical and/or archaeological artifacts
14. Easement requirements
15. Conditions affecting traffic maintenance and control

Copies, in accordance with the scope of services, of the comprehensive utility plan, phasing plan and engineering report shall be provided to the Chief Engineer. Following approval, the comprehensive utility plan and phasing plan cannot be revised without the authorization of the Chief Engineer. Revisions to the comprehensive utility plan and phasing plan will require a reevaluation by the Designer of the design flows and the ability of the proposed water and sewer systems to meet Design Manual requirements. Changes to the comprehensive utility plan and phasing plan shall be noted in the revision blocks.

D. Wastewater Flow Calculations

1. General

   All components of the sewer system shall be sized to handle the design flow rate for the contributing area. The design flow rate shall be the sum of the peaked residential, peaked institutional, peaked industrial and peaked commercial flow rates for the service area plus the corresponding infiltration and inflow components within the service area.

2. Residential Flow Rates

   Residential average day flow rates shall be determined by using the EDU table in the Appendix. The ratio of peak residential wastewater flow to average day residential wastewater flow is given by the empirical curve published by the Maryland State Department of Health and Mental Hygiene, now the Maryland Department of the Environment (MDE). A copy of the curve is included in the Appendix, "Diagram for Converting Average Daily Domestic Flow to Peak Flow".

All design computations for residential flow rates shall include the indicated allowance for inflow and infiltration. However, the Designer is cautioned not to include infiltration rates when determining peak residential flow rates since infiltration flows are considered to be constant flow rates. The design flow rate for residential areas is the peak residential flow rate plus the residential infiltration/inflow flow rate.

3. Commercial, Industrial and Institutional Flow Rates

Commercial, industrial and institutional average day flow rates shall be determined based on the information given in the EDU table in the Appendix.

All industrial, commercial and institutional design flow rates shall be calculated independently of residential design flow rates. Peaking factors for such facilities shall be determined by an analysis of historical data for such facilities. If such information is unavailable, the industrial, commercial and institutional wastewater design flow rates shall be determined by applying a peaking factor of 2 to the average day flow rate.

4.3 Gravity Sewer Main Design

A. Hydraulic Calculations

1. General

The Chief Engineer reserves the right to determine sizing of major wastewater conveyance lines and pumping facilities.

For extensions or improvements to the public sewer system serving more than 25 EDU's, or for critical areas of the public sewer system, the Chief Engineer may require the Designer to provide hydraulic calculations on the proposed sewer system improvements and the effects of the proposed improvements on the existing downstream sewer system. The Designer shall consult the Chief Engineer for information regarding available flow measurements, drainage area boundaries and other operational considerations. The hydraulic calculations on the proposed sewer system improvements and the effects on the downstream sewers shall be submitted to the Chief Engineer for review and approval.

The Manning Equation shall be used to determine the hydraulic capacity for all gravity systems. (See Table 4.1, "Manning 'n' Coefficients"). The Designer shall submit design data and calculations for all sewer projects, whether they are the work of others (properly referenced) or the Designer's own work. The design data and computations shall include average and peak flow rates, infiltration/inflow rates and design flow rates. Design computations for all special structures shall be submitted.

2. Pipeline Size

The size of the sanitary sewer shall be sufficient to carry the design flow rate with the hydraulic gradient coincident with or below the crown of the pipe. The design flow rate of the sewer shall not exceed the pipe capacity at full flow. Sanitary sewer designs allowing surcharging are not permitted. All sewer sizes shall be determined by the following Equation of Continuity relationship:

$Q = AV$
where:
Q = quantity of wastewater in cfs (design flow)
A = required cross sectional area of conduit in sq. ft.
V = velocity in feet per second

All sewer sizes shall continually increase progressing downstream.

3. Flow Velocity

Pipeline velocities shall be determined by the Manning formula:

$$V = \frac{1.486\, r^{2/3}\, s^{1/2}}{n}$$

where:
V = velocity in feet per second
n = coefficient of roughness
(see Table 4.1 "Manning "n" Coefficients")
s = slope of the hydraulic gradient in feet per foot
r = hydraulic radius = cross sectional area of liquid divided by wetted perimeter of the pipeline

Table 4.1: Manning "n" Coefficients

Pipe type (abbreviation)	"n" Coefficient
Polyvinyl Chloride (PVC)	0.010
Ductile Iron Pipe (DIP)	0.013
Reinforced Concrete Pipe (RCP)	0.013
High Density Polyethylene (HDPE)	0.010

Laying pipes on slopes that provide minimum velocities shall be avoided whenever possible. Minimum velocities of 2.0 feet per second at design flow shall be provided whenever possible. Velocities of less than 2.0 feet per second will be permitted only with written authorization of the Chief Engineer. When pipelines are flowing less than half full, the fluid velocity shall be examined on the basis of partial flow relationships and the pipeline shall be sloped to maintain minimum velocities under the design flow conditions.

Slopes producing design velocities greater than 10 feet per second shall be avoided whenever possible. Pipeline slopes exceeding 10%-20% are permitted only with the approval of the Chief Engineer. If practical, suitable drop manholes or other methods of dissipating energy and reducing eroding velocities shall be provided as approved by the Chief Engineer.

B. Pipeline Alignment

1. General

The layout of a gravity sewer system of collectors and interceptors is a function of the topography. The Facility Plan shows the existing and planned major wastewater facilities, along with the location and service areas of pump stations. The design of sewer subsystems relying on pumping stations not indicated on the Facility Plan must be approved by the Chief Engineer. Collector and interceptor systems shall be prepared to service all areas up to the drainage area limits and no further unless specifically authorized. The plan and vertical arrangement of the sewer system shall provide for future connections within the drainage area limits. The design shall accommodate future service requirements, while minimizing both expense and modifications to the existing system.

The Designer has the responsibility to identify where good planning and design are in conflict with these guidelines and the requirements of other agencies. The proposed alignment must be the best overall design. Failure to identify conflicts during the preliminary design may result in delays and possible costly changes. Consideration must be given to space requirements for future utilities, particularly water and storm drains. In the absence of water and storm drain design, the Designer shall recommend the space requirements for future water or drainage facilities and provide the necessary clearances. This requirement is particularly important at roadway intersections.

When plans of existing facilities are insufficient to accurately locate existing underground obstructions, the Designer shall request permission from the Commission to perform test pit excavations to uncover the subject facilities so that the horizontal and vertical positions of existing utilities can be accurately determined. If such permission is granted, the Designer shall be responsible for providing all traffic control and public safety measures necessary to locate the utilities and restore the surface. The Designer shall coordinate the test pit operations and provide a field survey crew to physically locate the subject facility.

2. Horizontal Alignment-Location

   The horizontal alignment shall take into account the following general alignment guidelines:

   a. Due to the greater depth of the sewer in relation to most other utilities, the location for the sewer main shall be given first priority.

   b. Sanitary sewers shall be designed with a straight horizontal alignment between manholes.

   c. For Developer Projects, the design of the public water, sewer and storm drain utilities within proposed developments shall be prepared concurrently to ensure compatibility of the utilities. If public water and sewer mains cannot be located within the paved roadway section, the Designer shall request a waiver of these design standards from the Chief Engineer, providing reasons why the standards cannot be met.

   d. In new developments where sewers are constructed in advance of the road pavements, the sewer shall be placed on the lower side of the street, 7 feet from the street centerline. On curved streets, this location must be compromised, since straight horizontal alignments are required between manholes, except as noted above. Where curbs will exist, the sewer shall be placed no less than 5 feet from the face of the curb. The sewer may be placed on the high side of the street if the number of house connections makes it cost effective.

   e. Sewer main easements are routinely acquired during the subdivision process for the future extensions of the sewer system to serve adjacent properties.

   f. Where the future extension of the sewer main would undermine the foundation of a structure, all such sewer mains shall be constructed as part of the subdivision.

   g. In residential developments where easements are required between two adjacent lots for the extension of the sewer system, a sewer main shall be provided within the easement between the adjacent lots. The sewer main shall extend the full length of the easement between the lots.

h. In cases where a utility easement is required to be extended to the limits of the property being developed to provide future service to an adjacent property, that easement shall be cleared of trees and otherwise prepared for the future extension of the main.

i. Where water and/or sewer mains leave the public road right-of-way, an all-weather access roadway is required.

j. Within private roads, public sewer mains shall be located within the paved roadway sections, whenever possible, and shall have a 5-foot minimum separation from other utilities.

k. In Developer Projects where all new facilities are to be constructed, and in existing developments with curbs, sewer mains are usually placed 7 feet from the centerline of the street and on the side nearest to the lower ground. Mains shall be located within the pavement area, wherever possible, and no less than 5 feet from face of curb or proposed curb and shall have a 5-foot minimum separation from other utilities.

l. In Developer Projects, the design of the public water, sewer and storm drain utilities within proposed developments shall be prepared concurrently to ensure compatibility of the utilities. If public water and sewer mains cannot be located within the paved roadway section, the Designer shall request a waiver of the design standards and provide reasons why the standards can not be met.

m. Sewer mains shall be designed to minimize disruption to environmental features. The Designer shall take into account all existing environmental factors and avoid disturbance of sensitive areas, whenever possible.

n. The sewer alignment within existing areas (streets or roads) shall avoid high traffic volume roads if other options are available. The alignment shall be designed to allow the construction of the pipeline without the need to have road closings. When a sewer main or lateral connection is required to cross a County road, the Designer shall recommend whether to open cut, tunnel or bore and jack the utility across the roadway after considering the type and condition of the road, traffic volumes, disruption to traffic, possible conflicts with existing utilities, and specific conditions on the project site.

o. In existing areas (streets or roads), the alignment shall attempt to avoid the removal of trees or landscaped areas. In parks and public rights-of-way where the location of the sewer main would require the removal of trees, the Designer shall obtain the approval of the appropriate agency (SHA or

DPW&T) for tree removal. When the pipeline must be located outside of the road right-of-way, the alignment shall minimize disruption to environmental features. In addition to trees, the alignment shall try to avoid steep slopes, wetlands and other sensitive areas. The alignment shall follow the property lines as much as possible.

p. When existing roadways are involved, the horizontal alignment of the road must be evaluated for acceptable geometry and the sewer main designed in respect to these possible roadway improvements to avoid costly future relocations. The Designer shall evaluate the plan geometry of the road with respect to movement of traffic and available right-of-way width for the accommodation of the pipeline. If easements must be acquired for the main, a recommendation shall be provided to the Chief Engineer as to whether additional rights-of-way should be acquired for future roadway modifications.

q. Where existing sewer mains are too shallow or do not contain adequate capacity for new incoming sewers, the existing sewers shall be redesigned as required and all existing connections shall be reconnected to the new sewer.

r. Within private roads, public sewer mains shall be located within the paved roadway sections wherever possible and an easement provided to MetCom.

s. Sewers and appurtenances shall not be placed in existing or proposed storm water management facility locations.

3. Vertical Alignment

a. Grades

The vertical position of gravity sewers is determined by the rate of slope between the unit to be served and the collector sewer, the rate of slope of the ground along the course of the pipeline and by the existence of obstructions that cannot be economically relocated. All sewer grades shall be established as to require the least excavation while satisfying minimum and maximum velocity requirements, design flow conditions, clearances, and depth requirements. All sanitary sewers shall be designed on a continuous grade between manholes. Table 4.2, “Minimum Allowable Sewer Slopes”, indicates the minimum slopes permitted.

Table 4.2: Minimum Allowable Sewer Slopes

Pipe Diameter	Minimum Slope in feet per 100 feet
8" Terminal Main	0.72
8"	0.40
10"	0.28
12"	0.22
14" and larger	Slope to provide min 2.0 ft/s velocity at the design flow rate

The minimum size for all collector and interceptor sewers shall be 8-inches in diameter. The minimum slopes noted above are required to maintain a velocity greater than 2.0 ft/s based upon a Mannings "n" coefficient (roughness) of 0.010 when the pipes are flowing full or half full.

Sewer house connections (SHCs) shall have the minimum slopes as shown in the Sewer House Connections section of this design manual. For gravity systems, pipeline layout is directly affected by minimum acceptable fluid velocities as determined by the design flow, pipe size, slope and applicable Manning "n" coefficients (roughness).

The maximum slope for all sewers shall be 6%.

Where different diameter pipes meet at manholes, the crown of all upstream pipes shall be set at the same elevation as the crown of the downstream pipe unless hydraulic gradient computations require a higher setting.

b. Sewer Depths: General

The collector sewer shall be designed at a sufficient depth to provide gravity sewer service to the basement or lowest floor level of all buildings unless the sewer line becomes excessively deep (over 10 feet) in order to serve the basements or otherwise directed by the Chief Engineer. In some cases injector pumps may be necessary in some basements in order for them to be served. These injector pumps will be internal to the building and will not be owned by MetCom and will be the responsibility of the homeowner. The minimum cover over any sewer or SHC within the road right-of-way or public easements shall be 4 feet. Where storm drains have not been designed or installed, each SHC shall have a minimum cover of 6.5 feet within the street right-of-way. The required service depth at the collector sewer shall be determined by the following criteria:

1) Improved Lots

Unless test pitted, the building sewer coming from existing houses shall be assumed to have an invert elevation 2.5 feet below the lowest floor elevation at the exterior wall. The invert elevation of the SHC at the collector sewer shall be calculated as follows:

$E= BE - 2.5' - (L_{SHC} \times G_{SHC})$

where:

E = invert elevation of SHC at collector sewer (ft.)

BE = basement elevation or lowest finished floor elevation (ft.)

L_{SHC} = required length from existing structure to the sewer main (ft.)

G_{SHC} = required building sewer and SHC grade (ft/ft)

(see Section 4.6.D)

When the septic tank is located in the rear of the existing structure, "L" shall be measured from the center rear of the building around the structure to the collector sewer in the street.

2) Unimproved Lots (Residential)

On vacant lots, in addition to providing an invert elevation of the SHC at the property line in the sewer profile, the basement elevation or the minimum service elevation shall also be shown on the plans for each lot to be served to the nearest 100^{th} of a foot (denoted thus: BE = 423.67 or FF= 432.02), which shall represent the lowest floor elevation that may be serviced by gravity. In determining this elevation, it shall be assumed that any future structure will be constructed so that gravity sewer service shall be available to the most distant part of the lot or property within the building restriction line.

3) Unimproved Lots (Commercial/Industrial)

For commercial and industrial sites, the Designer shall determine a reasonable sewer service elevation, taking into account the probable size of the building and the extent of gravity service required. Unless specific information is available regarding future development plans, it must be assumed that a large structure such as a warehouse may occupy the lot with the building located at the most distant part of the lot within the building restriction line. The sewer service elevation determined shall be shown on the plans as "minimum service elevation".

4) New Developments

In new developments, when subdivision plans include lot grading and structure elevations, the sewer shall be designed to serve the lowest floor level of each structure. When site plans have not been prepared, the sewer shall be designed in the same manner as for unimproved residential lots, with the minimum basement elevations shown on the plans to the nearest 100th of a foot (denoted thus: BE = 423.67 or FF= 432.02). For townhouse developments, the minimum basement elevations may be shown in tabular form.

c. Sewer Depths at Stream Crossings

Where a sewer parallels a water course, the Designer shall ensure that the proposed sewer depth will be adequate to facilitate future crossings of the stream while maintaining a minimum 3 feet of cover over any future stream crossings. The centerline of the adjacent stream bottom shall be indicated on the sewer main profile if the sewer is located within 25 feet of the stream.

Where sewer pipes cross streams, the crossing angle shall be as near to 90 degrees as possible, and the crossing pipe shall be set at an elevation to provide a minimum of 3 feet of cover over the pipe. Ductile iron pipe, Class 52, shall be employed for the stream crossing and shall extend from manhole to manhole.

4. Sewer Surcharge Protection

In order to ensure that pumping station malfunctions will not result in wastewater backing up into nearby residences, the Designer of collection systems connected to a pumping station shall:

a. Determine the rim elevation of the lowest manhole upstream from the pumping station that is not required to have a watertight frame and cover assembly.

b. Identify all basement elevations lower than the manhole frame and cover established in Item a. above.

c. Identify first floor elevations lower than the manhole frame and cover established in Item a above.

d. Identify vacant lots having a ground elevation lower than the manhole frame and cover established in Item a. above.

e. Provide on the plans for all dwellings, structures, and lots identified in Items b, c and d stating the following: “This lot may be subject to wastewater backup in the event of a pumping station malfunction. A back water valve is required on the private building sewer serving this lot.”

C. Sewer Mains: Plan

1. Sewer plans shall be drawn to a minimum horizontal scale of 1" = 50'.

2. All proposed pipelines shall be shown and symbolized as noted in the Standard Details. More specifically, the pipe is to be identified by two evenly shaded parallel lines. Pipelines 24-inches in diameter and smaller shall be shown symbolically as two feet wide as a minimum, based on a scale of 1" = 50'. Pipelines over 24-inches in diameter shall be shown to scale.

3. The plan location of the pipeline and appurtenances shall be carefully dimensioned so that its route is clearly identified. Appurtenances shall be called by symbols and notes and dimensioned both in respect to pipeline arrangement and in respect to required positions in relation to surface features in accordance with DPW&T standards.

4. Manholes shall not be shaded. Manholes shall be numbered in consecutive order with the numbers placed within a standard circle. The slope of the frame and cover shall conform to the proposed finished grade and shall be protected from sheet runoff. The type of manhole shall conform to the Standard Details.

5. All pipe sizes shall be clearly identified together with flow directional arrows.

6. A restoration schedule shall be provided on the plans. The table shall cover the entire limits of the project and include restoration of all disturbed surfaces including roadways, grassed areas, driveways and open space. Where more than one material is required for restoration of the surface at a location (i.e. bituminous pavement to the right of the pipeline and sod to the left of the pipeline), the limits shall be noted and the material replaced in kind. Soil Conservation District requirements may supersede the above items.

7. Sewer House Connections (SHCs)

   The following provides a description of the required design information for SHCs that must be provided on the sewer plans.

   a. All new SHCs shall be indicated in plan by a single heavy line with a wye at the collector sewer. All SHC are required to be made into a 6” x 6” horizontal wye, unless approval to connect into the vertical riser is obtained from the Chief Engineer prior to time on connection. A formal request form must be submitted and approved. The request form can be found in Appendix. All SHCs shall be extended to the property line and denoted by size (6-inch or 8-inch) and type (SHC or DHC). All proposed invert elevations of clean outs shall be indicated at the property line.

SHC inverts for townhouses and apartments may be shown in tabular form with the locations of the inverts well defined. Clean-outs shall be shown on the plan.

b. All buildings that cannot be served or are limited to first floor service shall be clearly noted on the plans. All such service limitations must be approved by the Chief Engineer.

c. Service connections to properties in low areas that may experience flooding in the event of wastewater backups and/or surcharging of main line sewers shall be identified as such. The plans shall note that preventive measures, as required by the International Building Code, provided by the property owner when the connection is made to the system by the plumber. See Section 4.3.B.4, "Sewer Surcharge Protection" for analysis requirements.

d. On vacant lots, minimum service elevations must be calculated as described in Section 4.3, "Vertical Alignment". This minimum service elevation must be provided on the plans in addition to the invert elevation of the SHC at the property line.

e. All percent grades for the SHC shall be indicated on the plans if the design grade for a SHC is either less than or greater than 2%.

D. Sewer Mains: Profile

1. Profiles shall be drawn for all public sewer mains at a minimum scale of 1" = 50' horizontal and 1" = 5' vertical.

2. Profiles shall be shown below the sewer plan view wherever possible. For Developer Projects, the complete layout of the piping system may be shown in the plan view drawings. Profiles shall then be shown on a separate sheet and cross referenced to the appropriate plan sheet.

3. Manholes in profile shall be numbered to correspond to the manhole numbering on the plan. The numbers shall be within a standard circle together with the manhole top elevation.

4. Minimum cover of 4 feet over gravity sewer mains.

5. Profiles Within Proposed Roads

   The methods for developing sewer profiles are identical with those described for water mains with the resultant opportunity to utilize a single profile arrangement for combined water and sewer projects. As in the case of the water mains, sewer lines and manholes to be located within proposed roadways shall be projected onto the centerline of stationing of the roadway even though the true stationing is developed between manholes. This procedure means that the scaled length of the sewer lines in the profiles will not equal the true length as shown in the plan view. On a combined water and sewer project, each utility shall be projected onto the centerline road grade. Manhole rim elevations shall be called out on the plans.

   If the sewer is outside of the proposed paved area then a proposed finished grade above the sewer shall be shown.

6. Profiles Within or Outside Existing Roads

   In developing the profile information within or outside existing roads, the centerline length of the sewer main in plan shall be used for the profile stationing, which will provide true length profiles. For existing roads that do not conform to DPW & T guidelines, a centerline road grade conforming to the design standards is to be shown on the profile and identified as "possible future centerline road grade." On a combined water and sewer project, the sewer shall be projected onto the water pipeline centerline.

7. Sewer and water line clearances shall be as specified in Recommended Standards for Water Works (Ten State Standards). A minimum of one-foot clearance from other utilities shall be maintained except for natural gas lines. A minimum of five-feet of clearance shall be maintained between water lines and natural gas lines. Water lines shall be above sewer and storm drain lines.

8. Utilities that cross sewer mains shall be plotted to horizontal and vertical scale and identified so as to advise the contractor of their specific locations. Stations and invert elevations shall be provided at every pipeline crossing for each pipe shown. If the elevation of the existing pipeline to be crossed is unknown and it is likely to have a significant impact on the sewer main vertical alignment, the Designer shall arrange to have a test pit excavated to determine the exact horizontal and vertical location of the existing utility or utilities.

9. For each SHC, a light vertical line shall be drawn from the collector sewer to the elevation of the SHC at the property line. All SHCs shall be shown as intersecting pipes in the profile. The applicable finished floor or basement

elevation of the dwelling to be served shall be shown at the appropriate elevation relative to the house connection, and to the correct vertical scale.

10. The date of the survey used to establish ground lines shall be noted on the profile. Existing and proposed ground lines shall be shown where applicable as well as the source from which the information was acquired. The following information as minimum requirements shall be shown on the profile:

    a. Road names – when plan and profile are on separate sheets.
    b. Existing ground elevation line
    c. Proposed ground elevation line
    d. Utilities, existing and proposed
    e. Pipe diameters and pipe type shown
    f. Stations and invert elevations shall be provided on the profile at all vertical and horizontal deflections.
    g. Limits of restrained joints for force mains.
    h. Limits of concrete encasement.

Table 4.3: Sewer Hydraulic Information

Information	Symbol	Units
Pipeline Diameter	NA	Inches
Pipeline Slope	NA	%
Pipeline Capacity	Q_{cap}	MGD or CFS
Design "n" value	N	NA
Velocity at Capacity*	V_{cap}	FPS
Design Flow*	Q_{des}	MGD or CFS
Velocity at Design Flow*	V_{des}	FPS

* For interceptors or collector sewers serving more than 25 EDU's or collector sewers receiving pumped flows

11. The sewer hydraulic information indicated in Table 4.3, above, shall be provided in the profile for each segment of sewer between manholes. When this design procedure is followed, it will be apparent where slight adjustments in invert slopes will provide a pipeline capacity closer to the total system capacity. In this way, restrictions due to a single, flat grade set within the larger system of manholes and pipe lengths may be avoided.

12. Excessive pipe slopes that may induce stripping of hydrogen sulfide will not be permitted. The Chief Engineer may require sulfide analysis calculations.

4.4 Pipeline Materials

A. General

Pipeline design practices and materials used in sewer systems for the Commission are employed to ensure maximum service capability with the least costs of installation and maintenance. Factors that determine the equivalency of pipe materials include the following:

1. Structural strength under field conditions.

2. Hydraulic capacity as determined by the roughness coefficient as used in the Manning formula for pipeline velocities.

3. Characteristics of existing site conditions, which may have detrimental effects on pipe materials.

4. Characteristics of wastewater, which may have detrimental effects on pipe materials.

The Designer must be aware of the particular properties of each type of pipe so as to include or exclude the possibility of its employment under the greatest range of applications, leaving the construction contractor as many options as possible for the selection of the type of pipe to be installed. Any special design features and/or special materials required due to the specific nature of the project shall be submitted for approval to the Chief Engineer. The Designer shall thoroughly stipulate in the Specifications and show on the plans which types of pipe materials are acceptable for the various applications on each project.

The following Table 4.4, “Sewer Pipe Materials” indicates the pipe materials that are acceptable to the Chief Engineer for interceptor and collector sewer construction. These materials are acceptable when supplied in accordance with the material and installation requirements of the Standard Specifications and this design manual.

Table 4.4: Sewer Pipe Materials

Pipe Type (abbreviation)	Specification	Diameter Range	Design Standard
Polyvinyl Chloride (PVC)	SDR 35 meeting ASTM D3034 ASTM F679	4" – 15" >15"	AWWA M23 AWWA M23
Ductile Iron (DIP) Glass lined epoxy coated	AWWA C151	8" and larger	AWWA C150
High Density Polyethylene (HDPE)	ASTM D3035 or ASTM F714	2" – 24"	ASCE Manual No. 60

Notes: See Sewer House Connections, Materials for acceptable SHC pipe materials

5. Special Circumstances

   a. In addition to the types of pipe shown above, other pipe materials may be considered on a case-by-case basis when recommended by the Designer and approved by the Chief Engineer. For special projects or conditions, the Designer and the Chief Engineer may select pipe manufactured to industry standards other than those listed in the Standard Specifications.

   b. The Chief Engineer will require the use of DIP under the following circumstances:

      1) When sewer depths exceed 18 feet.

      2) For all open cut stream crossings.

      3) Sewers within casing pipes or tunnels shall be restrained DIP.

      4) When flow velocities exceed 10 feet per second.

      5) When pipeline slopes exceed 20% (Designer shall also provide for pipe anchors when necessary).

   c. In areas where significant hydrogen sulfide concentrations are expected to exist, such as downstream from a pumping station or pressure sewer discharge, hydrogen sulfide resistant materials such as PVC shall be used if available in the required diameter. If PVC is not an option in the required diameter, the Designer shall investigate other solutions such as glass lined or epoxy coated DIP, HDPE or other special protective linings or materials.

d. Application of corrosion resistant materials indicated in paragraph c) above shall be required in other areas anticipated to be particularly aggressive to concrete, such as sewers which will handle industrial effluents, high temperature discharges and leachate from sanitary landfills.

B. Pipe Thickness Design

1. General

The acceptable installation depths discussed below for the various pipelines are based on the standard bedding, backfill, trench width and all other criteria indicated in the Standard Specifications. Even within these given parameters, the Designer shall be responsible for all pipe designs. For special applications that differ from those detailed in the Standard Specifications and the design criteria of this manual, a special analysis must be performed to determine the appropriate pipe thickness and/or increased bedding conditions and submitted to the Chief Engineer for approval. If such analysis is required, the pipe strength requirements for in-place trench conditions shall be determined by the design standards indicated in Table 4.4, “Sewer Pipe Materials,” for each pipe material. The following design criteria shall be utilized for pipe thickness design:

a. The maximum and minimum pipe depths along the pipeline alignment;

b. A unit weight of soil of 120 lb/cf unless site specific soil information is available indicating otherwise;

c. A trench bedding condition one “type” or “class” lower than actually specified for installation.

2. Polyvinyl Chloride (PVC) Pipe

The PVC pipe specified in the Standard Specifications is suitable for standard buried applications from four (4) feet to eighteen (18) feet of earth cover when installed using the specified bedding, backfill and compaction requirements detailed in the Standard Specifications. For situations requiring greater than eighteen (18) feet depth or for shallow installations less than four (4) feet, DIP shall be used.

3. Ductile Iron Pipe (DIP)

DIP for sanitary sewers and force mains shall be special thickness Class 52. For loading situations such as depths greater than eighteen (18) feet, less than four (4) feet, or where other extreme loadings are anticipated, thickness design shall be based on the design methods outlined in AWWA C150.

4.5 Gravity Sewer Appurtenances

A. Manholes

1. General

   a. Within the sewer pipeline system, the most significant appurtenance is the manhole. Manholes are employed for several functional requirements and to ensure their ability to perform these functions, their design features have been standardized. The design requirements for all manhole structures are provided in the Standard Details. All manholes shall be designed as pre-cast concrete structures. Inverts of manholes are generally constructed of brick carefully configured to provide smooth channels for both through-flow and directional changes. Pre-cast manhole channels are an acceptable alternative to brick channels. Manhole inserts are required at all manholes except those with watertight frames and covers.

   b. Inverts are formed to receive future flows when the direction and grade of future connections are identified in the design process. When a future extension from the manhole is to be provided, a formed invert channel and a 5-foot long stubbed connection shall be provided from the manhole.

   c. Manholes represent a significant potential source for infiltration and therefore, waterproofing is a standard feature. The exterior of all precast manhole sections shall be coated with coal tar epoxy and all joints shall be gasketed as required by the Standard Specifications. Standard heavy traffic manhole frames and covers shall be used on all manholes. Manhole cover inserts are required on all manholes except those with watertight covers.

   d. Manholes shall be kept away from inconvenient or inappropriate locations such as curbs, gutters, ditches, vehicular parking area, athletic and playing fields, near buildings and the like.

   e. The top of manholes placed in cross-country areas shall be set at a height equal to or above grade as recommended by the Designer based on actual site conditions. All such manholes shall be set a maximum of 18-inches above existing grade elevations.

f. When the manhole is within a 100-year floodplain, a raised watertight frame and cover shall be provided. Watertight frames and covers may be required in low-lying areas or areas prone to flooding.

g. When the pipe size entering and exiting manholes are the same, a minimum drop between invert in and invert out shall be 0.10 foot. The maximum drop between invert in and invert out shall be one (1) foot. For pipelines of different sizes, the pipeline crowns shall be matched. For manholes where vertical drops are required, see Section 4.5.B, "Drop Manholes."

2. Manhole Spacing

Manholes shall be installed under the following circumstances:

a. Change in horizontal direction or vertical grade
b. Change in pipe size
c. Change in pipe material
d. Pipeline junctions
e. At spacings not to exceed 350 feet for sewers less than 30-inches in diameter and 600 feet for sewers 30-inches in diameter and greater per Ten State Standards
f. At the terminal end of all sewers
g. At locations along the sewer where future extensions are planned
h. At any additional place required by the Chief Engineer for maintenance, sampling, venting or flow measurement purposes
i. At transitions from private to public sewer mains

3. Manhole Size

The minimum manhole size for all gravity sewer pipelines shall be 4 feet in diameter. For pipeline sizes of 24-36 inches in diameter, a minimum 5 feet in diameter manhole shall be utilized. For pipelines greater than 36-inches in diameter, the Designer shall submit design drawings and details of the manholes to the Chief Engineer for approval prior to placement of the details on the plans.

Manholes over 15 feet in depth shall be 5 feet in diameter or larger depending on pipe size.

4. Manhole Channels

Typical manhole channels are illustrated in the Standard Details. If channeling for standard manholes is required that differs in geometry from those configurations shown in the Standard Details, the Designer shall detail the channel on the plans, showing curve data, invert and bench elevations, bench slopes, etc. This effort shall also be provided for all manholes over 5 feet in diameter, bend structures and junction chambers. Manhole channels shall not have a centerline radius of less than 2.5 times the pipe diameter.

5. Manhole Linings

   The Designer must take into consideration the use of special invert and manhole lining materials when significant hydrogen sulfide (H_2S) concentrations are anticipated. In addition, the use of drop manholes is discouraged when hydrogen sulfide is present or likely in the wastewater. The use of spray-on manhole liners shall be approved by the Chief Engineer.

6. Deep Manholes

   The manhole depth is defined from the lowest invert to the top of the frame and cover. An intermediate landing is to be provided for all manholes greater than 18 feet in depth and at 10-foot intervals when the manhole depth exceeds 25 feet. In addition, if the manhole depth exceeds 20 feet, the Designer shall take into consideration the following design requirements:

   a. Check the manhole for flotation.

   b. Verify that the groundwater pressure on the precast concrete manhole section joints will not exceed the requirements of ASTM C 443 and the Standard Specifications.

   c. Verify that the groundwater pressure on the pipe to manhole connections will not exceed the requirements of ASTM C 923 and the Standard Specifications.

   d. Identify any modifications necessary to the standard manhole details as a result of the manhole depth and groundwater pressure.

B. Drop Manholes

Design details as well as maximum and minimum allowable drops are indicated for drop manholes in the Standard Details for various sewer sizes. When the drop required is less than the minimum indicated on the standard details (2'-0” or 2'-6”, depending on pipe size), no drop manhole is required. In lieu of a drop manhole, the slopes of the connecting pipelines and manhole channel shall be adjusted to limit the difference between the invert in and invert out of the manhole to less than one foot.

All drop manholes shall typically utilize outside drop connections. Inside drop connections to existing manholes shall only be considered when there is imminent damage to existing utilities or structures in construction of an outside drop connection.

All use of inside drop connections will require the approval of the Chief Engineer. A 5' manhole shall be used if more than one (1) inside drop connection is proposed in any single manhole.

C. Inverted Siphons

1. General

   Inverted siphons are considered for use when it is necessary to maintain a suitable protective ground cover over a pipeline or to reduce extensive trench depths when an obstruction to the preferred grade requires a lowering of the sewer for a significant distance. Inverted siphons should be avoided wherever possible. Inverted siphons will only be permitted with the approval of the Chief Engineer. The Designer shall provide all required specialized details to the Chief Engineer for approval.

   a. Design

      When a siphon is determined to be an acceptable design alternative, at least two pipes shall be provided with a minimum pipe size of 6-inches. One redundant pipe shall be provided for bypass capacity, for emergencies or when the other pipeline is taken out of service. Each pipe shall be capable of carrying the full design flow rate. In pipe sizes 6-inch to 24-inch in diameter, restrained DIP shall be used.

      Siphons shall be designed preferably for a minimum velocity of 4 fps at the design flow rate with an absolute minimum velocity of 3 fps. The capacity of the inverted siphon shall not be less than the capacity of the sewer system upstream of the siphon. Sufficient hydraulic head shall be available to pass the design flow without submergence of the upstream sewer. All hydraulic calculations shall utilize the Manning's equation.

      Inlet and outlet structures shall be designed with valve arrangements to facilitate flushing of each siphon line and to minimize maintenance. All inverted siphons shall be designed with inlet and outlet vaults. Vaults shall contain sluice gates on the inlet and outlet of each barrel and shall have clear access from above for maintenance. Sluice gates shall have operators on top of the vaults.

   b. Alignment

The horizontal and vertical alignments of an inverted siphon shall be maintained as straight as possible. Abrupt alignment changes shall be avoided.

D. Connections Into Existing Systems

1. General

   All connections into the existing public sewer system are subject to the approval of the Chief Engineer. The Designer shall provide on the plans all applicable notes and details for any required connections to an existing system. All connection designs must address all issues regarding maintaining flow in the existing system at all times. See the Standard Details for typical connection details.

2. Connections Into an Existing Manhole

   If the existing manhole within the sewer system has an existing stub connection, the Designer shall match the existing pipe material or remove the connection if the existing pipe material is not one of the approved pipe materials. If the existing manhole does not have an existing opening or a knockout for a future connection, the manhole shall be cored, the invert channel formed and a field gasket connector installed to secure the new sewer to the existing manhole as illustrated in the Standard Details for Construction.

   When there is not sufficient clearance between the existing pipe openings in the manhole and the new pipe opening, the Designer may provide a design for the sewer to enter the existing manhole offset from the manhole centerline. The Designer shall provide all required details, dimensions, etc. to the Chief Engineer for approval.

3. Connections Into an Existing Sewer

   If a new manhole must be designed over an existing sewer, the Designer shall refer to the Standard Details. The following items shall be considered when designing a connection into an existing sewer:

   a. When the existing sewer is above the new pipeline, the Designer must submit details of the connecting manhole to the Chief Engineer for approval for the connection between the new manhole and the existing sewer.

   b. Manhole drop connections may be designed for connections into an existing sewer when the drop connection is for the new pipeline.

4.6 Sewer House Connections (SHCs)

A. General

SHCs are to be provided to connect individual buildings to the collector sewer main.

All SHC configurations are connected to the main line by a combination of fittings including wyes, tees and bends as indicated in the Standard Details. SHCs shall be indicated in plan and profile.

B. Location

1. The Commission owned portion of sanitary sewer house connections shall be built to the property line. It is the practice of the Commission to provide a SHC at the time of initial sewer construction to all properties having frontage on the collector sewer. All such properties shall be provided with a capped cleanout at the property line as shown in the Standard Details.

2. All SHCs for improved lots shall be located so as to readily serve the basement or lowest floor of the existing dwellings or buildings in a cost effective manner. All SHCs for unimproved lots shall be located at the low point of the lot. Where the location or depth of the sewer main is established by the Critical Area, this connection shall be located by the Designer in the most advantageous position to minimize costs to the Commission while providing basement service to the lot. In non-critical areas, the actual location of the SHC shall be determined by the property owner in the field prior to construction as long as it is compatible with the system as designed. However, it shall be the responsibility of the Designer to propose a feasible location for the SHC based on the location of existing wells, septic tank facilities, topography and other features.

3. In developments where an easement is required between two adjacent lots for the extension of a SHC, the SHC shall be constructed within the easement between the adjacent lots as part of the development. The SHC shall extend the full length of the easement between the lots.

C. Size

The size of all SHCs shall be 6-inch depending on the land use type and the discharge flow requirements established by the Designer. Additional sizes may be considered by the Chief Engineer.

D. Grades

SHCs shall be designed for a 2% minimum grade. If this rate of slope results in an excessively deep collector sewer, a reduction in the SHC slope may be considered by the Chief Engineer. The maximum allowable grade for a SHC shall be 5% or that approved by the Chief Engineer. All SHCs designed on a grade of less than or greater than 2% shall be noted on the plans.

E. Depth

All SHCs shall be installed at the required depths to provide gravity service to the basement of each lot served.

F. Type

All SHCs shall be of the single service type. A twin SHC shall not be used unless approved by the Chief Engineer. A Drop House Connection (DHC) shall be provided when the invert of the SHC at the collector sewer is greater than 2 feet higher than the invert of the collector sewer when the house connection is extended from the house at a 2% grade to the sewer main. Where conditions permit, the Designer may use a 45° DHC if approved by the Chief Engineer.

In specifying a 45° DHC, the Designer shall ensure that the use of a 45° DHC will not preclude or interfere with the placement of future utilities.

G. Materials

The following Table 4.5, "SHC Materials" shows pipe materials that are acceptable to the Chief Engineer for SHCs when supplied meeting the material and installation requirements of the Standard Specifications.

Table 4.5: SHC Materials

Pipe Type (abbreviation)	Specification
Polyvinyl Chloride (PVC)	SDR 35 meeting ASTM D3034
Ductile Iron (DIP)	AWWA C151
High Density Polyethylene (HDPE)	AWWA C905

For all new sewer construction, SHCs shall be of the same material as the sewer. For existing sewers, SHCs shall be either PVC or DIP subject to the approval of the Chief Engineer.

H. Appurtenances

Cleanouts shall be provided on all SHCs at the property line on the homeowner's side.

Cleanouts shall be as shown in the Standard Details and in plan view.

I. Manhole Connections

SHCs can be installed as a drop house connection using an outside drop at the manhole. See Section 4.4.B, "Drop Manholes" of this Chapter for information regarding drop manhole connections.

Multiple SHCs installations into a single manhole are subject to the approval of the Chief Engineer. The following information shall be considered when making multiple connections:

1. A maximum of three (3) SHC installations will be permitted into any one manhole.
2. SHCs shall not enter the manhole at an angle less than 90 degrees to the downstream flow direction.
3. The centerline of the SHCs shall pass through the centerline of the manhole.
4. When radial installation is not possible, a maximum of two (2) parallel SHCs may be installed at any one manhole.
5. See the Standard Details for information regarding multiple radial and parallel SHCs installations.

J. Structural Considerations

Minimum and maximum permissible SHC depths shall be in accordance with the guidelines of this Chapter when installed in accordance with the standard bedding, backfill, trench width and all other criteria indicated in the Standard Specifications. In all cases, proper bedding shall be provided for SHCs.

4.7 Force Main Design

A. Hydraulic Calculations

1. General

   - Force mains shall be designed based on the existing and/or future pumps.
   - A minimum scouring velocity of 2.0 feet per second shall be provided at the design pumping rate.

- The minimum force main size shall be four (4) inches in diameter for "high" pressure and one and a half (1.5) inches in diameter for "low" pressure.
- The need for air and vacuum relief valves shall be evaluated. The use of air and vacuum relief valves shall be minimized as much as possible by adjusting the force main profile to minimize high points.
- Force mains may be constructed of DIP, HDPE or PVC.

The design of a wastewater force main must be coordinated with the design of the wastewater pumping station. The proposed alignment and profile of the force main shall be developed. The profile shall depict the changes in force main elevations. The Designer shall strive to achieve a vertical profile that rises continuously from the pumping station toward the transition manhole. The system curve for the force main, showing the total energy losses associated with the range of possible pumping rates, shall be developed. Using the system curve, the Hydraulic Grade Line (HGL) profiles can be developed.

The Hazen-Williams equation shall be used for estimating friction losses in force mains. Minor losses at transitions and bends shall also be added in the determination of the total energy losses. The HW coefficient of roughness ("C" factors) for force mains shall be as follows:

Material	**"C" Factor**
DIP (Glass –lined)	120
HDPE	130
PVC	130

The use of HDPE pipe is allowable for directional drill applications if approved by the Chief Engineer. The use of PVC is allowed for corrosion control protection and if approved by the Chief Engineer.

The Hazen-Williams factors indicated are representative of long-term design values for the system. The Designer shall check all pump station and force main selections for the anticipated lower headlosses (higher C value) that are typical of newer pipelines to ensure the satisfactory operation throughout the design life of the system.

a. HGL profiles shall be developed for the various flow scenarios planned for the pumping station. All HGL profiles shall be provided on the plans separately from the standard force main design profiles. Such profiles shall be condensed at a scale of 1"=200' horizontal; 1"=20' vertical and shall indicate hydraulic gradients, flows, force main velocities, design friction coefficients, existing ground, proposed pipe invert elevations and all other pertinent data.

b. The static head shall be based on the difference in vertical elevations between the lowest "normal pump stop" level in the wet well and the point the force main discharges to the gravity sewer or at the highest point along the system, whichever is higher.

2. Size

Force main size shall be based on the required pipe's maximum carrying capacity to convey the design flow rate at permissible velocities, while minimizing life cycle costs including construction, maintenance and pumping costs. The minimum force main size shall be four (4) inches in diameter for "high" pressure and one and a half (1.5) inches in diameter for "low" pressure.

3. Velocity

Design velocities in force mains shall be between 2.0 to 6.0 feet per second (fps). A minimum velocity of 3 fps-3.5 fps shall be required to re-suspend any solids within force mains that have multiple high and low points. The maximum velocity shall be based on the ultimate design pumping rate.

B. Force Main: Plan

Force mains shall be located within public road rights-of-way whenever possible. The design location of the force main shall be as described for a water main with the following exceptions:

When installed parallel to a water main, the force main shall be designed per the horizontal and vertical clearances indicated between water and sewer mains as specified in Recommended Standards for Water Works (Ten State Standards). Water mains and water house connections shall be placed higher than the force main. A minimum of one and a half (1.5)-foot clearance from other utilities shall be maintained except for natural gas lines. A minimum of 5-feet of clearance shall be maintained between force mains and natural gas lines.

When installed parallel to an existing sewer pipeline, provide 10 feet minimum horizontal clearance.

C. Force Main: Profile

The profile layout for a force main shall be as described for a water main in with the following exceptions:

1. Ideally, the force main shall be designed without intermediate high points and with the top of the force main being below the hydraulic grade line at the

minimum pumping rate so that air release valves will not be needed. If the elimination of high points is not feasible or if the design requires long, relatively flat vertical alignments, the design may require air release and air and vacuum valves.

2. Blowoffs along 4-inch and larger force mains are required where the force main contains a depressed section between two high points.

3. Continuous uphill pumping is preferred for a force main, where the force main discharge point to the gravity sewer is at a higher elevation than the rest of the system, so as to keep the force main full.

4. Force mains with intermediate high points above the gravity sewer discharge point can create partial vacuum conditions in the force main under circumstances such as draining conditions that occur due to intermittent pumping or when the HGL profile drops below the pipeline profile. The Designer shall provide appropriate air release and air vacuum valves to protect the force main against damage under these conditions.

5. Downhill pumping is prohibited.

6. All force mains shall have a minimum 4.5-foot and maximum 6-foot depth of cover. In street rights-of-way, cover shall be measured from the top of the force main to the proposed grade, or in cases when the proposed grade is above the existing ground surface, the depth of cover shall be measured from the existing ground line. In easements across private property, future development in the area shall be given consideration when developing the force main profile and possible future development grades shall be evaluated to ensure that the minimum depth of cover is met.

7. The top of the force main and its appurtenances shall generally be designed to be lower than the HGL.

D. Pipeline Materials

1. Allowable force main materials for routine projects are indicated in the Standard Specifications. HDPE will only be considered for directional drill installations in certain circumstances such as unavoidable conflicts with existing utilities, crossing sensitive areas and corrosive soils. The use of HDPE shall require the approval of the Chief Engineer. PVC C900 Certa-Lok is also used for force mains.

2. Special consideration shall be given to the character of industrial wastes before selecting the types of material and/or coatings for force mains. External loading, corrosive soils, abrasive wastes, foundations, minimizing the number

of joints, and similar problems shall also be investigated. Joints shall be as specified in the Standard Specifications.

E. Types of Joints/Fittings

Allowable pipe joints and fittings shall be as described in Water Main Design. Force mains shall be anchored at all fittings by restrained joints or buttress construction. The operating pressure and the surge pressure shall be considered in designing thrust restraint.

F. Appurtenances

1. Air Release and Air and Vacuum Valves

   Force mains shall ideally be designed to rise continuously in profile from the pumping station to the point of discharge. To minimize installation and maintenance costs, the Designer shall evaluate the feasibility of eliminating intermediate high points by installing the main deeper below grade. Where this is not practical, the Designer shall include automatic combination air and vacuum valves at the intermediate high points to expel accumulated air under pressure, to allow air into force mains to prevent vacuum conditions and expel larger quantities of air when the mains are filled. Valves on wastewater force mains shall be specifically manufactured for wastewater service, be sized according to manufacturer's recommendations, include quick-connect flushing hoses, and shall be placed in pre-cast manholes per the Standard Details. The following guidelines shall be used to locate combination air and vacuum valves:

   a. Peaks in pipeline profiles
   b. Abrupt increases in downward slopes
   c. Abrupt decreases in upward slopes
   d. Long ascents - 1,500 ft. to 3,000 ft. intervals
   e. Long descents - 1,500 ft. to 3,000 ft. intervals
   f. Long horizontal - 1,500 ft. to 3,000 ft. intervals

2. Flushing Connections

   A flushing connection shall be located at all low points along the force main; spacing is not to exceed 400 feet. The flushing connection shall be designed to allow the Commission to clean the force main in a manner appropriate to their equipment. A witness post shall be located at all flushing connections.

3. Transition Manholes

   The connection between the force main and gravity sewer shall be designed with a transition manhole. The termination of the force main in the transition manhole shall be designed so that the force main will be flowing full at all times. See the Standard Details for transition manhole details.

a. The invert of the gravity sewer shall be designed one (1) inch above the crown or top of the force main.

b. When the force main is 12-inches in diameter and larger, the Designer shall provide a means to protect maintenance personnel from falling into the pipeline at its connection to the manhole.

c. The interior of the transition manhole and at least one hundred feet of force main leading up to the transition manhole shall be coated to resist hydrogen sulfide corrosion.

d. The interior of the gravity sewer pipeline after the force main discharges into a gravity system shall be coated to resist Hydrogen Sulfide corrosion if it is other than PVC pipe.

e. All transition manholes shall have a watertight frame and cover.

f. There shall be no branch laterals or SHCs at a transition manhole.

4. Witness Posts

A witness post shall be located at all flushing connections and at all road crossings.

G. Water Hammer

When the velocity of a fluid is changed, a phenomenon known as water hammer may result, leading to fractures of pipe and fittings and other damage. This condition is especially serious on long force mains or where static pumping heads are high.

The Designer shall prepare a complete study of each force main design in conjunction with the related pumping station. A written detailed analysis along with supporting calculations shall be submitted to the Chief Engineer for approval during the engineering report phase of the project. This analysis shall include, and is not necessarily limited to the following:

1. Transient pressures due to water hammer and the effect of these pressures on the entire system.
2. Investigation of the pipeline profile to determine the possibility of water column separation.
3. Reverse rotation characteristics of the pumps.
4. Shut-off characteristics of the proposed pump control valves.
5. A computer analysis of the transient pressures combined with the total system characteristics.

6. Substantiation for the use of surge valves, when necessary, listing recommended size and computed discharge pressures.

   When the maximum transient pressure plus the static head is greater than the working pressure strength of the pipe, the Designer shall perform an economic evaluation of alternatives to increase the design working pressure of the force main, including fittings, valves and all necessary restraints and buttress requirements. The Designer of the force main shall coordinate this evaluation with the pumping station Designer to determine the least expensive method for controlling water hammer pressure.

4.8 Low Pressure Sewer Systems

A. Hydraulic Calculations

1. General

   The design of a low pressure sewer system is similar to the design of a large pumping station and force main. See Section 4.7 for any items not described in this section.

   Simplex, or single pump, systems are typically used for residential units. Duplex, or two pump, systems shall be required for commercial, multi-family and higher flow sites where a simplex will not be adequate or the redundancy of a second pump is required as determined by the Chief Engineer.

   The use of HDPE and PVC pipes are allowable for low pressure sewer systems.

   The Hazen-Williams factors indicated are representative of long-term design values for the system. The Designer shall check all pump station and force main selections for the anticipated lower headlosses (higher C value) that are typical of newer pipelines to ensure the satisfactory operation throughout the design life of the system.

   HGL profiles shall be developed for the various flow scenarios planned for the system and shall be shown as described in Section 4.7.

2. Size

   Main size shall be based on the maximum carrying capacity of the pipe to convey the design flow rate at permissible velocities, while minimizing life cycle costs including construction, maintenance and pumping costs. The minimum main size shall be two (2) inches in diameter unless approved by the Chief Engineer.

3. Velocity

Design velocities in force mains shall be between 2 to 6 feet per second (fps). A minimum velocity of 3 fps shall be required to re-suspend any solids within force mains that have multiple high and low points. The maximum velocity shall be based on the ultimate design pumping rate.

B. Main: Plan

1. Mains shall be located as described above for force mains.

2. The grinder pump shall be located as close to the connecting sewer main as allowable by gravity flow from the house or building. It is preferred for the grinder pump to be located on the property line if possible. The electric panel that supplies the grinder pump shall be located within line of sight from the grinder pump. The location of this panel needs to be clearly shown on the plans. The grinder pump shall be installed at the time of connection to the sewer system.

C. Main: Profile

1. The profile layout for a low pressure sewer system main shall be as described above for a force main.

D. Pipeline Materials

1. Allowable low pressure sewer systems main materials shall meet the requirements for force main materials.

E. Types of Joints/Fittings

Allowable pipe joints and fittings shall be as described in Chapter 2, “Water Main Design.” Mains shall be anchored at all fittings by restrained joints or buttress construction. The operating pressure and the surge pressure shall be considered in designing thrust restraint.

F. Appurtenances

1. Valve Pits

   Valve pits shall be in conformance with the manufacturer’s recommendations and shall be located on each property.

2. Flushing Connections

   A flushing connection shall be located at all low points along the main, spacing is not to exceed 400 feet. The flushing connection shall be designed to allow the Commission to clean the main in a manner appropriate to their equipment. A witness post shall be located at all flushing connections.

3. Witness Posts

A witness post shall be located at all flushing connections and at all road crossings.

4.9 Vacuum System Design

A. Hydraulic Calculations

1. General

   The design of a vacuum system must be coordinated with the design of the receiving wastewater pumping station. The proposed alignment and profile of the vacuum main shall be developed. The profile shall depict the changes in vacuum main elevations. The Designer shall strive to achieve a profile that falls continuously along the collection system, with intermediate vertical steps (sawtooth), toward the pumping station. Design of the force main from the pumping station to the discharge point shall be in accordance with Section 4.7 above.

   The use of HDPE pipe is allowable for directional drill applications if approved by the Chief Engineer. The use of PVC is allowed for corrosion control protection if approved by the Chief Engineer.

   The Hazen-Williams factors indicated are representative of long-term design values for the system. The Designer shall check all pump station and vacuum main selections for the anticipated lower headlosses (higher C value) that are typical of newer pipelines to ensure the satisfactory operation throughout the design life of the system.

   HGL profiles shall be developed for the various flow scenarios planned for the system. All HGL profiles shall be provided on the plans separately from the standard vacuum main design profiles. Such profiles shall be condensed at a scale of 1”=200’ horizontal; 1”=20’ vertical and shall indicate hydraulic gradients, flows, vacuum main velocities, design friction coefficients, existing ground, proposed pipe invert elevations and all other pertinent data.

2. Size

   Vacuum main size shall be based on the maximum carrying capacity of the pipe to convey the design flow rate at permissible velocities, while minimizing life cycle costs including construction, maintenance and pumping costs. The minimum vacuum main size shall be four (4) inches in diameter unless approved by the Chief Engineer.

3. Velocity

   Design velocities in vacuum mains may be between 12 to 15 feet per second (fps).

B. Vacuum Main: Plan

1. Vacuum mains shall be located as described above for force mains.

C. Vacuum Main: Profile

1. The profile layout for a vacuum main shall be as described above in for a force main.

D. Pipeline Materials

1. Allowable vacuum main materials shall meet the requirements for force main materials.

E. Types of Joints/Fittings

Allowable pipe joints and fittings shall be as described in Chapter 2, "Water Main Design." Vacuum mains shall be anchored at all fittings by restrained joints or buttress construction. The operating pressure and the surge pressure shall be considered in designing thrust restraint.

F. Appurtenances

1. Valve Pits

   Valve pits shall be in conformance with the manufacturer's recommendations and shall be located on each property.

2. Flushing Connections

   If required by the Chief Engineer, the Designer shall provide a flushing connection on the vacuum main. The flushing connection shall be designed to allow the Commission to clean the vacuum main in a manner appropriate to their equipment. Therefore, the spacing of flushing connections and the size shall be determined by the Chief Engineer.

3. Vacuum Station

   The vacuum pump station shall meet the requirements of Chapter 5 with the addition of a minimum of two vacuum pumps adequately sized for the vacuum system, a collection tank and appropriate controls.

4.10 Hydrogen Sulfide Analysis

A. Analysis

Sulfides are produced when wastewater does not have a sufficient supply of oxygen.

This is especially true downstream from a pump station or pressure sewer/force main discharge. These situations may result in the release of hydrogen sulfide (H_2S) that may corrode concrete manholes, concrete pipe, concrete lined pipe or ferrous pipe materials.

The Designer shall evaluate the design of all proposed wastewater and grinder pump force mains to determine the sulfide control method and materials best suited in each case. The following Pomeroy equation shall be utilized for the calculation of sulfide generation in closed force main piping systems:

$$S_2 = S_1 + (M)(t)\ (EBOD)\ [(4/D)+1.57]$$

where:
S_2 = Effluent sulfide concentration from force main (mg/l)
S_1 = Influent sulfide concentration from wetwell (mg/l)
M = Empirical coefficient for sulfide production=0.0003 m/d
t = time (days)
EBOD = $(BOD_5)[1.07_{(T-20)}]$
T = wastewater temperature (degrees C)
D = force main diameter (meters)

B. Design Considerations

If sulfide concentrations for a system are predicted at concentrations greater than 1.0 mg/l, the Designer shall include provisions to either neutralize the hydrogen sulfide at the pumping station or protect the piping and structures downstream of where the force main discharges into the gravity system. The following general design considerations are for systems where 1.0 mg/l is anticipated to be exceeded.

1. The use of drop manholes is discouraged when it is found or predicted that Hydrogen Sulfide (H_2S) is already present or likely in the wastewater.

2. Where substantial concentrations of sulfide cannot be avoided, the structure at the junction of the force main and gravity sewer must be constructed or protected with acid resistant materials. All interior surfaces and inverts of sanitary sewer manholes within 100 feet downstream of either a force main or

grinder pump discharge shall be coated with a hydrogen sulfide resistant material such as H_2S resistant epoxy paints, polyvinyl chloride (PVC), polypropylene (PP) and high-density polyethylene (HDPE). In addition, hydrogen sulfide protection shall be provided downstream of a force main or grinder pump discharge where significant turbulence may be caused due to a drop manhole, severe pipeline slopes or any other sources of turbulence within a sewer system. Protection must be provided to all surfaces exposed to the sulfides. All applications of specialized coatings and liners are subject to the review and approval of the Chief Engineer. See the Standard Specifications for all coating and lining material requirements.

3. For references purposes, the Designer may use the latest publication from the U.S. Environmental Protection Agency for design guidelines in evaluating the sulfide generation.

End of Chapter 4