DISTRICT OF COLUMBIA
WATER AND SEWER AUTHORITY
(DC Water)

"SERVING THE PUBLIC - PROTECTING THE ENVIRONMENT"

PROJECT DESIGN MANUAL
VOLUME 3
LINEAR INFRASTRUCTURE DESIGN

July 2018

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AUTHORIZATION FORM

Project Design Manual, Volume 3 Linear Infrastructure Design LOG OF REVISIONS		
Revision Number	**Date**	**Brief Description of Revision**
1	July 31, 2001	Interim Draft Project Design Manual Volume 3 Infrastructure Design.
2	July 2018	This is a significant rewrite to the Interim Draft and is an overall update of all sections.

The 2018 Version of the Project Design Manual, Volume 3 Linear Infrastructure Design is authorized by:

Leonard R. Benson, Chief Engineer
DC Water

7-2-18
Date

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ACRONYMS AND ABBREVIATIONS

A	Area.
AACE	ACCE International.
AASHTO	American Association of State Highway and Transportation Officials.
AC	Alternating Current.
ACP	Asbestos Cement Pipe.
AISC	American Institute of Steel Construction.
ANSI	American National Standards Institute.
ANSI/MSS	American National Standards Institute/Manufacturers Standardization Society.
ASCE	American Society of Civil Engineers.
ASTM	American Society for Testing and Materials.
AWWA	American Water Works Association.
C	Runoff Coefficient.
CAD	Computer Aided Design.
CCI	Construction Cost Index (published by ENR).
CE	Civil Engineer.
CFS	Cubic Feet per Second.
CI	Cast Iron.
CI	Construction Institute (within ASCE).
CIP	Cast Iron Pipe.
CIPL	Cured-in Place Lateral.
CIPP	Cured-in-Place Pipe.
CIR	Construction Impact Report.
CLSM	Controlled Low-Strength Material.
CM	Centimeters.
CP	Cathodic Protection.
CPI	Consumer Price Index (published by Bureau of Labor Statistics).
CPVC	Chlorinated PolyVinyl Chloride.
DC	Direct Current.
DC	District of Columbia.
DC Code	District of Columbia Official Code.
DC Water	District of Columbia Water and Sewer Authority.
DCMR	District of Columbia Municipal Regulations.
DCRA	District Department of Regulatory Affairs.
d/D	Maximum Depth Ratio (maximum flow depth divided by pipe diameter).
DDOT	District Department of Transportation.
DEQ	Virginia Department of Environmental Quality.
DOEE	District Department of Energy and the Environment.
DIP	Ductile Iron Pipe.
DIPRA	Ductile Iron Pipe Research Association.
District	District of Columbia.
DPR	District Department of Parks and Recreations.
DPW	District Department of Public Works.
DR	Dimension Ratio.
DWS	Department of Water Services (within DC Water).
E	Young’s Modulus.
E’	Modulus of Soil Reaction.
EA	Each.
ENR	Engineering New Record.
FEA	Finite Element Analysis.
FEM	Finite Element Model.
FGCC	Federal Geodetic Control Committee.
FPVC	Fusible PVC Pipe.
FRP	Fiber Reinforced Pipe.
FT	Feet.
FOWM	Federally Owned Water Main.
GIS	Geographic Information System.
GPAD	Gallons Per Acre per Day.
GPCD	Gallons Per Capita per Day.

GPM	Gallons Per Minute.
GRP	Glass Reinforced Plastic.
GUTS	Guaranteed Ultimate Tensile Strength.
GWI	Ground Water Infiltration.
H	Height.
H	Horizontal.
HDPE	High Density Polyethylene Pipe.
HGL	Hydraulic Grade Line.
I	Intensity.
I/I	Inflow and Infiltration.
ICCP	Impressed Current Cathodic Protection.
IDM	Inch Diameter Mile.
IDW	Intrusion Detection Warning.
IFB	Invitation for Bidders.
IN	Inch.
JOL	Joint Offset – Large.
JOM	Joint Offset – Medium.
HR	Hour.
K	Coefficient of Lateral Earth Pressure.
KSF	1000 PSF.
LF	Linear Feet.
LS	Lump Sum.
LWD	Low Water Datum.
MACP	Manhole Assessment and Certification Program.
MBE	Minority-Owned Business Enterprise.
MDE	Maryland Department of the Environment.
MS4	Municipal Separate Storm Sewer System.
MSL	Mean Sea Level.
mV	milliVolts
MWCOG	Metropolitan Washington Council of Governments.
N	N-value (SPT blow count).
N	Manning's N value (for pipe roughness).
NACE	National Association of Corrosion Engineers.
NAD	North American Datum.
NASSCO	National Association of Sewer Service Companies.
NATM	New Austrian Tunneling Method.
NAVD	North American Vertical Datum.
NE	Northeast.
NEPA	National Environmental Policy Act of 1969.
NGVD	National Geodetic Vertical Datum.
NOAA	National Oceanic and Atmospheric Administration.
NPS	National Park Service.
NW	Northwest.
OHWM	Ordinary High Water Mark.
OPCC	Opinion of Probable Construction Cost (also known as engineer's estimate).
ORP	Oxidation-Reduction Potential.
OSHA	Occupational Safety and Health Administration.
P	Basic Lateral Earth Pressure.
PACP	Pipe Assessment and Certification Program.
PC	Point of Curvature.
PCC	Point of Compound Curvature.
PCCP	Prestressed Concrete Cylindrical Pipe.
PDE	Project Design Engineer.
PDM	Project Design Manual (consisting of Volumes 1-3).
PE	Polyethylene.
PE	Professional Engineer (licensed in jurisdiction of work to be constructed).
PP	Polypropylene.
PPM	Parts Per Million.
PPV	Peak Particle Velocity.
PRC	Point of Reverse Curvature.

PSF	Pounds per Square Foot.
PSI	Pounds per Square Inch.
PT	Point of Tangency.
PVC	PolyVinyl Chloride.
Q	Flow Rate.
RCP	Reinforced Concrete Pipe.
RDII	Rainfall Derived Inflow and Infiltration.
SDR	Standard Dimension Ratio.
SE	Southeast.
SF	Safety Factor.
SIPP	Spray-in-Place Pipe.
SPT	Standard Penetration Test.
SSWP	Safe System of Work Plan.
SUP	Special Use Permit (issued by NPS).
SW	Southwest.
TEB	Three Edge Bearing Test.
TCP	Terra Cotta Pipe.
TCP	Traffic Control Plan.
USACE	United States Army Corp of Engineers.
V	Vertical.
VCP	Vitrified Clay Pipe.
Volume 1	Volume 1 – Project Management.
Volume 3	Volume 3 - Linear Infrastructure Design.
WAD	Washington Aqueduct Division US Army Corps of Engineers.
WBE	Women-Owned Business Enterprise.
WEF	Water Environment Federation.
WMATA	Washington Metropolitan Area Transit Authority.
WNY	Washington Navy Yard.
WPCF	Water Pollution Control Federation (now known as WEF).
WSSC	Washington Suburban Sanitary Commission.
ZOI	Zone of Influence.

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PROJECT DESIGN MANUAL
VOLUME 3 – LINEAR INFRASTRUCTURE DESIGN

1. INTRODUCTION

1.1 PURPOSE

Volume 3 - Linear Infrastructure Design (Volume 3) is the primary guidance document for the design of water and sewer projects in the District of Columbia (District). This volume supplements the project design requirements in Volume 1 – Project Management (Volume 1) of the Project Design Manual (PDM). Volume 3 of the PDM presents design criteria, standards, and procedures to be used for the design of all linear infrastructure projects within the District. The goal is to provide a consistent design approach that meets the District of Columbia Water and Sewer Authority (DC Water) design requirements. Volume 3 is written at a level that assumes a working knowledge of engineering principles for the design of water and sewer infrastructure. Design of linear infrastructure constructed in the District shall comply with this Volume.

1.2 AUDIENCE

The audience for Volume 3 includes all parties who design water or sewer linear infrastructure in the District as well as select linear infrastructure outside the District that will be maintained or operated by DC Water. This includes designers, contactors, agencies and developers. The audience for Volume 3 also includes those who design or construct facilities adjacent to water or sewer linear infrastructure.

The Project Design Engineer (PDE) is defined as the individual responsible for designing the project, specifically the individual or firm who is in responsible charge of the design as defined by the District's regulatory requirements. The PDE may include, but is not limited to:

- DC Water staff.
- Parties under contract with DC Water.
- District Departments (DDOT, DOEE, DPR, or others).
- Parties under contract with District departments.
- Private entities (such as developers or property owners).
- Parties under contract with private entities.
- Any party involved with design of water and sewer.
- Any party involved with design of facilities adjacent to water and sewer infrastructure.
- Public private partnerships or other joint ventures involving any of the above parties, and parties responsible for designing water or sewer infrastructure for any of the above parties.

The PDE shall ensure the project design complies with all requirements of this Volume.

1.3 ORGANIZATION OF VOLUME 3

The Project Design Manual is organized into three volumes. Refer to Volume 1 for a high-level description of the items included in each Volume. The scope of Volume 3 includes additional requirements specific to linear infrastructure.

Section 1– Introduction – Describes the purpose of Volume 3, its audience and organization, as well as other administrative requirements.

Section 2 – Opinion of Probable Construction Cost (OPCC) – Provides requirements and guidelines specific to the development of cost estimates for linear infrastructure that supplement requirements and guidelines for cost estimating described in Volume 1.

Section 3 – Site Investigation – Provides requirements and guidelines for topographic surveys, subsurface utility investigation, geotechnical investigations, and right-of-ways/easements.

Section 4 – Water Mains – Provides requirements and guidelines for design of linear water infrastructure.

Section 5 – Sewers – Provides requirements and guidelines for design of linear sewer infrastructure.

Section 6 – Earth Backfill and Lateral Support for Buried Pipes – Provides requirements and guidelines for applying soil properties to the design of buried utilities and facilities.

Section 7 – Abandonment and Removal of Sewer and Water Systems – Provides requirements for showing utility systems that will be abandoned or removed on the drawings.

Section 8 – Corrosion Control – Provides design requirements and guidelines to protect existing and proposed linear infrastructure from corrosion.

Section 9 – Protection of Utilities – Provides requirements and guidelines for design of utilities and other buried objects that are located near, adjacent to, or crossing infrastructure owned, operated, or maintained by DC Water.

Section 10 – Water Body Crossings – Provides requirements and guidelines for design of linear infrastructure crossing water bodies such as the Anacostia River, Rock Creek, drainage ditches, swales, and other areas that convey storm water runoff.

Section 11 – Bridge Crossings – Provides requirements and guidelines for design when linear infrastructure is attached to bridges.

Section 12 – Erosion and Sediment Control – States all designs shall comply with regulations for erosion and sediment control in accordance with DOEE.

Section 13 – Standard Specifications and Details – Provides requirements for using DC Water's standard specifications and details in the design.

While not part of the PDM, the DC Water Standard Specifications and Guide Specifications are available to provide consistency in design and quality of constructed projects. Standard Specification sections are available at https://www.dcwater.com/design-and-construction-standards. Guide Specifications can be provided in both hard copy and electronic files upon request. All constructed work shall comply with the requirements of DC Water Specifications.

1.4 DESIGN MANUAL REVISIONS

This Volume 3 (dated July 2018) supersedes all previous versions of Volume 3. Volume 3 is a "living" document, and, therefore, will be periodically revised.

Users of Volume 3 are encouraged to propose revisions to the manual that will improve its usefulness for all designers. To propose a revision, contact any DC Water employee or onsite program manager. The DC Water employee or program manager can then access the website below to submit the proposed revision for review. The DC Water employee or program manager will receive a tracking number and status updates via email regarding acceptance or rejection of the proposed revision. Proposed revisions will be evaluated by the Supervisor, Standards and Specifications group, and other relevant stakeholders within DC Water. All revisions to the Design Manual require the approval of the Chief Engineer.

https://dcwater.sharepoint.com/sites/eng/dets/ssdocs/Lists/Feedback%20Form%20%20Status%20Update/Tiles.aspx

In future updates, changes from the most previous revision will be denoted with a side bar in the margin next to the portion of the specification that was changed. This version is a significant rewrite so specific, individual changes are not denoted.

1.5 COMPLIANCE AND DEVIATIONS

Existing infrastructure need not be upgraded to meet the requirements of Volume 3 until it is repaired, replaced, or rehabilitated. New infrastructure and infrastructure that is being replaced or rehabilitated shall be designed in accordance with Volume 3. Repairs may be designed to the requirements of Volume 3 or the requirements that were in place at the time the infrastructure was built. The determination of which design criteria to use will be the sole responsibility of DC Water.

One-time, project specific deviations from the requirements of Volume 3 shall comply with the deviation procedures described in Volume 1. Additionally, proposed deviations may be submitted to any Director within the Engineering Division. Any Director within the Engineering Division can approve a project specific deviation. Approved deviations shall be in writing to be valid.

1.6 PROFESSIONAL REQUIREMENTS

Professional requirements shall comply with procedures as described in PDM Volume 1. Also, electronic signatures shall comply with the appropriate District regulations.

Requirements in Volume 1 and 3 do not supplant sound engineering judgement or the need for the PDE to exhibit responsible charge of the project design. The PDE has ultimate responsible charge of the project design and shall ensure the design complies with relevant volumes of the PDM and is consistent with the contents of the Standard Specifications, Supplemental Standard Specifications, Guide Specifications, Project Specific Specifications, and sound engineering judgement. If there are any conflicts between these documents or the requirements therein are not appropriate for a given project, submit a design recommendation to DC Water with a request for a deviation to the requirements.

1.7 REFERENCES

Documents referenced herein shall be latest version.

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2. OPINION OF PROBABLE CONSTRUCTION COST (OPCC)

2.1 PURPOSE

The purpose of the opinion of probable construction cost (OPCC) is to provide a reliable construction cost estimate for DC Water funded projects throughout the life of the project (i.e. planning, design, and bidding process). OPCC's are essential for responsible fiscal management at every stage of the project to avoid setbacks, delays, and/or cancelation of the project. In addition, the OPCC serves as the benchmark for analyzing bids and is a crucial component in the project approval process. Note this chapter applies only to DC Water funded projects.

2.2 ESTIMATING METHODS

There are a few basic methods to develop the OPCC: actual cost, historical data, and a combination of historical data and actual cost. A combination approach is DC Water's preferred method of determining the OPCC. The use of historic data from recently awarded contracts is a cost-effective technique to develop the OPCC, though solely relying on historic data may not be applicable when the data is based on a non-competitive bidding environment. Use bid tabs from DC Water to prepare the OPCC for major components of work so that quantities and historical unit prices are consistent with the bid line items. Actual cost approach takes into consideration factors related to actual performance of the work (i.e. current labor cost, equipment costs, material costs, sequence of operations, and a reasonable value of overhead and profit).

2.3 RESPONSIBILITIES

Identify all bid items required for constructing the project and prepare a quantity takeoff and OPCC that is inclusive of all construction activities. The quantity takeoff and OPCC shall be reviewed by a quality control reviewer experienced in estimating. The OPCC shall also be checked by the DC Water Project Manager or designee. The final quantity takeoff and OPCC shall be signed and sealed by the Engineer of Record.

2.4 PROCEDURES

Linear projects shall include a line item OPCC based on the Schedule of Prices. Lump sum bids (where one lump sum price is used for the entire project) shall not be used on linear projects funded by DC Water, unless approved by DC Water. A bid schedule with individual line item(s) listing a unit as lump sum is known as a mixed bid schedule and is also acceptable. Prepare the quantity takeoff and OPCC using an electronic spreadsheet format or other cost estimating software that can export the final deliverable to electronic spreadsheet format. Make pdf files of the quantity takeoff and OPCC for each deliverable and keep a copy in the project file folder.

The quantify takeoff and OPCC shall include, at a minimum, the following information:

- **Project Title:** Name of project (i.e. SDWMR 13A).
- **Project No.** Project Number (i.e. F101).
- **Invitation No.:** Invitation Number (i.e. IFB#160020).
- **Contract No.:** The Construction contract number (i.e. 160020).
- **Prepared By:** Person performing the quantity take off and preparing the OPCC.
- **Reviewed By:** QC Reviewer.
- **CSI Information (only if multiple disciplines are included in the bid):** Construction Specification Institute Division and Name (i.e. Division 33 00 00 Utilities).
- **Bid Item:** The Bid Item obtained from the Schedule of Prices. Items that are contingent shall be identified as such.
- **Unit:** The unit of measurement for the item, such as EA, LF, or LS.
- **Unit Price:** An estimated unit cost for a bid item.

- **Quantity per Sheet Number:** A listing of the quantities of a bid item found on each sheet of the plans.
- **Plan Quantity:** A total of quantities for the entire plan set including general items and the sum of the quantities per sheet number.
- **Allowance:** Line items with costs set aside for known unknowns. Note there can be multiple allowances where appropriate to specific project issues.
- **Bid Item Estimate:** The total estimated cost for that specific bid item. This is obtained by multiplying the Bid Quantity by the Unit Price.
- **Contingency:** Budget to cover change orders and unforeseeable elements.
- **OPCC:** Total estimated cost of the contract.

For multi-disciplinary projects, submit the quantity takeoff and OPCC in the CSI format. Projects with only civil/structural/minor mechanical activities need not submit costs estimates using the CSI format.

Activities used in determining the OPCC include but are not limited to:

- Reviews plans, specifications, special provisions, and contingencies.
- Identify items to be estimated.
- Collect detailed cost data for each item to be included in the OPCC.
- Define and list work associated with identified items.
- Review construction schedule information.
- Determine material requirements.
- Determine equipment requirements.
- Determine labor requirements.
- Estimate unit prices.
- Add allowance(s).
- Add contingencies.
- Round estimate up to nearest relevant round number appropriate to the expected level of accuracy.

2.5 CONTINGENCY

Contingency is used to account for change orders and other increases in costs that are unknown at the time of bid. Apply contingency to all costs, including allowances and markups such as overhead and profit.

The OPCC shall include contingencies listed in Table 2-1 below.

Table 2-1: Contingency To Be Used In The OPCC

Lifecycle Phase	Construction Cost		
	OPCC < \$5M	\$5M ≤ OPCC ≤ \$10M	OPCC > \$10M
Preliminary / CFR	35%	30%	25%
Intermediate	25%	20%	15%
Pre-Final / Final	15%	10%	5%

If the PDE believes a particular project warrants a higher contingency, the PDE shall use a higher contingency and explain on the OPCC why a higher contingency is being used. DC Water may or may not accept the higher contingency based on the explanation.

2.6 ALLOWANCES VERSUS CONTINGENCIES

2.6.1 Allowances

Allowances are for known unknowns. An allowance is used to set money aside to address known unknown without having to issue a change order. An allowance can be set aside for a specific unknown or grouped with several known unknowns to develop a general allowance for the project. The OPCC can have any number of allowances.

For example, an allowance is often used to cover the cost of replacing services lines when the material type is unknown. Copper service lines may not be replaced but lead service lines are. If the material type is known, an allowance would not be needed. When the PDE does not know the existing service line material an allowance can be used to account for the possibility the service line will be replaced because it might be lead. In this example, the number of lead service lines are unknown. The quantity of lead lines that may be encountered is included in the bid line item for bidding purposes. An allowance is used to account for the cost of replacing additional lead services lines if more than the known number of lead service lines are encountered.

2.6.2 Contingencies

Contingencies are for unknown unknowns. If a service line is found to be set in concrete instead of common backfill, this may be considered a changed site condition because it is not reasonably expected for service lines to be encased in concrete. Changed site conditions are an example of an unknown unknown and can result in a Contractor's change order. If it is a change order, a contingency can be used to cover these costs.

2.7 ACCURACY AND METHODOLOGY

DC Water relies on the accuracy of OPCCs for budgeting and funding projects. If an OPCC is too low, then DC Water may have insufficient funding to build the projects and only find this out after the project has bid. If an OPCC is too high, then it is possible another project was unnecessarily canceled or postponed. Development of an OPCC has an inherent degree of inaccuracy. DC Water defines the methodology, level of effort, and expected accuracy using information developed by AACE International (AACE) and presented in AACE 17R-97: Cost Estimate Classification System.

Provide the level of effort, methodology, and accuracy for the OPCC in each phase of the project design based on the following estimate classes:

- Preliminary Design / Concept Finalization Report: Class 4.
- Intermediate Design: Class 2.
- Pre-Final Design / Final Design: Class 1.

Note: Table 1 of AACE 17R-97 uses relative values for expected accuracy and level of effort. The expected accuracy value of one (1) at DC Water is plus ten percent (+10%) to negative five percent (-5%). The value of one (1) for preparation effort is project specific.

2.8 SUPPLEMENTAL REQUIREMENTS AND GUIDANCE

Prepare OPCCs in accordance with PDM Volume 1 plus the following supplemental requirements and guidance.

- Labor costs, wage rates, and other contractor business factors need not be separated in the OPCC if the data used to estimate the costs includes those items. For example, if an OPCC is being developed for a small diameter water main project and the data used to develop the OPCC is data from previous bids, and the line items of the previous bids included labor, materials, operations, and other business factors, such as overhead and profit, then the OPCC need not separate or describe those items. If this is the case, document the fact that the input data considers this information.
- Breaking the OPCC into CSI format is not needed for line item bids or single discipline projects. This includes projects that are predominantly a single discipline and include only minor structural or mechanical work. Instead, format the OPCC to mirror the Schedule of Prices.

- All OPCCs shall be dated and include the Engineering News Record (ENR) Construction Cost Index (CCI) for the date of the OPCC. When using price data from previous projects, document and correlate the CCI for the date of that information as well.
- The CCI is based on a 20-city average. When relating costs from other areas, regions, and even suburbs of the District; great care must be taken as costs in the District are often significantly higher than other areas. Note the CCI does not have data specific to the District. Based on anecdotal research and data conducted by DC Water, costs in the District have often far exceeded costs in Philadelphia and Chicago. The only city with a CCI higher than Philadelphia and Chicago is New York, NY and comparisons between the District and New York, NY must also be carefully judged.
- When escalating the cost to the midpoint of construction, consider current market conditions. The Consumer Price Index (CPI) calculated by the Bureau of Labor Statistics is the most commonly cited value of inflation that also has a wealth of available predictive information, but the CPI doesn't always correlate to the heavy construction industry which is more accurately measured by the CCI. During times of high inflation, annual escalation should be higher. During the 1970s inflation rates (as defined by the CPI) were often as high as ten percent (10%) and for much of the early 2000's inflation rates were regularly less than two percent (2%). Under normal, average market conditions, three percent (3%) is an acceptable starting point. When predicting future inflation over the course of a project's duration, it is reasonable to rely on published CPI predictions, but also consider any effects particular to the District and/or heavy construction. For example, in the past copper shortages and cement shortages have caused inflation in heavy construction to significantly outpace overall inflation.
- Notify DC Water, in writing, of any projects if the type of work being performed may not allow the Contractor to meet participation goals of 32% for Minority-Owned Business Enterprise (MBE) and six percent (6%) for Women-Owned Business Enterprise (WBE). In these cases, prepare a corollary OPCC identifying which line items can, in part or full, be subcontracted to an MBE or

3. SITE INVESTIGATION

This section provides guidelines for performing topographic surveys, utility surveys, and geotechnical studies.

3.1 TOPOGRAPHIC SURVEY

3.1.1 Horizontal Control

Horizontal control networks shall comply with the Classification and Minimum Distance Accuracy shown in Table 3-1 below and published by the Federal Geodetic Control Committee (FGCC) in the 1984 document, Standards and Specifications for Geodetic Control Networks. Survey datum shall be Maryland State Plane NAD83 with a classification of Second-order, class II unless specified otherwise by DC Water. Computation method shall be least squares.

Table 3-1: Minimum Distance Accuracy

Classification	Minimum Distance Accuracy
First-order	1:100,000
Second-order, class I	1:50,000
Second-order, class II	1:20,000
Third-order, class I	1:10,000
Third-order, class II	1:5,000

Survey monuments shall be permanent reference points. Recovery sketches for traverse stations shall include three ties to existing permanent features. When projects require accurate depiction and location of property lines, a survey-to-mark shall be completed in accordance to District survey standards.

3.1.2 Vertical Control

Vertical control networks shall comply with the Classifications and Maximum Elevation Difference Accuracy's shown in Table 3-2 below and published by the FGCC in the 1984 document, Standards and Specifications for Geodetic Control Networks. Survey datum shall be Maryland State Plane NAVD88.

Table 3-2: Maximum Elevation Difference Accuracy

Classification	Maximum Elevation Difference Accuracy
First-order	0.5
Second-order, class I	0.7
Second-order, class II	1.0
Third-order, class I	1.3
Third-order, class II	2.0

3.1.3 Survey Data to be Collected

Data collected during surveys shall include, but not be limited to:

- Location of permanent improvements such as houses, outbuildings, roads, curbs, steps, poles, trees, pipelines, vaults, manholes, overhead utility lines, channels, fences, etc.
- Location of top and toe grade points, flow lines, rock outcroppings, depressions and changes in grades and provide spot elevations sufficient to produce a 3-dimensional (3D) surface model.
- Location of manholes and vaults, vents, hatches, valves, meters, and any other utility structure or feature found within the survey limits.
- Invert elevations of all sewers, storm drain and any other gravity piping.

- Locate property lines and boundaries.
- Survey monuments and other reference points.

Survey data shall be 3D and capable of generating electronic 3D topographical maps and be compatible with AutoCAD. Provide traverse reports, field notes, and electronic data to DC Water with the survey files.

3.1.4 Historic Vertical Controls

The vertical datum information in this section was extracted from the *Washington District Flood Emergency Manual* issued by the U.S. Army Corps of Engineers in January 1958. The same information can be found in more recent revisions of the *Flood Emergency Manual*, which is issued periodically by the U.S. Army Corps of Engineers. Table 3-3 gives the vertical datum planes used by different federal agencies and other organizations in the District.

Table 3-3: Vertical Datum Planes And Water Elevations In Washington, DC

Vertical Datum Plane (ft)	Agency
+2.35	Washington Aqueduct and Filtration Plants (WAD)
+2.11	District of Columbia Agencies
+2.11	Potomac Electric Power Company
+2.11	Washington Gas Company
+2.11	Bell Atlantic Telephone Company (Verizon)
+1.98	Anacostia Pennsylvania Railroad
+1.98	Pennsylvania Railroad
+1.41	Washington Metropolitan Area Transit Authority (WMATA)
+1.41	Sea Level Datum (1929 General Adjustment; MSL)
+1.41	U.S. Geodetic Survey
+1.41	U.S. Geological Survey
+1.41	Naval Research Laboratory (Bellevue)
+1.41	R.F. and P. Railroad
+1.41	B. and O. Railroad (Alexandria Branch)
+1.26	Sea Level datum (1912 General Adjustment)
+1.26	Washington Suburban Sanitary Commission (WSSC)
0.00	Low Water Datum – Washington Harbor (LWD)
0.00	U.S. Army Corp of Engineers (Except Wash. Aqueduct)
0.00	National Park Service
0.00	Federal Highway Administration
0.00	Washington National Airport
-0.22	Bolling Air Force Base (Bolling Field)
-3.09	Washington Navy Yard (WNY)
-3.29	Anacostia Naval Air Station
-3.29	Washington Naval Air Station

Source: Washington District Flood Emergency Manual, Flood job #P-1746-C, U.S. Army PDE District, Washington Corps of PDEs, First and Douglas Streets, N.W., Washington D.C. 20025. Issued January 1958, Revised January 1960, Copy No. 537.

To convert Datum Source to District of Columbia Datum, use the positive or negative difference as shown in Figure 3-1 below:

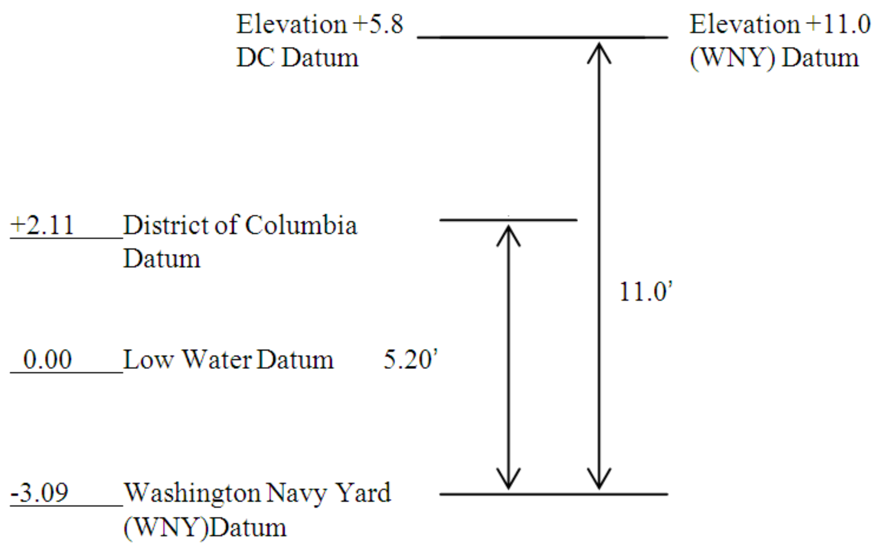

Figure 3-1 Conversion To District Of Columbia Datum

To convert to DC Datum an elevation of +11.0 in Washington Navy Yard Datum, add the negative difference -5.20, from Table 3-3. The resulting elevation for the example above is +5.8.

One of the bench marks that has been used for comparison of different vertical datum planes is the Capitol Bench Mark. The bench mark is the apex of a bronze bolt set in the east window sill of the south side of the senate wing of the U.S. Capitol. It was placed in position by the U.S. Coast and Geodetic Survey in 1884 and is inscribed "Capitol B.M."

The District of Columbia Low-Water Datum is defined as 91.95 feet below the Capitol Bench Mark. This datum was adopted by agreement with the Corps of Engineers and was subsequently adopted by the National Park Service. It is the reference for waterfront construction, maps, charts, bench marks, and other records of the Corps of Engineers and National Park Service for the Washington area. Table 3-4 gives some other datum references to the Capitol Bench Mark.

The vertical datum plane shown in Table 3-4 for the District of Columbia was once used by DC Water and D.C. Government agencies such as the Office of the Surveyor, the Department of Public Works (DPW). However, although all three agencies have used the same vertical datum plane, the elevation of the project bench marks used by the three (3) agencies is almost never the same. This is also true for the elevation of water and sewer bench marks.

Table 3-4: Datum Referenced To Capitol Bench Mark Elevation

Datum Source	Elevation (feet) below Capitol Bench Mark
D.C. Low Water Datum	91.95
U.S. Geodetic Survey	90.54
District of Columbia	89.84

3.1.5 Base Maps

Base maps shall include the data and follow the requirements found in the DC Water Computer Aided Design (CAD) Manual.

Show contours on base maps with a vertical distance that supports the accuracy required by the design. The default contour spacing is one (1) foot for minor contours and five (5) feet for major contours. However, based on the existing grade, finished grade, and accuracy of the finished surface, evaluate the need to show minor contours at six (6) inches for flat grades or two (2) feet for steep grades.

3.1.6 Geographic Information System (GIS)

DC Water utilizes a GIS map to show approximate locations of utilities. This GIS information does not have the accuracy necessary to meet survey tolerance requirements for locating utilities and shall not be substituted for Level B or higher subsurface utility location identification as required by Section 3.2. Additionally, depiction of utility locations on maps and drawings using GIS data points shall not be used in place of a topographical survey.

3.2 SUBSURFACE UTILITY ENGINEERING

Utility designations shall be performed during design as described in CI/ASCE 38-02 to identify underground utilities. Unless otherwise stated, the minimum utility survey designation for locations anticipating excavation work shall be Level C. Level A is required when an excavation will be within 12 inches of an existing water or sewer utility. Level B is required for new water and sewer assets that will be located within two (2) feet of other buried utilities. Levels B and A may be required in other site(s) specific circumstances when directed by DC Water.

3.3 TEST PITS AND PAVEMENT CORE SAMPLES

3.3.1 Test Pits

Select the quantity, location, and depth of test pits based on an analysis of location, condition, record search, construction or rehabilitation, and the deepest pipelines near the pipeline in question. Quantity, location, and depth shall be approved by DC Water prior to execution of test pits. In certain cases, DC Water may require a deep soil boring to the invert level of the deepest pipeline.

Submit all test pits results, data, and reports to DC Water and show test pit locations on Contract Drawings.

3.3.2 Pavement Core Samples

Pavement core samples may be required during design for each significant change in restoration condition or as directed by DC Water.

3.4 GEOTECHNICAL INVESTIGATIONS

This section is provided as a guide for geotechnical work associated with exploration, testing, design, and construction for infrastructure projects. This Paragraph recommends procedures and policies for geotechnical investigations, which may vary based on local subsurface conditions.

3.4.1 Geotechnical Investigation

Perform geotechnical investigations for:

- New pipelines 16 inch and larger in diameter.
- Projects where thrust blocks on new water mains will be required.
- Projects with tunnel construction or where rock is expected in the excavation.
- Projects with sewer outlet structures to the river.
- Projects where organic or soft soils are expected in the excavation.
- Projects requiring excavation greater than 15 feet.

Preform the geotechnical investigation so that the geotechnical report is complete prior to completion of the preliminary design.

The number and location of borings is dependent upon the projects constraints, site conditions, and many other factors, but when borings are required they should be spaced no farther than 1000 feet apart. A typical new transmission main would usually have borings located every 500 feet, but this could also vary based on expected soil conditions and other factors.

3.4.2 Subsurface Exploration Plan

Prepare a subsurface exploration plan showing the location of borings and test pits. The plan shall contain the following information:

- Location of boring/test pits.
- Locations with a suspected high water table.
- Access to boring/test pit locations.
- Estimated depths of boring/test pits.
- Development of traffic plan (if necessary).
- Location of existing utilities.

Locate borings and/or test pits at the following locations:

- Major structures.
- Pile supported structures.
- Locations where thrust blocks might be anticipated.
- Areas where competent soil may not be available.
- Areas of suspected corrosive soil.
- Excavations greater than 15 feet.
- Every 500 feet for pipelines.

3.4.3 Data Collection

Take boring samples and collect data as follows:

- At five (5) foot intervals except that continuous sampling shall be performed at:
  - The interface between unconsolidated deposits.
  - From the top of the proposed pipe installation to a minimum of five (5) feet below the proposed pipe invert.
- At locations of high groundwater.
- Sample manhole and vault locations to a minimum of five (5) feet below the proposed structure.
- Take Standard Penetration Tests (SPT) in cohesive and non-cohesive soils and obtain samples in accordance with ASTM D1586.
- Take thin-walled tube samples in cohesive soils in addition to SPT samples and obtain samples in accordance with ASTM D1587.
- If bedrock is encountered prior to reaching the required depth of the borehole, perform a five (5) to 15 foot core run in the rock in accordance with ASTM D2113.
- Take groundwater readings.

3.4.4 Field Sample Data

Daily field notes shall include project name, project number, date, time, weather conditions, sampler's name, and project objective(s).

Describe the samples in the following order:

- Descriptive information (color, mottling, odor) in accordance with ASTM D2488.
- Degree of saturation (dry, moist, percent, etc.).
- Description of density (from blow count).
- Soil description (layering, grain shape, grading, plasticity) in accordance with ASTM D2488.

- Other: fossils, weathering, mineralogy and rock types, observed odor, stains/discoloration, organic content, and depositional information.

3.4.5 Drilling Information

Include the following information in the drilling logs:

- Drill rig manufacturer, model, and driller.
- Project location, sample point identification and location.
- Type of sampler, measurements or method of advancing boring or equipment, method of driving sampler, and weight of hammer.
- Drill fluids.
- Ground surface or grade elevation in accordance with the project bench mark; static ground water elevation.
- Depth penetrated, blow counts/six (6) inches interval of penetration for ASTM 1586 and sample number, as well as “N” value.
- Closed hole intervals and advancement.
- Recovery.
- Strata changes and changes within samples.
- Sampling tool behavior.
- Drill string behavior.
- Use(s) of sample point or borehole.

3.4.6 Logging Rock Samples

When describing rock samples, document the data as follows:

- Color.
- Rock Quality.
- Porosity.
- Beds.
- Thickness.
- Contact.
- Foliation.
- Joints.
- Weathering.
- Surface.
- Hardness.
- Texture.
- Grain Shape.
- Sorting.
- Mineral Components.
- Rock Classification.

Use capital letters for formation names and rock types.

3.4.7 Laboratory Testing

Perform a minimum of one (1) laboratory test on each soil type encountered.

- Identification tests:
  - Moisture content (ASTM D2216).
  - Sieve analysis (ASTM D422).
  - Atterberg limits (ASTM D4318).
- Compaction, compressibility, and strength testing:
  - Backfill moisture density testing (ASTM D698, ASTM D1557).
  - Unconfined compression test (ASTM D2166 or Rock ASTM D2938).
  - Unconsolidated, undrained triaxle test (ASTM D2850*)*.
  - Consolidation test (ASTM D2435).

3.4.8 Geotechnical Report

The geotechnical report shall include following information:

- Existing site conditions - including accessibility, slopes, vegetation, site geology, seismic considerations, frost depths, surface water, potential wetlands, and elevations.
- Site plan showing boring locations.
- Soil classification including boring logs with elevations in accordance with the project bench mark.
- Standard penetration values and "N" values.
- Angle of internal friction and cohesion.
- Unconfined compressive strength.
- In-situ soil density.
- Location of ground water table and estimated seasonal high.
- Modulus of soil reaction (E').
- Allowable bearing capacity.
- Allowable passive soil pressure as a function of depth.
- Allowable design parameters for uplift and download.
- Recommended design parameters.
- Recommended construction techniques.
- Slope stability evaluation of critical areas, recommend stabilization methods and guidelines for contractor identification or potential slope problems.

3.4.9 Contract Documents

Show the location of the borings and the boring logs on the Contract Drawings and make the Geotechnical Report available to Contractors at the time of bid.

3.5 RIGHTS OF WAY AND EASEMENTS

3.5.1 General

Locate water and sewer assets within the public space right-of-way in the District. Water and sewer assets may also be located in property managed by another government agency if appropriate property documents provide legal right for DC Water to operate and maintain the assets. Locate water and sewer assets in easements on private property only after appropriate legal recording of easements. Water and sewer assets shall not be located in alleys (public or private). Relocate existing service sewers and water mains in alleys into public space when being replaced.

3.5.2 Railroad Property

Contact the railroad company to obtain the latest set of requirements for pipeline occupancy. Railroad companies usually charge an annual fee for leasing their property for pipeline occupancy, but DC Water's policy is to make a one (1) time payment for processing the applications. Railroads may not provide a full easement, rather may provide an access agreement, right-of-entry, long-term lease, or similar agreement.

3.5.3 National Park Service (NPS) Property

Design all work to be constructed on NPS property to comply with the National Environmental Policy Act (NEPA). The requirements of NEPA are met through one of three procedures: Categorical Exclusion, Environmental Assessment, or Environmental Impact Statement. Although it is NPS' responsibility to comply with NEPA, NPS usually requires DC Water provide the technical information required to demonstrate compliance with NEPA.

A Special Use Permit (SUP) is also required for work constructed on NPS property and prior to performing any design tasks on NPS property, including, but not limited to topographic survey, setting aerial photography targets, geotechnical work, subsurface utility location, any work that will disrupt the ground surface or trees, site visits, and other similar tasks.

These documents are useful when trying to identify requirements for work on NPS property:

- Special Park Use, NPS-53. "*Procedures Workbook".*
- Director's Order #12 (DO-12): "*Conservation Planning, Environmental Impact Analysis, and Decision Making"*; as well as the associated *"NEPA Handbook".*
- DO-28*: "NEPA and Historic Preservation".*
- Procedural Manual #77-1: "*Wetland Protection".*

3.5.4 Private Property

Prepare documents to be filed with the DC Surveyor's Office or Recorder of Deeds for final easement execution.

3.5.5 Rights Of Way and Easement Drawings

During the preliminary design phase, when the required width of a right-of-way or easement for a proposed water main or sewer pipe extends into property that is not public space, evaluate and show on drawings the proposed pipeline, right-of-way, easement, temporary construction easements, and any other feasible alignment for the pipeline. Verify the ownership of the properties and show in the drawings the parcels of land that will be affected. Prepare the necessary documents in accordance with requirements resulting from the type of ownership of the property where the proposed pipeline will be located.

3.5.6 Width Requirements

Table 3-5 gives the minimum widths for rights-of-way and easements for water and sewer pipes of various diameters. Center easements over the pipeline whenever possible.

Table 3-5: Minimum Right Of Way / Easement Width For Pipelines

Pipeline Diameter	Width of Right-of-Way / Easement Centered over Pipeline	
	Water	Sewer
Smaller than 16"	20 feet	20 feet
>16" to 24"	25 feet	30 feet
>24" to 36"	30 feet	40 feet
>36" to 42"	40 feet	50 feet
>42"	50 feet	50 feet

When determining the width of a proposed right-of-way or easement, consider the minimum width listed in the table above, as well as any additional width necessary to allow for future inspections, repairs, maintenance, and replacement of the pipeline. Also consider the topography along the alignment of the pipeline (e.g., steep side slopes that require benching of an area to perform work on the pipeline, deep excavations, etc.), the distance between access points to the right-of-way or easement, and the type of equipment that will be required to perform the work. Another consideration in determining the width of a right-of-way or easement is the potential for damage caused by a break or collapse of the pipeline. The force of water from a water main break has the potential to inflict personal injury to the public and significant property damage if the right-of-way or easement is too small and structures and/or buildings are constructed too close to the pipeline.

3.5.7 Preparation of Documents

Documents required include, but are not limited to:

- Taking Maps.
- Plat.
- Meter and Bounds Description.
- Covenant.

The covenant shall include a hold harmless clause for DC Water for any damage caused by a break or collapse of the pipeline. It shall also clearly specify the level of restoration for which DC Water will be responsible if the pipeline needs to be repaired or replaced. For example, DC Water will not be responsible for restoring or replacing any trees, landscaping or ornamental work done in the right of way or easement.

3.5.8 Historic Preservation

Identify projects (or portions thereof) located in DC Historic Districts as such on the construction drawings. Design projects to comply with all appropriate historic preservation laws, rules, and regulations.

In some of DC Water's historic records, reports and maps, the term "trunk main" is used to identify the transmission mains and the major distribution mains that form the backbone of the water distribution system, and the term "secondary trunk main" is used to identify the distribution mains that tie the trunk mains to the grid of service mains from which the local customer service lines are taken.

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4. WATER MAINS

4.1 TYPES OF WATER MAINS

- Distribution mains (formerly called service mains) provide localized service and include extensive valve controls normally located at street intersections. These mains form the local piping grid serving the customers in houses and buildings through customer service lines (connections). Customer service lines connect only to distribution mains. In the District, existing distribution mains range in size from four (4) inch to 12 inch diameter. See Section 4.2.2 for a description of allowable sizes for new distribution mains. Distribution mains could be owned and operated by DC Water or by Other entities, public or private. A given distribution main serves only one (1) pressure zone.
- Transmission mains (formerly called distribution mains) convey water from the pumping stations, underground reservoirs, and elevated tanks to the distribution mains. Their size is usually 16 inch diameter and larger. DC Water does not allow customer service lines to connect to transmission mains. There are exceptions when it is the only potable water source in the vicinity but this shall only occur with written deviation per Section 1.5. There are a significant number of active customer service lines to transmission mains, but this is being corrected through projects. There are transmission mains in the system owned and operated by DC Water and by the Washington Aqueduct Division US Army Corps of Engineers (WAD). Transmission mains owned and operated by WAD are classified as Federally Owned Water Mains (FOWM). Transmission mains serve only a single pressure zone, but must be evaluated for higher pressures near their source, at low points in grade, and at other similar locations.
- Raw water transmission mains convey raw water from the river and surface reservoirs to the treatment plants. Raw water transmission mains in the District are under the jurisdiction of WAD but are operated and maintained in coordination with DC Water. Pressure in raw water transmission mains is evaluated on a case-by-case basis.
- Customer Service Line (or “water service line” or “water connection”) is the pipe from the water main or other source of potable water supply to the water distribution system of the building served. Water service lines are two (2) inches in diameter and smaller; most commonly made of copper and one (1) inch in diameter. Water connections are greater than two (2) inches in diameter.

4.2 WATER MAIN PIPE REQUIREMENTS

4.2.1 Pressure

4.2.1.1 Working Pressure

The working pressure (also referred to as the operating pressure) of a pipe is a function of the pipe elevation and the overflow elevation of the tank or reservoir serving the pressure zone. In the case of the 4th High Pressure Zone, the overflow elevation is function of the pressure relief valve and the discharge pipe at the booster pump station. Table 4-1 and Table 4-2 show the overflow elevation for each pressure zone and the ground elevation range that each pressure zone serves.

Table 4-1: Overflow And Ground Elevations For Pressure Zones West Of The Anacostia

Datum Point	Pressure Zone					
	Low	1st High	2nd High	3rd High	4th High (East)[1]	4th High (West)[2]
Overflow Elevation (ft.)	172	250	335	424	485	510
Ground Elevation (ft.)	0-70	70-140	140-210	210-350	350-Above	350-Above

Note 1: 4th High service east of Rock Creek, but still west of the Anacostia.

Note 2: 4th High service west of Rock Creek.

Table 4-2: Overflow And Ground Elevations For Pressure Zones East Of The Anacostia

Datum Point	Pressure Zone			
	Low	Anacostia 1st High	Anacostia 2nd High	Anacostia 3rd High
Overflow Elevation (ft.)	172	250	335	424
Ground Elevation (ft.)	0-70	70-170	170-Above	170-Above

Most pipes within the water system are installed at an elevation within the range of ground elevation shown, but pipes listed below are outside the elevation range shown in Table 4-1 and Table 4-2:

- 2nd High Pressure Zone:
  - 20 inch/24 inch main in P Street NW, as it crosses under Rock Creek.
  - 42 inch transmission main in Tilden Street NW, as it crosses under Rock Creek.
- 3rd High Pressure Zone:
  - 48 inch transmission main in Military Road NW, as it crosses through Rock Creek Park.
  - 12 inch main in Military Road NW, as it crosses through Rock Creek Park.
  - 16 inch main in Western Avenue NW (extended), as it crosses through Rock Creek Park.
  - 48 inch transmission main in Park Place NW, to Bryant Street Pumping Station.
  - 16 inch transmission main in Michigan Avenue NW.
- Anacostia 3rd High Pressure Zone:
  - 30 inch transmission main in S Street SE, from Anacostia Pumping Station.
  - 24 inch transmission main in 18th Street SE, from Anacostia Pumping Station.

When design includes work on the pipes listed above, a detailed analysis shall be performed to determine the working pressure, surge pressure, and hydraulic test pressure.

When multiple water mains of different pressure zones are in a single roadway, DC Water will determine which pipe is to be in which pressure zone and which customer service lines connect to which pipes.

See Appendix A for a map of the pressure zone boundaries.

4.2.1.2 Surge Pressure

The following conditions are some of the considerations that should be evaluated to determine if a surge analysis is warranted:

- Existence of pumps on the system.
- Isolation valve actuation.
- Control valve modulation.
- Discharge condition of the water system.
- Potential for power failure.
- Potential for line break or rupture.

Use a minimum surge pressure allowance of 100 psi for the design of all water mains. Design the system to prevent and/or minimize the need for mechanical surge control systems. When mechanical surge control systems are necessary, evaluate the following control systems as possible methods to control surge:

- Flywheels.
- Standpipes.
- Hydro-pneumatic tanks.
- One-way tanks.
- Combination air valves.
- Surge anticipation valves.
- Pressure relief valves.

4.2.1.3 Test Pressure

The default pressure for hydrostatic pressure and leakage testing is 200 psi unless the PDE, with the approval of DC Water, determines a different test pressure is necessary. If a test pressure other than the default test pressure is used, the minimum test pressure shall be 1.5 times the working pressure or the working pressure plus the surge pressure, whichever is greater. Test pressures, other than the default test pressure, shall be explicitly stated on the design drawings and/or specifications.

4.2.1.4 Design Pressure

Design pressure is the maximum pressure that the pipeline is expected to be exposed to. Use the maximum pressure as the design pressure as determined from the following equations:

$P_D = P_w \times 1.5.$

$P_D = P_w + P_{s.}$

Where:

PD = Design Pressure.

Pw = Working Pressure.

Ps = Surge Pressure.

4.2.2 Sizing

The minimum allowable size of pipe for a water main is six (6) inches if the water main is not used to supply water for fire protection. The minimum allowable size of pipe for a water main which is used to supply water for fire protection is eight (8) inches. Existing pipe not meeting these requirements will be up sized when the pipe is replaced. DC Water may consider exceptions to the minimum allowable pipe sizes based on demand, fire protection, and water quality concerns.

Design water mains with a minimum pressure of 35 psi at the curb during peak hourly flow and a residual pressure not lower than 20 psi during maximum daily flow plus fire demand.

4.2.3 Water Main Pipe Material

The selection of pipe material primarily depends on the design pressure, corrosion protection, and location of the main. However, DC Water has determined that all buried water mains six (6) to 64 inches in diameter shall be cement mortar lined ductile iron pipe (DIP) with an exterior coating and pipe classification meeting the requirements of the Standard Specifications published by DC Water. Materials other than DIP are acceptable only as directed in writing by DC Water for a specific project.

Pipe larger than 64 inches in diameter shall be evaluated on a case-by-case basis to determine the pipe material to be used. Recommendations will be reviewed by DC Water for appropriate and acceptable use.

In areas of known green infrastructure, give special consideration to pipe material and location due to increased possibility of corrosion on the pipe. Where DIP is not used, provide justification for the selected material proposed to be used.

Refer to Section 6 Corrosion Control for corrosive conditions under which DIP may be replaced with a less corrosive material. Polyvinyl chloride (PVC) pipe may be an acceptable material in corrosive conditions when approved by DC Water. When allowed, the minimum thickness of PVC pipe shall have a Dimension Ratio of 14 and Pressure Class of 305 psi in accordance with AWWA C900. Note that AWWA M23, 2nd Edition uses a different pressure class rating for DR 14 but, per AWWA, M23 will be updated in the 3rd Edition to match AWWA C900.

4.2.4 Water Main Pipe Joints

Pipe joints for buried pipes shall follow DC Water's Standard Specifications. Restrain all joints on pipes smaller than 16 inches in diameter.

When deflection of pipe joint is necessary, design for a maximum permissible joint deflection not to exceed 75% of the manufacturer's recommendation. This provides for a 25% joint deflection tolerance (when compared to the Standard Specifications) available for use during construction.

4.2.5 Water Main Pipe Fittings

Fittings included in the design shall comply with the requirements of DC Water's Standard Specifications. The following types of fittings are allowed:

- Bends (90, 22 1/2, 11 1/4, and 5 5/8 degrees).
- Tees and crosses.
- Tapping sleeves and valves.
- Plugs and caps.
- Reducers.
- Adapters.
- Solid mechanical joint sleeves (for connection of 12 inch and smaller diameter pipe water mains to existing cast and ductile iron pipes).
- Sleeve type couplings (16 inch and larger diameter pipe).
- Transition solid sleeves.
- Offsets.

Use crosses only if other configurations are not possible and after receiving written approval from DC Water. Designs that limit or eliminate their use shall be considered.

For fittings 48 inches and smaller, design using standard size fittings complying with AWWA C110. In special circumstances and when approved by DC Water, fittings complying with AWWA C153 may be used. For fittings 54 inches and larger in diameter use compact fittings complying with AWWA C153. Restrain all fitting unless approved otherwise. Buried flanges are to be used only when approved by DC Water. PVC fittings may be considered when installing PVC pipe, but only after receiving written approval from DC Water.

4.3 ALIGNMENT REQUIREMENTS

4.3.1 General Considerations

Perform the following activities and consider the conditions identified below when establishing a pipeline alignment.

- Identify and locate all existing and proposed utilities and structures before selecting the location of the pipeline.
- Align the pipeline parallel to the property lines, rights-of-way or easements as much as possible. This is necessary for conformity in the utilization of public space and for locating the utility in the future.
- Locating structures over pipelines is to be avoided and are permitted by exception only. See Section 9.7 for activities required to obtain an exception.
- Pipelines located inside the Zone of Influence (ZOI) shall transfer building loads around water and sewer pipelines.
- In existing streets align the pipeline, where possible, to avoid the removal of trees and landscaped areas.
- When the pipeline must be located outside the public right-of-way, the alignment shall be selected to minimize disruption of environmental features.
- Avoid steep slopes, wetland areas, trees, and other environmentally sensitive areas.
- For pavement restoration and future work considerations, the pipeline design should stop short of intersections curb returns when intersection restoration is not a part of the project.
- When intersection work or restoration is included in the project the pipeline should include the entire intersection and extend through the intersection, beyond the curb return.

- Consider the information found in the geotechnical report when selecting the horizontal alignment. The existence of rock, groundwater elevation, and poor soils that would require special backfill, bedding, or foundation support are important factors in alignment selection.
- See *DC Water Green Infrastructure Utility Protection Guidelines* for guidance on the design and construction of green infrastructure adjacent or connected to DC Water utilities.
- DC Water is not responsible for maintaining pipelines beyond an obstruction in the public space.

4.3.2 Horizontal Alignment

The location of distribution mains depends on the width of the street. If the street right-of-way is 90 feet wide or less, only one (1) water main is required to service the lots, and it will be located six (6) feet from the curb line and within the travel or parking lane. If there is an existing wall (or retaining wall or other obstruction) a five (5) foot minimum separation is required. Figure 4-1 shows the typical location for streets less than 90 feet wide.

If the street right-of-way is wider than 90 feet, the lots are usually served by dual distribution mains to keep the length of the customer service lines to a maximum of 50 feet; one (1) on each side of the street. Dual distribution mains were sometimes installed in streets where streetcar tracks existed. DC Water approval is required for customer service lines greater than 50 feet. See Figure 4-2 for utility separation requirements in rights-of-way greater than 90 feet.

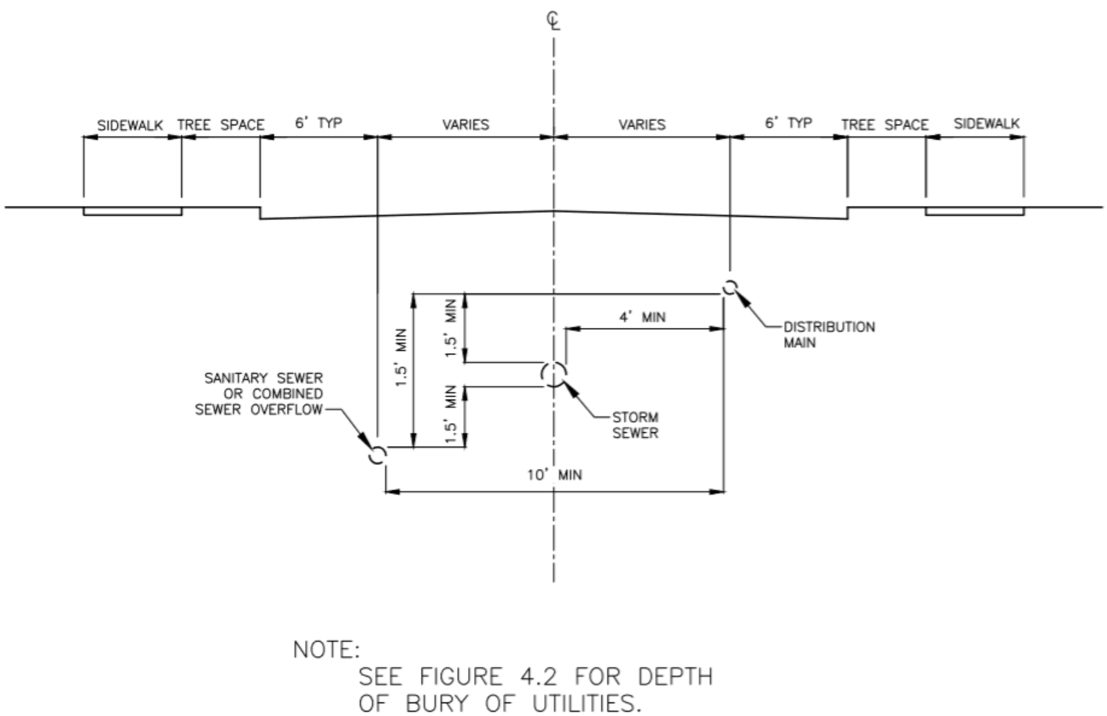

Figure 4-1: Typical Location Of Utilities In Streets Less Than 90 Feet Wide

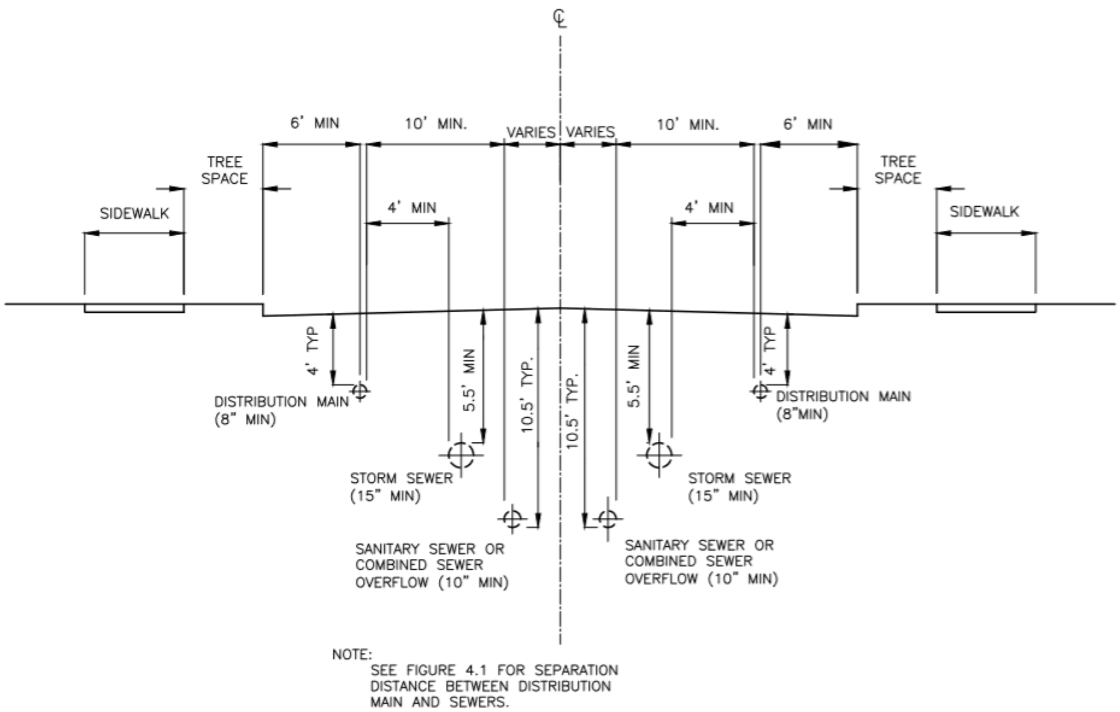

Figure 4-2: Typical Location Of Utilities In Streets Greater Than 90 Feet Wide

4.3.3 Vertical Alignment

Design the distribution mains with a minimum depth of four (4) feet from final grade to top of pipe. Design the transmission water mains with a minimum cover of four and a half (4-1/2) feet from final grade to the top of pipe.

Adjust high and low points to allow air relief and drains to be located outside intersections. Depth of pipe may be greater than the minimum bury depth which is shown on Figure 4-2 for utilities regardless of the width of the street.

When selecting the vertical alignment of water mains verify the alignment does not interfere with existing buried utilities. Prepare profiles drawings showing interferences and crossing utilities.

4.3.4 Vertical and Horizontal Separation From Other Utilities

Exceptions to the horizontal and vertical clearances defined in this manual require a DC Water one (1) time deviation approval as described in Section 1.5.

Design the water lines to run above sanitary sewer lines. No water pipe shall pass through or contact any part of a sewer manhole.

The minimum vertical clearance between water mains and sanitary sewer and other utilities shall be 18 inches (outside of pipe to outside of pipe) unless otherwise approved by DC Water. Separation distances are shown in Figure 4-1 and are applicable regardless of the width of the street.

The minimum horizontal clearance between water mains and sanitary sewer shall be ten (10) feet (outside of pipe to outside of pipe), DC Water may allow deviation on a case-by-case basis, if supported by data from the design engineer and shall only be approved of in writing.

The minimum horizontal clearance between the water lines and other utilities shall be four (4) feet. Where four (4) feet separation is not available, the separation distance may be reduced to three (3) feet or as required to permit excavation of the pipes without causing interference to the adjacent pipe using the minimum trench excavation widths shown in DC Water's Standard Details, whichever is greater. Additionally, the design shall require the trench backfill to be CLSM to a depth of one (1) foot above the pipe and, if shoring/piling is used, the shoring/piling shall be required to remain in place to an elevation not less than the top of the pipe but below the finished grade at a distance that will not obstruct final backfill and compaction requirements for pavement and other finished surfaces.

Maintain a minimum distance of five (5) feet from walls, structures, or other similar obstructions.

The following conditions requires special design to prevent cross contamination of the water main from the sewer:

- The minimum horizontal separation between water and sewer cannot be met.
- The minimum vertical separation when the sewer crosses below the water main.
- The sewer crosses above the water.

Special design to prevent cross contamination of the water main from the sewer shall include one of the following:

- Both the water main and sewer are constructed of materials that are approved by DC Water for pressure pipe with joints that are equivalent to water main standards for a distance of nine (9) feet on each side of the crossing. The center (longitudinally) of the pipes shall be located at the point of intersection so the joints are equidistance and as far from the crossing as possible. The sewer pipe shall be pressure tested in place without leakage prior to backfilling.
- Both the sewer and water main shall be encased in concrete or placed within a steel cylinder casing with the annular space filled with general purpose controlled low-strength material (CLSM) as defined in the DC Water Standard Specifications.
- The water main shall be constructed per DC Water Standard Specifications and the existing sewer shall be lined with CIPP per DC Water Standard Specifications.

If a new water main crosses an existing sewer pipe, but the sewer pipe is not being exposed, the sewer need not be upgraded to meet these special design requirements. Adequate structural support shall be provided for sewers crossing over water mains to prevent excessive deflection of the joints and the setting on and breaking of the water main. For additional requirements for separation between water and sewer lines, refer to section 5.6.1

4.3.5 Pipeline Drawings

Prepare drawings using plans and profiles. Information shown on pipeline drawings shall include, but is not limited to:

- Typically, all horizontal information is shown on plans and vertical information is shown on profiles. Exceptions to this may be required and/or authorized based on the complexity of the project and other project specific needs.
- Preparing profiles for all water mains eight (8) inches in diameter and greater.
- The existing surface over the centerline of the pipeline profile, including an existing surface elevation callout in the profile grid.
- The final surface over the centerline of the pipeline profile if different from the existing surface, including a finish surface elevation callout in the profile grid.
- Station and elevation of the pipeline at all changes of horizontal or vertical alignment. Station and elevation of each change in vertical alignment shall be shown in profile. For water mains, station of each change in horizontal alignment shall be shown on the plan.
- Station and elevation at every low and high point on the pipeline.
- Size, service type, and location accuracy of existing utility crossings. Location accuracy shall be Level A, B, C, or D for buried utilities as defined by *ASCE 38-02*. Additional call outs of stationing and elevation shall be included as warranted based on design needs and the level of location accuracy.

- Include the elevation of the tee to fire hydrants. Long hydrant leads may include a profile per the PDE's or DC Water's judgment.
- Limits of restrained joints when the pressure pipeline is not fully restrained.
- Concrete thrust restraints, pipe anchors, cut off walls, and all appurtenances necessary to show the complete design of the pipeline.

4.4 THRUST RESTRAINT DESIGN

Thrust restraint is required for all pressure pipes at locations including, but not limited to bends, tees, reducers, dead ends, offsets, and valves. See the Standard Specifications for allowable restrained joint types.

4.4.1 Pipelines 12 inch Diameter and Smaller

Joint restraint shall be included at all joints on pipelines 12 inches diameter and smaller.

4.4.2 Pipelines Larger than 12 inches

Pipelines larger than 12 inches shall include restrained joints for a length calculated using the methods described in AWWA M41. Use the criteria in Table 4-3 to calculate thrust and joint restraint length.

Table 4-3: Thrust Restraint Design Criteria

Variable	Criteria
Pressure (whichever is greater)	• Working pressure plus surge pressure • Working pressure x 1.5 • 200 psi
Soil Type for Bearing Strength	• Actual soil type • Soft clay (if soil type is unknown) or 1000 psf
Safety Factor	• Two (2)
Trench Type or Laying Designation	• Two (2)
All other variables	• Per design conditions

4.4.3 Combination of Bends and Fittings

Provide continuous restraint of the pipeline between the bends and fittings, and analyze the section of the pipeline containing the bends and fittings as a single unit.

4.4.4 Types of Joint Restraints

DC Water has approved specific joint restraint systems for use on pressure pipe. The approved joint restraint systems are included in DC Water's Standard Specifications.

4.4.5 Concrete Thrust Blocks

Thrust blocks may only be used:

- On the existing pipe when connecting new pipe to existing pipe, and
- When the length of new pipe to be restrained exceeds the length of pipe to be installed.
- Approved otherwise by DC Water.

If the length of new pipe that needs to be restrained to resist the thrust exceeds the length of pipe to be installed, an in-line thrust block is required unless the existing pipe is fully restrained and the new pipe is fully restrained against the existing pipe.

Refer to DC Water's Standard Details for thrust blocks at connections to existing and inline thrust blocks. Refer to additional information in this Design Manual regarding connections to existing pipe.

Design of concrete thrust block for pipelines shall include the following considerations and activities:

- Verify a sufficient area of unobstructed (no utilities, etc.) soils is available to allow for the required thrust block size.
- Perform a geotechnical analysis including at least one (1) test boring located at each thrust block location.
- The soil at the proposed thrust block location shall have a standard penetration test blow count (N) greater than ten (10) and the soils shall not be organic material.
- If the condition stated above does not exit, the use of piles or replacement of the in-situ soil with structural fill within the ZOI of the thrust block is required.
- Determine if overhead power lines, telephone lines, trees or any other existing structure that may interfere with pile driving operations when the design includes piles.
- When concrete thrust blocks are installed on fittings that are near each other, ensure that sufficient room exists so that the concrete blocks and passive pressure soil zones do not overlap.
- Locate thrust blocks such that the soil passive pressure ZOI does not affect other utilities or structures.
- Include piles in the design of the thrust block if future excavations within the ZOI of the thrust block are likely to occur.
- Ensure a minimum soil cover over thrust blocks of 18 inches.
- Account for the slope of surfaces that are ten (10) degrees or more from the horizontal in the design calculations.
- Design the thrust block for submerged conditions.
- Show thrust blocks and piles on drawings at scale.

4.4.6 Combined Restraint Systems

When using thrust blocks, the thrust block system and restrained joint system shall be designed independently of the other and incorporate both systems into the piping system.

4.5 ANCHORING PIPE ON STEEP SLOPES

Pipe installed at slopes between 20% and 50% shall follow DC Water Standard Details. Pipes installed on slopes greater than 50% require special design be submitted to DC Water.

4.6 EXPOSED WATER MAINS

Exposed water mains shall be flange joint DIP, unless approved otherwise by DC Water, with adequate expansion joints included. The pipe shall be coated to protect the pipe from the elements, UV, and corrosion. Coating selected shall ensure the design life of the water main and be approved by DC Water.

As part of the design, evaluate the water main for potential freezing. Submit calculations, for review, with the assumptions and method used for the analysis clearly indicated.

Design exposed pipes with insulation or active heat tracing to protect against freezing. Support and protect insulation and heat tracing from damage with a suitable shield. Design for any future maintenance requirements.

See Section 11 Bridge Crossings for the design of pipeline crossings on bridges.

4.7 WATER MAIN APPURTENANCES

4.7.1 Valves

Valve size shall be the same size as the pipeline. Pipes 12 inches and smaller shall use gate valves.

For water mains greater than 12 inches, design may consider a butterfly valve in a valve vault or manhole in accordance with DC Water's Standard Details. Valves installed in the horizontal position are discouraged and shall only be allowed in specific cases as approved by DC Water.

With DC Water approval, insertion valves may be used on existing pipelines to facilitate or eliminate problems associated with the shutdown of a pipeline. Insertion valves shall not be used unless necessary. If insertion valves are used perform the following prior to including in the design:

- Provide calculations showing adequate restraint is provided for the valve.
- Evaluate the condition of the pipe to ensure it has sufficient integrity to support an insertion valve.
- Include in the design specific qualifications for the contractor installing the valve and approval of the materials and method of installation.

4.7.1.1 Valve Location

Valves shall be located in accordance with the following guidelines:

- All branch connections shall have valves located near the mainline pipeline.
- In a bypass connection between a main line and branch line, locate the valve on the bypass near the largest pipeline.
- The spacing of valves in the pipeline shall be as follows:
  - 12 inch diameter and smaller pipelines: maximum spacing of 1,200 feet or maximum 50 customer service lines, whichever is shorter.
  - Greater than 12 inch and up to 20 inch diameter pipelines: maximum spacing of 2,000 feet or maximum four (4) branch connections between valves, whichever is shorter.
  - Greater than 20 inch diameter pipelines: maximum spacing of 2,500 feet or maximum four (4) branch connections between valves, whichever is shorter.
- All customer service lines three (3) inches in diameter and larger shall have valves located near the branch connection to the main pipeline.
- When the water distribution system is looped between streets, the pipeline shall have valves provided at the end of each street.

4.7.1.2 Boundary Valves

Design of boundary valves (valves located between pressure zones) require special coordination with DC Water Operations Group and the Water Modeling Group. Any boundary valves shown on drawings (existing, replacement, or new) require the following information be shown in drawings:

- Label the valve between two (2) zones as a divide in service valve and indicate size.
- Show the pressure zone lines and indicate the zone on each side.
- Indicate that the valve shall be normally in the closed position.

4.7.2 Air Vacuum and Air Relief Valves

Use the following requirements to determine size and location of air vacuum and air relief valves:

- Perform an analysis of pressure pipe systems as described in AWWA M51 to determine recommended locations and size air vacuum and air relief valves.
- Minimum sizing criteria for air exhaust shall be determined by the flow rate of filling the pipe.
- Minimum sizing criteria for air intake shall assume a pipe rupture at the low point of the pipe segment and a discharge rate of 50% unless the discharge point is into an open system. The 50% assumes that the pipe is buried and the discharge flow of water is impeded by soil or other medium. Greater flows should be used if field conditions and design assumptions indicate a higher flowrate is possible.
- Consider accessibility and traffic avoidance when determining the actual location of the valve.
- Utilize the pipe profile to establish valve locations at high points.
- Adjust the pipe profile to prevent high points from being in intersections, if possible.

- Valves shall be easily accessible for maintenance and repairs.

Selection of air vacuum and air relief valves (make, model, manufacture, and size) for use in water piping in new locations shall be approved by DC Water and shall:

- Be designed for water service.
- Be of the type that allow personnel to perform maintenance, repairs, and replacement without entering a confined space.
- Be fully contained within an integral valve containment system.
- Prevent contamination from a cross-connection and backflow into the water main by venting above grade with an air gap that meets the requirements of AWWA M14.

Selection of air vacuum and air relief valves at existing installations shall have the same properties as valves at new installations except that the valve shall be installed in the existing containment system.

Design air vacuum and air relief valves on new pipe as follows:

- The branch tee shall be twice the diameter of the required valve size.
- Whenever possible, the valve shall be designed to be installed directly over the crown of the pipe.
- When installation over the crown of the pipe is not feasible, the tee shall be designed to be installed at the crown of the pipe with the pipe to the air vacuum and air relief valve:
  - Being reduced to the same size as the air vacuum and air relief valve after the tee.
  - Having a minimum slope upward of two (2) percent toward the air vacuum and air relief valve.
- Valves shall be designed with air intake and exhaust 12 inches above the ground or 12 inches above the 100 year flood zone, whichever is higher.

Air vacuum and air relief valves installed on existing pipe may be designed with a tap and corporation stop provided that the air vacuum and air relief valve are two (2) inch and smaller.

4.7.3 Drain Blow-offs

On pipelines 12 inch diameter and smaller, drain blowoffs are generally not required. DC Water may require drain blowoffs to be installed when necessary to facilitate draining the pipeline.

On pipelines 16 inch diameter and larger, install six (6) inch drain blowoffs:

- At low points or wherever it is possible that drainage will be required.
- Adjacent to a mainline valve when it may be required to drain the pipe if the valve is closed.

With approval from DC Water, fire hydrant installations may be used as drain blowoffs to drain the pipeline, if the hydrant tee is located at the low point of the pipeline and the hydrant provides sufficient drainage from the pipeline to evacuate a majority of the water from the pipe.

4.7.4 Check Valves

This section does not address check valves used in pump stations or backflow preventers used for cross-connection control and backflow prevention. For check valves related to operation of a pump station, refer to Volume 2 of the Design Manual. For backflow prevention, refer to the DC Water's Compliance Program.

Check valves on main lines shall only be used on a case by case basis and must be approved by DC Water.

Design check valves to be installed in vaults. Vaults shall include:

- An access opening large enough to remove the check valve.
- Isolation valves upstream and downstream of the check valve.
- A full-size bypass around the check and isolation valves, unless approved otherwise by DC Water.
- A valve that is normally closed on the bypass.

4.7.5 Fire Hydrants

All design including new hydrants shall be submitted to DC FEMS for review.

New hydrants shall be primarily located near intersections.

Spacing between fire hydrants shall be dictated by the following (whichever yields hydrants spaced closest together):

- Maximum spacing of fire hydrants shall be 400 feet.
- When existing water mains are replaced, fire hydrants shall be spaced at distances nominally equal to the existing spacing.
- When roadways have medians, hydrants shall be placed on each side of the roadway (such that fire hoses from the hydrant to a burning building would not cross the median).
- Principal arterials shall have hydrants placed on each side of the roadway (such that fire hoses from the hydrant to a burning building would not cross the roadway). Principal arterials are defined by DDOT on the *District of Columbia Functional Classification Map* or other documents published by DDOT.
- As directed by DC FEMS.

Fire hydrant leads shall be six (6) inch in diameter and have a six (6) inch shut-off valve in a separate casing. Hydrants shall be self-draining and have a gravel dry well for drainage as shown in DC Water's Standard Details.

Design hydrants in tunnels with special consideration to accessibility.

Design hydrants to be located:

- Two (2) feet behind the curb.
- Installed in the public roadway right-of-way.
- In line with a property lot line (or reasonably close) when a fire hydrant is located between intersections.
- With a three (3) foot minimum clear space around the circumference of fire hydrants.

Where fire hydrants are subject to impact by a motor vehicle, design appropriate protection such as a bollard or curb.

4.7.6 Flush-Type Hydrants

Design flush-type hydrants at dead ends in the water distribution system, such as a cul-de-sac(s), where there is no effective cost alternative for looping the main. Locate flush-type hydrants the same as fire hydrants.

Flush-type hydrant leads shall be six (6) inch in diameter and have a six (6) inch shut-off valve in a separate casing. Hydrants shall be self-draining and have a gravel dry well for drainage as shown in DC Water's Standard Details.

4.7.7 Access Manholes For Large Water Mains

DC Water shall approve location of access manholes for large water mains. These access manholes are placed for consideration of operations, maintenance, and condition assessment.

4.8 CUSTOMER SERVICE LINES

4.8.1 Service Lines

A customer service line (or "service line") is the pipe from the water main to a house or similar building. The design and construction of customer service lines is governed by the DC Plumbing Code. The minimum size of service line is one (1) inch but shall be greater if water demand requires.

Service lines are installed by the developer or owner of the property, and they are owned by the property owner. However, in accordance with D.C. Law 1-98, "*Water and Sewer Repair and Compensation Act of 1976*", DC Water is responsible for the maintenance and replacement, if necessary, of the service lines in public space, up to the property line or approved projection.

To distinguish between small and large water services, DC Water uses the following definitions:

- Water service line - When the size of the pipe between the public water main and the structure is two (2) inch or smaller diameter, the service is defined by DC Water as a water service line. Typically, these are services to supply water to individual houses or townhouses.
- Water connection - When the size of the pipe between the water main and the structure is larger than two (2) inch diameter, the service is defined by DC Water as a water connection. Typically, these are services for properties requiring a large water supply, like commercial, industrial and apartment buildings.

Perform calculations to demonstrate the size of service line selected for installation will provide sufficient head and flow to meet the demands of the intended service. However, in no case shall the flow exceed the values given in Table 4-4.

Table 4-4: Maximum Flow Rate In Customer Service Lines

Dia. (in)	2"	3"	4"	6"	8"	10"	12"	14"	16"
Flow (gpm)	30	95	200	590	1250	2220	3400	5500	7600

4.8.2 Service Line Replacement

When a water main is replaced, design the replacement of all lead, galvanized, or under-sized water service lines in public space. Undersized water service lines are any pipe smaller than one (1) inch or any pipe that will not supply the required flow and pressure as required by the DC Plumbing Code.

During the preliminary design phase of a water main replacement project, identify the location and size, if possible, of all existing water service lines affected by the replacement by:

- Searching records at DC Water's Permit Operations.
- Searching records at DC Water's Technical Information Center (TIC).
- Searching GIS records.
- Performing a field survey and subsurface utility evaluation.

Water connections to a water main shall have a valve six (6) inches in diameter or greater. Customer service lines smaller than six (6) inches in diameter, therefore, shall include a tee with a six (6) inch or greater branch, a six (6) inch or greater valve, and a reducer to downsize to the required water connection pipe size.

The nominal depth of cover required for customer service lines is four (4) feet. When the water main is designed with over four (4) feet of cover, special considerations (*i.e.*, raising the water connection and providing elevations on the drawings), may be required.

Customer service lines shall not be located in driveways.

4.8.3 Combination Customer Service Lines

A single water connection branching into a fire and a domestic service is permitted by the D.C. Plumbing Code. However, it must be approved by DC Water in writing and backflow preventer assemblies must be installed in accordance with code immediately after the domestic water and fire service are separated inside the building.

To determine the size of combined service line required, use the DC Plumbing and Fire Codes to calculate the size of pipe required for each type of service as if it were installed separately. Then use the following formula to determine the minimum size of the combined service line allowed.

$(D_d^2 + D_f^2)^{0.5} = D_c$.

Where:

D_d = Diameter of the domestic service pipe required.
D_f = Diameter of the fire service pipe required.
D_c = Dimeter of the combined service pipe required.

Small diameter combined service lines, two (2) inch diameter and smaller, serving residential properties may be sized for the service with the greatest demand as required by the District Department of Regulatory Affairs (DCRA).

4.8.4 Water Meters

Water meters two (2) inch and smaller are classified as small water meters. Locate small water meters in the sidewalk or tree space and house them in a meter pit in accordance with DC Water's standard details.

Water meters larger than two (2) inches are classified as large water meters. Large meters shall be located outside the building in a meter vault (in public space where possible).

When no sidewalk or tree space is available, locate the meter in an accessible location in public space. Meters shall not be located behind any retaining walls or similar obstructions. Install water meters away from existing trees.

Meter housings and lids installed in traffic areas shall be rated for H-20 loading.

During installation of a new or replacement water main, water meters located inside a building or in private property shall be relocated to public space. No premise (address) shall have more than one (1) meter monitoring/tracking water consumption.

4.8.5 Temporary Water Services

When shutdown of a water main is required for replacement or rehabilitation, the design shall require temporary water service, including fire protection, be provided to all customers.

4.9 CONNECTING NEW WATER MAINS TO EXISTING

Determine the pipe material, alignment, and depth of the existing water main. Branch connections to water mains shall be designed with a tee cut into the existing main and valves installed on all three (3) mains near the tee. Crosses may only be used with prior written approval from DC Water. For allowable uses of tapping sleeves or saddles and valves, see below. Show pipe information and branch connection details on the Contract Drawings.

4.9.1 Connection to Existing Pipelines

4.9.1.1 Steel, Cast Iron (CIP) and Ductile Iron Pipe (DIP)

For steel pipe, the connection shall be made using ductile iron pipe, fittings, and insulated transition coupling. For DIP or CIP, a non-insulated solid sleeve shall be used; however, if the outer diameter does not match, a transition coupling may be used.

Mechanical joint solid sleeves shall be used on 12 inch and smaller diameter water mains.

Connection to water mains 16 inch and larger diameter may be made using mechanical sleeve type couplings.

4.9.1.2 Concrete Pipe

All connections to concrete pipe shall be coordinated with the pipe manufacturer and approved by DC Water. Design shall take in to account the pipe size, joint type, pipe reinforcing, joint location, thrust restraint, and other factors.

The connection between existing concrete pipe and the new DIP connection pipe will require special design. If the size of the tap is too large for the size of the existing CP, propose a design to DC Water for review and approval. The design shall include removing a length of pipe and using concrete to ductile iron adapters.

Evaluate the existing pipeline to determine if a valve is also needed on the main line. If not required, request approval from DC Water to not include mainline valves on the existing line. The type and locations of joints to be encountered (bell, spigot, plain end, etc.) shall be identified on the drawings.

4.9.1.3 Prestressed Concrete Cylindrical Pipe (PCCP)

New connections to existing PCCP are prohibited.

4.9.2 Use of Tapping Sleeve and Valves

Tapping sleeves may be used only when the existing pipe to be tapped is ductile iron pipe installed in the last 70 years and in sufficiently good condition to receive a tap without damaging the existing pipe. Prior written approval from DC Water is required before installation of a tapping sleeve.

4.10 TRENCHLESS WATER MAIN CONSTRUCTION (NEW PIPE)

Trenchless construction methods are considered viable methods of construction by DC Water. When trenchless construction is considered, the design shall include performing appropriate studies, evaluations, and site investigations to gather the information necessary to determine if trenchless construction is beneficial and feasible. Studies and investigations that will provide useful information include, but are not limited to:

- Geotechnical investigation.
- Utility location evaluation.
- Subsurface locating investigation.
- Access pit locations evaluation.

4.10.1 Directional Drilling

4.10.1.1Preliminary Evaluation

Consider environmental impacts including the location of entry and exit points, space for staging area and pipe pullback, depth of cover, and disposal of drilling mud and spoils when assessing the feasibility of the directional drill installation method. Diligently investigate utilities adjacent to the pipeline being installed. This may require test pitting to verify clearances between the existing pipeline and the other utilities. Additionally, evaluate the site for adequate room to fuse the joints and string the pipe while it is being pulled.

Conduct geotechnical investigation with soil borings taken to a depth at least five (5) feet below the deepest portion of the vertical alignment.

4.10.1.2General Requirements

Vertical alignment shall be designed per the guidelines in ASTM F1962. Minimum radius in feet of directional drilled pipe shall not be less than 40 times the diameter of the pipe in inches (i.e. 12" diameter directional drilled pipe shall have a minimum radius of 480LF) with no greater than 20 degree entry or exit angles.

Design the directional drilled pipe and alignment to not exceed industry and manufacturer's guidelines for pull stress, critical collapse pressure, unconstrained collapse pressure, and long term reduced collapse strength. Design shall include good industry practices for directional drilled crossings.

4.10.2 Jack and Bore

4.10.2.1Preliminary Evaluation

Jack and bored crossings may be considered for used at obstacles such as stream, rail, or highway crossings. Evaluate the use of jack and bored crossings for cost, requirements from outside agencies, implications to private property Owners, and input from DC Water.

Take soil borings from both ends of the proposed crossing and other locations as appropriate. Extend boring to a minimum of five (5) feet below the proposed invert of the casing. If solid rock is present, arrange for the driller to take a sampling of rock cores for analysis in accordance with Section 3.4.

4.10.2.2General Requirements

All jack and bored crossings shall use a casing pipe. The outside of the casing pipe does not need to be coated. The ends of the pipes shall be designed and sealed to be water tight.

All carrier pipes shall have restrained joints. Require spacers between carrier pipe and casing to minimize movement of the carrier pipe in the casing. Minimum number of spacers shall be three (3) per pipe segment with additional spacers required if necessary to stabilize pipe. The annular space in the casing pipe shall not be filled unless otherwise specified by permits or right of way agreements issued by outside agencies. If the annular space must be filled, refer to Section 8 Corrosion Control for the requirements.

4.10.2.3Carrier Pipe Criteria

Design the carrier pipe using the same load parameters as the design of the casing pipe.

4.10.2.4Casing Criteria

Design the extent of casing and depth of installation as follows:

- Extent of Casing:
    - Highways – Ten (10) feet past the shoulder of the highway, or ten (10) feet past the toe of slope, whichever is greater;
    - Railroads – From right-of-way line to right-of-way line of the railroad.
    - Other public ways – From right-of-way line to right-of-way line.
    - Slopes Failure Line – In no case shall the casing be within the 1:1 slope failure line of the edge of pavement.
- Depth of cover – minimum of five (5) feet of cover over the top of the casing pipe at the shallowest point in the crossing.
- Show extents of cover, depth of cover and slope failure lines on the drawings.

Design the casing size to permit installation of spacer devices to center the carrier pipe in the casing pipe, with no points of contact, including bells and restrained joint systems, between the casing and carrier pipe. Spacers shall be large enough to minimize carrier pipe movement in the casing.

Design wall thickness of the casing using the following criteria:

- Dead load – Soil conditions from the trench conditions
- Live load – either E80 for railroads or HS-20 for all others.
- Minimum thickness requirements – As listed in DC Water's Standard Specifications or set forth by the permits or right of way agreements.
- Minimum wall thickness for steel casing of half inch (½").

4.10.3 Pipe Bursting

4.10.3.1Preliminary Evaluation

Pipe bursting for water mains and customer service lines may be implemented when circumstances limit open cut pipe replacement or, when approved by DC Water, other circumstances provide favorable conditions for this method of pipe replacement. Because soil and groundwater conditions affect the feasibility of pipe bursting, perform extensive subsurface explorations to obtain soil borings at proposed insertion, receiving, and access pit locations to confirm the feasibility of pipe bursting. Perform standard penetration tests, unconfined compression tests, and moisture content tests. Take groundwater readings within 24 hours after drilling boreholes.

Diligently investigate utilities adjacent to the pipeline to be replaced. This may require test pitting to verify clearances between the existing pipeline and the other utilities. A minimum three (3) foot clearance from gas lines is required for pipe bursting to be allowed. Verify adequate space exists for entry and receiving pits. Additionally, evaluate the site for adequate room to fuse the joints and string the replacement pipe while it is being pulled into the existing main.

Determine the depth of the existing pipeline to verify that there is sufficient cover to allow pipe bursting without causing ground heave. The pipe bursting process is likely to cause heave when the existing pipe is being upsized. According to the International Pipe Bursting Association the depth of the existing main should be at least equal to the difference between the expander head outside diameter and the existing pipe inside diameter, expressed in feet, multiplied by 12.

4.10.3.2General Requirements

Pipe bursting is most feasible in clay soil with unconfined compression strengths less than two (2) tons per square foot and above the groundwater table. Pipe bursting is less feasible in rock trenches. Pipe bursting can be used in fractural and non-fractural pipes four (4) inch in diameter and larger.

Pipe diameters can be upsized one or two diameters during the pipe bursting process. Replacement pipe material shall be HDPE or fusible PVC designed for the required water main pressure and pipe bursting pulling forces. Joints shall be butt-fused per the manufacturer's instructions and assembled in the field prior to beginning the pipe bursting.

Standard pipeline couplings, fittings, and appurtenances shall be used to make connections to the existing mains on either side of the replacement water main.

4.11 WATER MAIN REHABILITATION (EXISTING PIPE)

4.11.1 Water Main Lining

Rehabilitation of existing water mains shall only be considered on water mains eight (8) inches or greater in diameter with no lead customer service lines and with few recent breaks. Lining material to be installed shall provide complete structural integrity necessary to support all loads (internal and external) regardless of adhesion to existing pipe walls.

4.11.2 Valves

All in-line and side stop valves along the main to be rehabilitated shall be replaced. Location of valves, hydrants, and other appurtenances shall comply with standards described in this Design Manual regardless of existing location of valves, hydrants, and other appurtenances even if this requires excavation or replacement of water main. If some of the valves to be replaced are relatively new, require the Contractor to salvage them and turn them over to the Department of Water Services (DWS).

4.11.3 Blowoffs

Design air and/or drain blowoffs at each side of valves 16 inches and larger. Replace existing blowoffs if they do not conform to DC Water's current standards, (e.g., drain to sewer), or if they are in poor condition as determined by DC Water. Upon a case by case examination, some existing blowoffs or hydrants may be retained to function as blowoffs.

4.11.4 Fittings

Require all horizontal and vertical bends, fittings, reducers, and offsets to be removed and replaced unless they are restrained by large concrete thrust blocks with piles.

4.11.5 Disposal of Water

The design shall require the water that is used during the rehabilitation process to remove the corrosion deposits from the pipe to be passed through a settlement tank or desilting filter box and discharged to a sanitary or combined sewer. Highly chlorinated flushing and disinfection water must be discharged to a sanitary or combined sewer as well. Determine which discharge location option(s) will be available during construction and specify on the drawings acceptable locations for discharge and require the Contractor to pretreat the water to levels required for discharge to the selected sewer system(s).

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5. SEWERS

5.1 TYPES OF SEWERS

The following types of sewers exist in DC Water's system:

- Sanitary (or separate sanitary) sewer: Designed to convey domestic, commercial, and industrial wastewater, including allowances for groundwater infiltration (GWI) and rainfall derived inflow and infiltration (RDII)
- Storm sewer: Designed to convey only storm water runoff plus inflow and infiltration (I/I). Storm sewers do not carry wastewater.
- Combined sewer: Designed to convey wastewater under dry weather conditions (no rainfall) and a combination of sanitary and storm water runoff under wet weather conditions (rainfall).
- Gravity main: Designed to convey flow under open channel flow conditions without surcharging.
- Force main: Designed to convey wastewater under pressure from the discharge side of a pump to a discharge point.
- Service lateral: Connection between the main sewer line and the property that services only that property.

5.2 FLOW AND HYDRAULICS

No storm water connections shall be allowed to connect into separate sanitary sewers.

5.2.1 Hydraulic Design of New Sanitary Sewers

5.2.1.1 Flow Rates

Design sanitary gravity sewers to convey peak sewage flow for:

- The estimated ultimate tributary population.
- Flow pumped to the sewer shed from lift stations, and
- I/I consisting of GWI and RDII.

Determine the design flows for new sanitary sewers from flow metering and DC Water's hydraulic model results, where available. When using DC Water's hydraulic model to evaluate design flows that include conveying existing flows from existing upstream pipes, obtain flow metering data for the design to validate estimated design flows and calibrate the hydraulic model. Flow analyses shall include a sewer shed map showing the tributary area.

Calculating Sanitary Sewer Flows:

- Step 1: Calculate population and acreage of the sewer shed.

"Ultimate tributary population" shall be based upon population and employment densities (people per acre) obtained from the *Metropolitan Washington Council of Governments* (MWCOG) for the 25 year future forecast (i.e. if the current edition is 2015, use the densities provided in the future forecast of 2040). See the MWCOG website and documents at www.mwcog.org and follow the following path: Home > Documents > Cooperative Forecasts: *Employment, Population, and Household Forecasts* by Traffic Analysis Zone or use this link:

https://www.mwcog.org/documents/2016/08/01/cooperative-forecasts-employment-population-and-household-forecasts-by-traffic-analysis-zone-cooperative-forecast-demographics-housing-population/.

Use population densities to calculate the domestic sewage flow and employment densities to calculate the commercial and industrial sewage flow.

Acreage shall include all property bound by property lines located inside the sewer shed and buildings being served within the sewer shed.

- Step 2: Estimate average flow within the sewer shed.

Calculate total average flow based on:

- Population within the sewer shed.
- Acreage of the sewer shed, and
- Sum of all of the flows per Table 5-1.

Table 5-1: Average Sewage Flow

Description	Estimated Average Sewage Flow
Domestic sewage	80 gpcd
Commercial and industrial sewage	15 gpcd
Sewage from other major commercial or industrial sources	Special consideration for each case
Average ground water infiltration (GWI)	700 gpad

- Step 3: Estimate peak dry weather flow within the sewer shed.

Calculate the peak flow by applying a peak factor to the calculated average flow from the previous step. The peak factor shall be taken from the "Ratio of Peak Hourly Flow to Design Average Flow" as taken from the most recent edition of the *Recommended Standards for Wastewater Facilities* by the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers.

Sanitary sewers shall have a minimum design peak dry weather flow rate of 300 gpcd.

- Step 4: Estimate peak wet weather flow within the sewer shed.

RDII allowances are obtained from Figure 5-1 using the acreage and population density of the sewer shed.

5.3 HYDRAULIC CAPACITY

Design pipe sizes to convey the calculated peak flow while meeting the hydraulic capacity requirements described below. The capability of downstream sewers to convey future tributary flow shall be included in the analysis.

Design pipe grade to meet the following requirements:

- Minimum velocity of two (2) feet per second at average flow (to prevent deposition of solids).
- Maximum depth ratio (d/D) of 70% at peak wet weather flow where:
  d = depth of flow.
  D = Diameter of pipe.
- Manning's formula with an "n" value not less than 0.013.
- Minimum diameter of any public gravity sanitary sewer shall be not less than ten (10) inches.

If the above requirements do not allow for drainage into an existing downstream sewer, then additional sewer must be designed and installed until the sewer can catch grade.

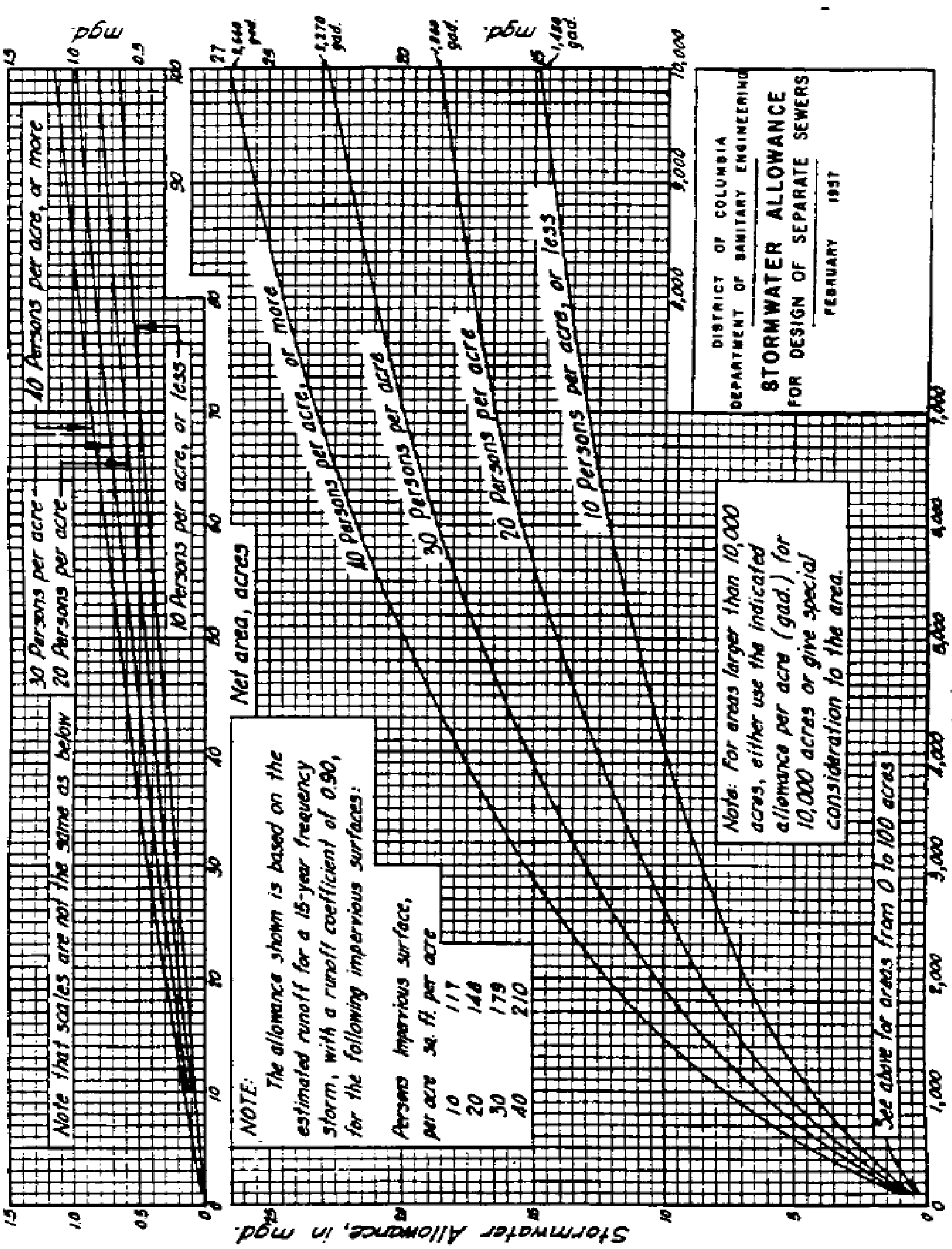

Figure 5-1: RDII Stormwater Allowance For Design Of Separate Sanitary Sewer

5.3.1 Hydraulic Design of New Storm Sewers

5.3.1.1 Flow Rates

Calculate the rate of storm water runoff for design of storm sewers using the *Rational Method* for a 15 year 24 hour frequency storm as follows:

$$Q = CIA.$$

Where:

Q = storm flow (cfs).
C = dimensionless runoff coefficient.
I = peak rainfall intensity (in/hr).
A = drainage area (acres).

Calculate Peak flow assuming:

- The entire watershed is contributing to the storm flow.
- Rainfall intensity is the same over the entire drainage area.
- Rainfall intensity is uniform over a duration equal to the time of concentration, t_c, and,
- The frequency of the computed peak flow is the same as the frequency of the rainfall intensity, i.e., the 15 year rainfall intensity is assumed to produce the 15 year peak flow.

The time of concentration is the time required for water to travel from the hydraulically most remote point of the basin to the point of interest.

- The runoff coefficient, C, is the same for all storms of all recurrence probabilities.
- The runoff coefficient, C, is a function of the ground cover and other hydrologic abstractions. It relates the estimated peak discharge to a theoretical maximum of 100% runoff. If the basin contains varying amounts of different land cover or other abstractions, a composite coefficient can be calculated through areal weighing as follows:

$$\text{Weighted } C = \Sigma\, (C_x\, A_x)/A_{total.}$$

Where:

x = subscript designating values for incremental areas with consistent land cover.
C = values as cited from a published hydrology textbook.

Table 5-2 provides rainfall intensities for the 15 year frequency storm based on storm duration. The total rainfall and rainfall intensities are derived from the *Precipitation-Frequency Atlas of the United States*, NOAA Atlas 14, ten (10) year and 25 year 24 hour storms and interpolated to a 15 year storm from the ten (10) year and 25 year data.

Table 5-2: Rate Of Rainfall For 15-Year Frequency/24-Hour Storm Events

Parameter	NOAA 15-yr Storm
Duration (hrs)	24
Total Rainfall (in)	5.49
Max 5 min Intensity (in/hr)	7.12
Max 10 min Intensity (in/hr)	5.68
Max 15 min Intensity (in/hr)	4.79
Max 60 min Intensity (in/hr)	2.32

The assumed inlet time for urban areas is generally taken as five (5) minutes. The time of flow through the existing sewers and the corresponding sewer capacity are computed from velocities determined by using an appropriate value for the coefficient of friction, *n*, in the *Manning Formula*.

For areas of 100 acres or more, longer inlet times may be used as appropriate. If the impacted area of the future development was greater than 100 acres, then storm runoff can be determined by using the NRCS (formerly SCS) *Curve Number Method*.

Figure 5-2 shows the NOAA Hyetograph from "*Selection of DC Water Design Storm District of Columbia*" Memorandum for the 15 year, 24 hour storm.

5.3.1.2 Hydraulic Capacity

Design the grade of the pipe to meet the following requirements:

- Velocity between three (3) and 15 feet per second at peak flow.
- HGL at peak flow equal to or less than the pipe diameter.
- Manning's formula with an "n" value not less than 0.013.
- Minimum pipe diameter of ten (10) inches for any public gravity storm sewer.

If the above requirements do not allow for drainage into an existing downstream sewer, then additional storm sewer must be designed and installed until the sewer can catch grade. For steep grades which result in velocities greater than 15 feet per second, drop manholes and other means of controlling the flow shall be considered.

Other evaluation requirements are stated in sections 5.3.2 Sewer Quantity Management, 5.3.4 Hydraulic Evaluation of Existing Combined Sewers, and 5.3.5 Hydraulic Evaluation of Existing Sewer System.

5.3.2 Sewer Quantity Management

Contributions from new development or redevelopment shall not exceed the capacity of the existing sewer regardless of whether the property was previously sewered. If the available capacity in public sanitary or storm sewer is not adequate to convey all generated flows from development, design the final outlet flow rate from the property to be less than available capacity in the sanitary or storm sewer pipe.

5.3.3 Hydraulic Evaluation of New Combined Sewers

Construction of new combined sewers is prohibited except as required by the Long-Term Control Plan (DC Clean Rivers).

5.3.4 Hydraulic Evaluation of Existing Combined Sewers

Design flows for combined sewers shall be based on flow metering and DC Water's hydraulic model results. When using DC Water's hydraulic model to evaluate design flows that include conveying existing flows from existing upstream combined sewers, flow metering data shall be obtained to validate estimated design flows and calibrate the hydraulic model.

Stormwater flows for combined sewers shall be based on the 15 year, 24 hour frequency storm.

5.3.5 Hydraulic Evaluation of Existing Sewer System

Hydraulic evaluations for the existing sewer system to determine 1) sufficient capacity, 2) downstream hydraulic impacts, and 3) other hydraulic needs will be conducted by DC Water. The PDE shall develop and provide computations to evaluate the impact of added flow to downstream sewers. Projects increasing flow into the sewer system shall mitigate increased potential for overflows farther downstream. Determine the length of downstream sewer pipeline from a new connection point and the number of downstream manholes that may be subject to potential overflows in the hydraulic evaluation.

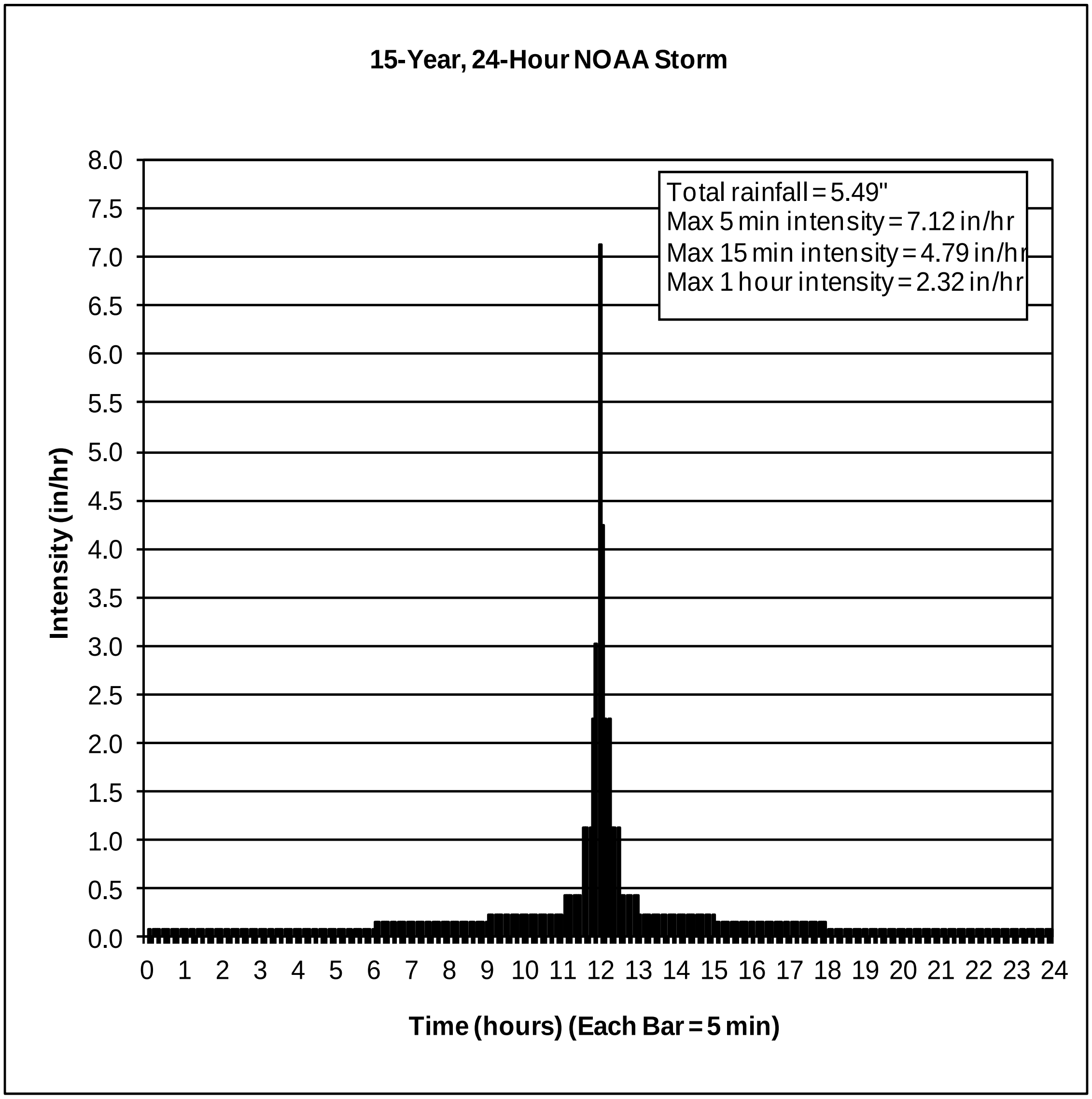

Figure 5-2: NOAA Hyetograph

5.3.6 Changes in Pipe Size and Slope Alignment

Changes in sewer pipe size and grade are only permitted at manholes or structures. At manholes with multiple incoming pipes, the incoming inverts of sewers shall be such that the hydraulic grade lines of the sewers at the junction are at the same elevation, except that the minimum drop across the manhole shall be not less than 0.2 feet. Perform calculations to determine the required drop across the manhole.

5.3.7 Protection for High Velocities

Design velocities are as follows:

- Preferred max velocity = Six (6 fps).
- Permissible max velocity = 15 fps.

Drop manholes may be provided to break steep slopes to limit the velocities in the connecting sewer pipes.

Under special circumstances, DC Water may approve velocities greater than 15 fps. If approved, evaluate pipe material and thicknesses for the impact from abrasion and erosion.

5.4 ANCHORING PIPE ON STEEP SLOPES

See Section 4.5 for requirements.

5.5 ODOR CONTROL

Evaluate the need to design and install odor control measures on sanitary and combined sewer systems.

5.6 NEW AND REPLACED SANITARY AND COMBINED SEWER CONSTRUCTION

5.6.1 Alignment and Separation from Other Utilities

5.6.1.1 General

Refer to Section 4.3.1 for general requirements and considerations to be followed when determining the location of pipelines.

5.6.1.2 Sewer Horizontal Alignment

Design sewers using the following horizontal alignment requirements:

- Sewers shall have straight horizontal alignments between manholes.
- Locate new sewers within the street right-of-way, not in sidewalks, and in accordance with Figure 4-1 and Figure 4-2.
    - If the street right-of-way is 90 feet wide or less, only one (1) sanitary sewer is required and shall be located as shown in Figure 4-1.
    - If the street right-of-way is greater than 90 feet wide, dual sanitary sewers shall be located as shown in Figure 4-2.
    - If the space shown in either Figure 4-1 or Figure 4-2 is already occupied by another utility, consider alternative alignments which meet the following conditions:
        - The maximum sewer service length is 50 feet.
        - A minimum horizontal separation of ten (10) feet between water mains and sewers.
- The minimum horizontal clearance between a sewer line and other utilities shall be four (4) feet. Where four (4) feet separation is not available, the separation distance may be reduced to three (3) feet or as required to permit excavation of the pipes without causing interference to the adjacent pipe using the minimum trench excavation widths shown in DC Water's Standard Details, whichever is greater. Additionally, the design shall require the trench backfill to be CLSM to a depth of one (1) foot above the pipe and, if shoring/piling is used, the shoring/piling shall be required to remain in place to an elevation not less than the top of the pipe but below the finished grade at a distance that will not obstruct final backfill and compaction requirements for pavement and other finished surfaces.
- If the proposed sewer can only be located outside of paved areas, the sewer alignment shall:
    - Minimize disruption of environmental features such as wetlands, steep slopes, trees, etc.
    - Maintain a minimum distance of five (5) feet from walls or other similar obstructions.
- Consider geotechnical conditions, including the existence of rock, groundwater elevation, and poor soils that would require special backfill, bedding, or foundation support when selecting sewer alignments in unpaved areas.
- Cross-lot sewers (sewers that cross from one private property to another) and cross lot service laterals are prohibited.
- New sewer construction outside paved areas shall be approved by DC Water in writing during design.

5.6.1.3 Sewer Vertical Cover

Typically, the flow channel invert elevation of sanitary sewers shall be at least 10.5 feet below grade to allow for service laterals from house basements to drain by gravity. The cover above sewers may be reduced to a minimum of four (4) feet when justified in isolated instances at the upper reaches of the system, and where the pipe is located in grassy areas. See Figure 4-2 for vertical cover requirements of sewers.

5.6.1.4 Separation from Other Utilities

Sewer lines shall be separated from other utilities as follows:

- See Section 4.3.4 for separation requirements between sewer and water lines.
- Vertical separation from other utilities shall be as shown in Figure 4-1.
- Sewer lines shall not pass within 50 feet of a potable water supply source or structure such as a potable water reservoir unless special construction and/or pipe materials are used to obtain adequate protection.
- The minimum vertical clearance between sewers and other utilities shall be 18 inches (outside of pipe to outside of pipe) unless otherwise approved by DC Water.
- DIP sanitary sewer lines crossing gas transmission lines shall be designed in accordance with Section 8.

5.6.2 Force Mains and Valves

Pressurized service laterals are not permitted to be directly connected to gravity sewers. Pumped sanitary or storm discharge shall transition to gravity flow upstream of the property line and prior to entering DC Water infrastructure.

Force mains and valves shall be designed according to the *Recommended Standards for Wastewater Facilities* by the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers.

5.6.2.1 Velocity and Pipe Size

Force mains shall be designed to the following requirements:

- A minimum velocity three (3) feet per second.
- A maximum velocity of eight (8) feet per second.
- A minimum diameter of four (4) inches.

5.6.2.2 Air Vacuum and Air Relief Valve

Design for sewage air vacuum and air relief valves shall be the same as for water air vacuum and air relief valves except for that that valve shall be designed for use on sewage systems and the following:

- Sewage valve systems shall be designed to ensure there is no discharge to the environment.
- Odor control shall be evaluated where necessary and as directed by DC Water to contain odors.
- If odor control is required, the valve system shall include a filter system.

5.6.2.3 Termination

The force main shall enter the receiving manhole with a smooth transition of flow to the gravity sewer system at a point not more than one (1) foot above the flow line. The design of the transition manhole shall include energy dissipation, erosion, drop considerations, and corrosion protection.

5.6.2.4 Pipe and Design Pressure

Pipe and joints shall be equal to water main strength materials suitable for design conditions. The force main, reaction blocking, and station piping shall be designed to withstand water hammer pressures and associated cyclic reversal of stresses that are expected with the cycling of wastewater lift stations. Evaluate the use of surge valves, surge tanks, or other suitable surge devices to protect the force main against severe pressure changes.

5.6.2.5 Special Construction

Force main construction near streams or water structures and at water main crossings shall meet the applicable provisions of Section 10 titled, "Water Body Crossings".

5.6.2.6 Friction Losses

Friction losses through force mains shall be based on the *Hazen-Williams formula*. The design value for "C" shall be 100 for unlined iron or steel pipe. For other smooth pipe materials such as PVC, polyethylene, lined ductile iron, etc., a higher "C" value, not to exceed 120, may be used for design.

When initially installed, force mains will have a significantly higher "C" factor. To prevent damage to pump motors, the effect of the higher "C" factor should be considered when calculating maximum power requirements and duty cycle time. The effects of higher discharge rates on selected pumps and downstream facilities should also be considered.

5.6.2.7 Identification

Design shall require the Contractor to identify force mains as sewage to prevent them from being mistaken for potable water mains. Pipe color, locating tape, and other means may be used to achieve this.

5.6.2.8 Maintenance Considerations

Isolation valves should be considered where force mains connect into a common force main. Cleanouts at low points and chambers for pig launching and catching should be considered for any force main to facilitate maintenance.

5.6.3 Sewer Pipe Materials

5.6.3.1 General

Existing sewers within the District are typically constructed of VCP and concrete/brick pipe in circular, egg, horseshoe, and semi-elliptical shapes.

Prior to specifying pipe material, assess the soils for contamination. Should the assessment reveal hydrocarbon contamination (even trace amounts) or other contaminates detrimental to rubber, determine and specify gasket material appropriate for the contamination. Nitrile gaskets shall be specified when locating sewer pipes in areas of soils contaminated with hydrocarbons.

Replacement pipe used to repair pipe between manholes shall be the same as the existing unless otherwise approved by DC Water. When approved by DC Water the design shall include the use of suitable couplings to join dissimilar materials.

The pipe material and classification shall be shown on the project plans and/or specifications. Table 5-3 shows materials allowable under certain circumstances; refer to the relevant sections below for further requirements and limitations on use of each material. Additional materials may be considered on a case by case basis with DC Water approval. For corrosive soil conditions see the Section entitled Corrosion Control.

Table 5-3: Typical Sewer Pipe Materials

Use	Diameter	PVC	RCP	VCP	DIP	FRP/GRP
Sanitary Sewer (gravity)	36” and less	X		X	X	
	>36”	X				X
Sanitary Sewer (force main)	36” and less	X			X	
	>36”	X				X
Storm Sewer	All	X	X			X
Combined Sewer (CSO)	All	X		X		X

Note: Some materials listed in this table have limitations on their accepted use described throughout this document. This table does not mean the material may be used under all scenarios. Sewer rehabilitation often requires alternative materials; this list does not limit rehabilitation methods with their relevant materials.

5.6.3.2 Sewer Pipe Design

All sewers shall be designed to prevent damage from live, dead, and frost induced loads. Proper allowance for loads on the sewer shall be made because of soil and potential groundwater conditions, as well as the width and depth of the trench. Where necessary, special bedding, haunching and initial backfill, concrete cradle, or other special construction shall be used to withstand anticipated potential superimposed loading or loss of trench wall stability.

Design shall follow practices and guidelines given in *Gravity Sanitary Sewer Design and Construction, ASCE Manual, Engineering Practice No. 60 or WEF Manual of Practice No. FD-5* and other manuals specified herein. Design loads and conditions shall be as follows and as specified elsewhere herein.

- Dead load – Soil conditions from the trench conditions.
- Live load – either E80 for railroads or HS-20 for all others.
- Trench width per DC Water's standard detail.

Joints shall be designed to minimize infiltration and to inhibit the entrance of roots throughout the life of the system.

Sewers within flood zones shall include buoyancy force calculations which incorporate the base flood elevation. Pipe to be installed below ground water shall be designed for buoyancy forces assuming ground water level is at the ground surface.

5.6.3.3 Polyvinyl Chloride Pipe

All buried sewers up to 36 inches in diameter shall be PVC unless otherwise approved by DC Water. For sewers greater than 36, perform an evaluation to determine if PVC is the most appropriate material.

If soils or sewage have or may have high levels of hydrocarbons, evaluate the need to substitute another material for PVC.

Perform design of PVC pipe in accordance with AWWA M23 PVC Pipe – *"Design and Installation"*. Design the pipe for the loading, soil, and ground water conditions that will be present and applied to the pipe. Minimum wall thickness shall be ASTM D3034 SDR 35 for pipe with diameter less than or equal to 15 inches. For pipe 18 inches in diameter and greater the minimum wall thickness shall be ASTM F679 with pipe stiffness 46.

5.6.3.4 Vitrified Clay Pipe

VCP may be used to replace pipe in kind (to maintain the same pipe material between sewer manholes) or as approved by DC Water on a case-by-case basis. VCP shall be designed per the "*Vitrified Clay Pipe Engineering Manual"* published by the National Clay Pipe Institute.

5.6.3.5 Reinforced Concrete Pipe

RCP shall only be used in separate storm drains and shall be designed per ASTM C76, *"Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe"*. The required RCP class shall be calculated based on the procedures in the "*Concrete Pipe Design Manual"* by the American Concrete Pipe Association and the following design criteria:

- DC Water standard sewer pipe bedding (Class B) with load factor of 1.9.
- Soil backfill material, saturated top soil with maximum *Ku'* equal to 0.150.
- Minimum pipe wall per ASTM C76 - Wall B.

Notwithstanding the design criteria above, RCP shall be Class III minimum; Classes I and II are not permitted.

5.6.3.6 Ductile Iron Pipe

DIP shall only be used on sewers when a distribution main does not meet the minimum horizontal or vertical separation. DIP shall be designed in accordance with Ductile Iron Pipe Research Association (DIPRA) recommendations. When DIP is used in a sewer, coatings shall be per DC Water Standard Specifications and lining shall be ceramic epoxy.

5.6.3.7 Fiber Reinforced Pipe / Glass Reinforced Pipe

Fiber Reinforced Pipe (FRP) and Glass Reinforced Pipe (GRP) may only be used on a case-by-case basis as approved by DC Water for a specific project.

5.6.3.8 Other Materials

High Density Polyethylene (HDPE) and Polypropylene (PP) may only be used on a case-by-case basis as approved by DC Water for a specific project.

5.6.4 Open Cut Installation

5.6.4.1 Pipe Replacement Considerations

Manhole to manhole sewer pipe replacement is required when:

- Multiple point repairs are less than 60 feet apart.
- The length of the open cut replacement is greater than 40% of the pipe length between manholes.
- There are multiple offset joints greater than one (1) inch or if sealing rings protrude more than one (1) inch.
- Sags are greater than 60 percent of the pipe diameter.
- Heavy roots through pipe joints cannot be removed by interior cutting or where heavy roots have compromised the structural integrity of the pipe.
- There are structural deformations, restrictions of flow, settlement, or collapses.
- The pipe has holes where visible voids (i.e., soil missing outside of the hole) exist, or
- Sinkholes are above or within proximity of the pipe.

Where sewers are replaced, service laterals shall also be replaced up to the property line. The design shall include a regular DC Water Standard cleanout to be installed adjacent to the property line if the size of lateral is six (6) inches or smaller. If the lateral is greater than six (6) inches in diameter the design shall include a manhole installed near the property line.

5.6.4.2 High Water Table Conditions

Groundwater barriers (also known as clay dams or trench plugs) shall be designed in adequate numbers to prevent groundwater migration along sewer trenches when there exists a possibility that groundwater may be diverted and follow the path of the new sewer.

5.6.5 Trenchless Construction

The following trenchless methods are acceptable.

5.6.5.1 Directional Drilling

High density polyethylene (HDPE) or fusible PVC pipe may be considered. Soil borings shall be offset from the pipe centerline to prevent creating potential blowout points for drilling mud. Environmental impacts for this construction method, including the location of entry and exit points, depth of cover, and disposal of drilling mud and spoils shall be assessed. Sufficient area shall be provided for both the drill rig and the pull-back pipe.

5.6.5.2 Jack and Bore

Carrier pipes for sewers shall meet all design requirements for gravity sewers assuming the steel casing is not present. See Section 4.10.2 for additional requirements.

5.6.5.3 Pipe Bursting

Pipe bursting for sewers may only be implemented by exception and only when extenuating circumstances limit open cut pipe replacement as a viable alternative. Pipe bursting shall not be considered when the sewer has four (4) or more laterals within 200 feet. Pipe bursting shall not be used when the existing pipe has sags greater than 20% or has sags that continue in length for more than eight (8) feet. Pipe bursting shall not be implemented under railroads, buildings, or structures.

Extensive subsurface explorations shall be performed and soil borings shall be obtained at proposed insertion and access pit locations to confirm the feasibility of pipe bursting. Standard penetration tests, unconfined compression tests, moisture content tests, and groundwater readings after drilling and again no sooner than 24 hours after drilling shall be performed. All nearby utilities shall be located to ASCE Level

A per ASCE 38-02. A minimum three (3) foot clearance is required between the pipe to be burst and any gas or water mains (outside of pipe to outside of pipe).

Pipe bursting replacement pipe shall be HDPE or fusible polyvinyl chloride (FPVC). Pipe joints shall be fused and cooled prior to bursting. VCP or DIP may only be used for pipe bursting when insufficient laydown area is available.

Generally, the long-term loading conditions govern the required wall thickness for gravity lines, although consideration for the pull (tensile) strength is necessary. A ten percent (10%) wall thickness allowance shall be added to serve as a sacrificial layer to account for scarring and gouging during installation.

The minimum cover for new pipe shall be:

- Ten (10) times the burst displacement.
- Three (3) times the new pipe diameter.
- Four (4) feet below the ground surface.
- Three (3) feet clear from the nearest utility.

Adequate space shall be provided for insertion and reception pits. The space required may vary in size and shape depending on the depth, diameter, and stiffness of the pipe and soil conditions.

5.6.6 New Manholes

5.6.6.1 General

All manholes shall have a unique alphanumeric identifier on the project plans. DC Water shall provide manhole numbers to use. All manholes deeper than 20 feet shall be designed for the specific depth, standard details are not applicable.

New manholes shall typically be constructed of pre-cast reinforced concrete manufactured in accordance with ASTM C478, *"Standard Specification for Circular Precast Reinforced Concrete Manhole Sections"* or poured-in-place concrete.

Castings shall meet the requirements of ASTM A48, *"Standard Specification for Gray Iron Castings, Class 30"*.

The top elevation of the manhole shall be one (1) foot above the surrounding grade when the top of the manhole is not within a pavement or developed lawn area.

Manholes shall be vented every 1,000 feet or every other manhole, whichever is greater. Ventilation may be provided via sanitary stacks and/or perforated manhole covers.

5.6.6.2 Manhole Locations and Maximum Spacing

Provide sewer manholes at all sewer intersections; at all points of changes in sewer size, horizontal alignment, or slope; and at the terminal end of the line.

The maximum spacing between sewer manholes shall be:

- 300 feet for sewers less than 24 inches in diameter.
- 400 feet for sewers 24 inches and larger, but less than 48 inches in diameter.
- 500 feet for sewers 48 inches and larger.

Variances for larger spacing may be considered in instances where there is adequate access for cleaning and maintaining the sewer system.

Manholes shall not be located in ornamental areas, tree pits, sidewalks or gutter pans, where feasible. Consider maintenance access when determining location of manholes.

5.6.6.3 Manhole Drop Connections

Manholes shall have external drop connections at sewer junctions where the invert of the inlet sewer is more than 2.5 feet higher than the invert of the outlet sewer. Where the difference is less than 2.5 feet, the base of the manhole shall be filleted to prevent solids deposition.

Encase external drop connections in concrete. The encased drop connection shall be structurally tied to the manhole base with either a monolithically poured connection or with steel reinforcement ties.

Where an external drop connection is not possible, with DC Water approval, an internal drop connection may be considered. Secure the internal drop connection to the interior wall of the manhole and provide an access for cleaning. Inside drop connections shall have a plate at the top of the riser pipe to prevent splashing.

5.6.6.4 Manhole Diameter

Manholes for sewers up to 18 inches in diameter shall have a minimum four (4) foot inside diameter.

Manholes for sewers larger than 18 inches shall be sized such that the bench on each side of the channel is at least 15 inches wide.

The minimum diameter for manholes with internal drop connections shall be five (5) feet.

The minimum clearance between pipe openings within the manhole shall be 3.5 inches plus the outside diameter of the outlet pipe or nine (9) inches, whichever is greater. If clearance is a problem, details showing the sewer offset at the manhole shall be provided and/or the manhole size shall be increased.

Show the inside diameter of manholes on the project plans.

5.6.6.5 Pipe to Manhole Connections

In general, design manhole barrel risers such that the pipe connections do not intersect manhole barrel riser joints.

Include pipe to manhole connection details in the project plans for pipes with slopes ten percent (10%) or greater. Require connections between pipe and manholes to be sealed.

5.6.6.6 Manhole Watertightness

The joint design for concrete manholes shall meet the requirements of ASTM C443, *"Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets"*.

Seal manhole lift holes and grade adjustment rings with non-shrinking mortar.

Join inlet and outlet pipes to the manhole with gasketed flexible watertight connections or any watertight connection arrangement that allows for differential settlement of the pipe and manhole wall to take place.

Design manholes for protection from flooding if located in a flood zone according to FEMA:

- Being two (2) feet above the Base Flood Elevation.
- Being watertight and vented two (2) feet above the Base Flood Elevation.

Specify watertight manhole covers wherever the manhole tops may be flooded by street runoff or high water. Additionally, watertight manhole covers are required at locations where it is necessary to guard against sanitary surcharge conditions.

5.6.6.7 Protection against Manhole Settlement

Evaluate the soil conditions and design bedding as to prevent settlement.

5.6.6.8 Manhole Buoyancy Protection

Design manholes for anti-flotation, particularly where high groundwater conditions are anticipated. The buoyancy calculations shall assume:

- A minimum factor of safety against flotation of 1.2.
- The groundwater table is at grade.
- Resisting upward forces are countered only by the weight of the empty manhole plus the weight of overbearing soil. The weight of the manhole shall exclude the bench. *[Note: This requirement is to protect the manhole after installation but before acceptance]*.
- The backfill to grade is in place.
- No resisting forces from the weight of the live load cap, or soil friction (i.e., there shall be no credit for a soil wedge or for soil resistance).

The design of extended manholes bases shall include consideration of the manhole manufacturer's recommendations. Any radial steel reinforcement bars drilled into the base of the manhole shall be designed to resist the net upward shear force. The clearance between the manhole base and the trench wall shall be at least two (2) feet to provide sufficient room for compaction equipment.

5.6.6.9 Manhole Corrosion Protection

Specify corrosion protection via special coatings for the interior of the manholes where corrosive conditions are observed or anticipated. See Section 7 for other corrosion protection information.

When sewer force mains are tied into manholes, protect the downstream manholes within 1,000 feet or the first three (3) manholes downstream (whichever is the greater number of manholes) of the discharge and the first manhole upstream of the discharge from corrosion by the application of an epoxy lining system. Show manholes to be lined on the project plans.

5.6.6.10Protection for Manholes with High Flow Velocities

Protect manholes against displacement by erosion and impact where high flow velocities are anticipated.

5.6.6.11Manhole Steps, Ladders, Safety Rails, and Fall Arrest Systems

Manholes less than 20 feet deep shall have steps.

Manholes greater than 20 feet deep shall have aluminum ladders, safety rails, and fall arrest systems.

Manholes less than 20 feet deep shall follow DC Water standard details. Design manholes greater than 20 feet deep in accordance with OSHA requirements.

5.6.6.12Manhole Flow Channels

Design sanitary and combined sewer manholes with flow channels. Flow channels that are straight through a manhole shall be smooth and made to conform as closely as possible in shape and slope to that of the connecting sewers. Flow channels that are curved for branch inlets shall be smooth and have increased slopes to maintain acceptable velocities. Flow channel walls shall be formed or shaped to three quarters (¾) of the height of the crown of the outlet sewer.

5.6.6.13Conditions for Manhole Replacement

Manholes shall be replaced under the following conditions:

- Manhole has structural failure or in general very poor condition.
- Manhole is less than four (4) feet in diameter.
- Manhole has severe infiltration.
- Manhole has previously been rehabilitated and the rehabilitation has failed.
- Manhole has a connecting pipe requiring replacement unless a suitable and proper boot connection can be made between the manhole and pipe.

5.6.7 Sewer Laterals

The design and construction of sewer laterals is governed by the *DC Plumbing Code*, and its respective supplement. New sewer laterals are installed by the developer or owner of the property and are owned by the property Owner. However, in accordance with D.C. Law 1-98, *Water and Sewer Repair and Compensation Act of 1976*, DC Water is responsible for the maintenance and replacement, if necessary, of the sewer lateral within in public space, up to the property line.

New sewer laterals shall not be combined (i.e., the plumbing carries both house sewage and storm water). Combined sewer laterals are no longer permitted by the plumbing code. New construction requires separate sanitary and storm laterals which may be combined at the property line with DC Water approval. Some locations within the District have existing combined plumbing on private properties. However, the separation of sewer laterals is not required unless a major renovation of the building is done.

Sewer laterals for single family homes shall have a minimum diameter of four (4) inches. Sewer laterals for multi-family, commercial, and industrial buildings shall have a minimum diameter of six (6) inches. Each property shall have its own independent sewer lateral.

Typically, existing sewer laterals within the District are cast-iron, PVC, VCP, or asbestos cement pipe (ACP). New sewer laterals that are located within dedicated rights-of-way and easements shall be constructed of PVC pipe per DC Water standard specifications and details.

Sewer laterals shall be designed as follows:

- Have a minimum two percent (2%) slope.
- Make changes in alignment or grade at manholes, not cleanouts.
- Have a clean-out with a brass cap adjacent to the property line.
  - Do not locate cleanouts in a sidewalk, driveway, or entrance.
  - Cleanouts on eight (8) inch or larger service laterals are prohibited and a manhole shall be installed instead of a cleanout.
- Connect to the sewer system at a manhole if the sewer lateral has a grease interceptor, oil/water separator, or other pretreatment device.
- Provide protection against backwater in accordance with the Chapter 7 of the International Plumbing Code. Locate backwater protection systems and devices inside the property lines. Owner of the property is responsible for maintaining the system.

In the case of deep sewers, riser pipes from the sewer shall be installed at a minimum 45-degree angle. Settlement joints shall be provided where the riser pipe connects to the sewer.

The method that service laterals are connected to the existing public sewer in the street depends on the size and material of the public sewer and the size of the service lateral, as shown on the Table 5-4.

For new sewer laterals, a sanitary sewer lateral table shall be included in the project plans. The sanitary sewer lateral table shall include:

- Invert of the lateral at the main.
- Size, length, and slope of the laterals.
- Elevation of the manhole cover of the next upstream manhole in the public sewer.
- Elevation of the lowest finished floor in the building.
- Elevation of the lowest plumbing fixture in the building.

Table 5-4: Service Lateral Connection To Existing Sewer

PVC and VCP Sewers				Brick, Concrete, and RCP Sewers		
Public Sewer Diameter	**Lateral Diameter**	**Connection Method**		**Public Sewer Diameter**	**Lateral Diameter**	**Connection Method**
8”	4”-6”	Y branch		15”	4”-6”	Thimble
	8”	Manhole			8”-15”	Manhole
10”	4”-6”	Y branch		18”	4”-6”	Thimble
	8”-10”	Manhole			8”-18”	Manhole
12”	4”-6”	Y branch		21”	4”-8”	Thimble
	8”-12”	Manhole			10”-21”	Manhole
15”	4”-8”	Y branch		24”	4”-8”	Thimble
	10”-15”	Manhole			10”-24”	Manhole
18”	4”-10”	Y branch		27”	4”-10”	Thimble
	12”-18”	Manhole			12”-27”	Manhole
21”	4”-10”	Y branch		30”	4”-12”	Thimble
	12”-18”	Manhole			15”-30”	Manhole
24”	4”-12”	Y branch		33”	4”-12”	Thimble
	15”-18”	Manhole			15”-33”	Manhole
27”	Case by case basis			36”	4”-12”	Thimble
					15”-36”	Manhole
				Over 36”	Case by case basis	

Note: Thimbles shall be ductile iron and enter above the springline.

For sewer replacement design, determine the location and size of all sewer laterals affected by the sewer replacement. At a minimum, the design shall show on the plans:

- The type and description of work to be performed.
- How the existing service lateral is to be replaced or reconnected at the sewer service.
- The number of laterals to be reconnected.
- The property address, lot, and square numbers.

5.6.8 Inverted Siphons

Inverted siphons (also known as depressed sewers) shall be avoided and only used when crossing an obstacle such as a river or pedestrian tunnel, and when lowering the downstream sewer system is impractical. The use of siphons requires approval by DC Water.

Siphons shall be designed as follows:

- Have at least two (2) barrels with a minimum pipe size of six (6) inches in diameter.
- The inlet and outlet pipes shall be designed so that normal flow can be diverted to either barrel while the other barrel is taken out of service for cleaning.
- Ensure sufficient head for selected pipe size to secure velocities of at least three (3) feet per second for average flows.
- Have necessary appurtenances for convenient flushing and maintenance and adequate clearance for rodding.
- Siphon barrels shall be installed in a casing and the annular space filled with CLSM.
- Pressure pipe shall be specified at the required pipe strength for the anticipated internal pressures resulting from excessive surcharging.
- Siphon pipes and chambers shall have sufficient weight or anchorage to prevent their flotation when subject to hydrostatic uplift forces.
- For designing inlet and outlet chambers, refer to Wastewater Engineering*: "Collection*, *Treatment Disposal*" by Metcalf and Eddy, Inc. and Water Pollution Control Federation (WPCF) Manual No. 9, "*Design and Construction of Sanitary and Storm Sewers"*.
- Siphon chambers shall be located away from the stream and stream banks to prevent the possibility of damage from floating fallen trees or other debris washed up during storm events.
- An air jumper pipe between barrels shall be included in the design to avoid the accumulation of odorous, hazardous, and corrosive gases such as hydrogen sulfide in the siphon.

5.7 NEW AND REPLACED SEPARATE STORM SEWER CONSTRUCTION

All new or replaced storm sewers shall be designed in accordance with this standard, as well as the Department of Energy and Environment's "*Stormwater Management Rule and Guidebook"* and the District of Columbia Department of Transportation's "*Standard Specifications for Highways and Structures"*. When these standards differ from state and/or federal requirements, the more stringent requirement shall apply.

5.7.1 Alignment, Profile, and Separation from Other Utilities

General requirement and considerations to be followed when determining the location of pipelines are found in Section 4.3.1.

Design the storm sewers to have sufficient cover to allow basin connections to drain by gravity. See Sections 5.2 and 5.3 for additional hydraulic requirements.

The minimum horizontal clearance between a storm sewer and water lines shall be four (4) feet. Where four (4) feet separation is not available, the separation distance may be reduced to three (3) feet or as required to permit excavation of the pipes without causing interference to the adjacent pipe using the minimum trench excavation widths shown in DC Water's Standard Details, whichever is greater.

Additionally, the design shall require the trench backfill to be CLSM to a depth of one (1) foot above the pipe and, if shoring/piling is used, the shoring/piling shall be required to remain in place to an elevation not less than the top of the pipe but below the finished grade at a distance that will not obstruct final backfill and compaction requirements for pavement and other finished surfaces.

Alignment, depth of bury, and separation distances are shown on Figure 4-1 and Figure 4-2 and separation requirements from the water lines are included in Section 4.3.4

5.7.2 Pipe Materials

For applicable pipe materials, see Section 5.6.3.

5.7.3 Open Cut Installation

Storm pipe open cut replacement shall follow the requirements in Section 5.6.4.

5.7.4 Trenchless Construction

Storm pipe trenchless construction shall follow the requirements in Section 5.6.5.

5.7.5 New Structures

Reserved for future use.

5.7.6 Catch Basins

Design of catch basins shall be in accordance with DC Water's Standard Specifications and Details.

Pursuant to D.C. Official Code §8-202(b), DC Water is only authorized to maintain the public sewer system, including appurtenances such as catch basins, from the public sewer to the property line of each lot, i.e. "public space." D.C. Official Code defines "public space" as all the "publicly owned property between lines on a street. As such property lines are shown on the records of the Surveyor of the District of Columbia, and include any roadway, tree space, sidewalk, or parking between such property lines." Also, pursuant to Section 4.3.7 of the DC MS4 Permit, the Government of the District of Columbia is responsible for implementing the operation and maintenance program at all municipal facilities located in the DC MS4 Permit Area. In this regard, stormwater catch basins located on a District facility property are the responsibility of that facility agency. Although DC Water cleans and maintains catch basins located in public space throughout the District including high capacity thoroughfares, DC Water does not clean and maintain those catch basins with granite top slabs, and those owned and maintained by NPS.

5.7.7 Outlet Structures

Outlet structures shall be designed and approved on a case-by-case basis.

5.7.8 Inverted Siphons

Siphons for storm water are prohibited.

5.8 SEWER REHABILITATION

5.8.1 General

Sewer rehabilitation design shall be based on an appropriate sewer inspection and condition assessment. Sewer rehabilitation methods shall be determined on a case-by-case basis. Perform a cost benefit and constructability analysis during conceptual design to recommend rehabilitation methods. The following are acceptable methods to be considered in design.

- Injection Grouting.
- Pipe Point Repairs.

- Cured-In-Place Pipe.
- Pipe Sliplining.
- Spiral Wound Pipe Lining.
- Spin Cast/Spray/Trowel Applied Lining.
- Manhole Rehabilitation and Replacement.
- Service Lateral Rehabilitation and Replacement.
- Bypass Pumping.

Inspect the pipe to be rehabilitated using CCTV or other approved inspection methods to determine the pipe's condition and evaluate the appropriate methods of rehabilitation. Make note of obstructions, protruding sewer laterals, crushed pipe walls, offset joints, and lateral connections to aide in selecting the appropriate rehabilitation method.

References to pipe conditions, such as JOM, JOL, etc. are in accordance with the definitions established by NASSCO for PACP.

The design shall include requirements for by-pass pumping when appropriate.

5.8.2 Injection Grouting

5.8.2.1 Implementation Guidelines

Consider using injection grouting to fill void spaces outside the pipe or structures and at lateral to mainline connections.

5.8.3 Pipe Point Repairs

5.8.3.1 Implementation Guidelines

Consider requiring point repairs for:

- Localized structural deformations.
- Restrictions of flow.
- Settlement.
- Collapses.
- Localized offsets greater than one (1) inch.
- Sealing rings protrude more than one (1) inch.

Require all necessary point repairs to be completed prior to lining pipe or performing pipe burst installation. Because point repairs may be subject to future settlement and infiltration migration (i.e., migration to an adjacent defect), the use careful engineering judgment when recommending point repairs.

5.8.4 Cured-in-Place Pipe

Consider rehabilitating pipe using CIPP when:

- There is only light infiltration (seepage) into the pipe. CIPP shall not be used if major infiltration/inflow is observed in the pipe until after infiltration/inflow is stopped.
- The offset pipe joints is a joint offset medium (JOM); joint offset large (JOL) shall not receive CIPP.
- Existing pipe has cracks, fractures, and minimal structural deformation.
- Light to medium roots can be removed by interior cutting.
- Debris can be removed from the pipe.
- Sags in the pipe are less than 30% of the pipe diameter. Sags greater than 30% shall be repaired prior to lining.

- Existing point repairs allow for safe insertion of the liner without causing significant deformations in the new liner.
- All protruding service laterals have been properly repaired prior to CIPP installation.
- The host pipe has severely exposed surface aggregate.

When holes are large enough that a CIPP liner will deform into the void, a restraining system or filling the void with soil stabilizing grout may be necessary.

5.8.5 Pipe Sliplining

5.8.5.1 Implementation Guidelines

Consider rehabilitating pipe using sliplining when:

- Pipe sizes are greater than or equal to 24 inches in diameter.
- Special situations exist and with DC Water approval.
- Sliplining will not cause a capacity reduction in the sewer, unless specifically approved by DC Water.

5.8.5.2 Design Considerations

Design of sliplining shall require the following:

- The liner pipe material shall be HDPE or DC Water approved equal.
- The inside diameter of the host pipe shall be at least ten percent (10%) larger than the outside diameter of the liner pipe.
- For storm sewers, the sliplined pipe shall have sufficient capacity to convey projected flows during a 15 year frequency 24 hour design storm event. Include a comparison of pre- and post-construction line capacities with the pipe design submittal.
- Liner wall thickness design shall account for all loads independent of existing pipe.
- A factor of safety of two (2) for situations where it can be reasonably assumed that the host pipe will provide significant structural support for the liner.
- A factor of safety greater than two (2) if it is not reasonable to assume that the host pipe will structurally support the liner.
- Design of the access pits shall include:
- Adequate space to install the liner based on depth, diameter, and stiffness of the liner pipe and soil conditions.
- Space allotted for insertion holes shall be based on.
- An entry slope down to the springline of the host pipe with a grade of 2.5-feet horizontal to one (1) foot vertical.
- A minimum length of level excavation equivalent to 12 times the diameter of the liner pipe.
- A minimum width that reflects the soil type, height of the water table, and diameter of the pipe.
- Adequate space shall be provided to excavate, expose, and reconnect service laterals.

5.8.6 Spiral Wound Pipe Lining

5.8.6.1 Implementation Guidelines

Consider rehabilitating pipe using spiral wound pipe lining when:

- Offset pipe joints are generally one (1) inch or less.
- The host pipe has severely exposed surface aggregate.
- Light to medium roots are removed by interior cutting.
- Debris can be removed from the pipe.

- Sags in the pipe are less than 30% of the pipe diameter. Sags greater than 30% shall be repaired prior to lining.
- All protruding service laterals have been properly repaired prior to installation.

5.8.7 Spin Cast/Spray/Trowel Applied Lining

5.8.7.1 Implementation Guidelines

Spin cast, spray, or trowel applied lining materials may be used on a case-by-case basis and as specified or directed by DC Water. Lining materials such as shotcrete, geopolymer, and cementitious materials may all be considered for sewer rehabilitation. Specific design parameters, criteria, and requirements shall be determined on a case-by-case basis according to the site and asset conditions.

5.8.8 Manhole Rehabilitation and Replacement

5.8.8.1 General

Manhole rehabilitation design shall be consistent with guidance found in ASCE - Manual of Practice 92, *"Manhole Inspection and Rehabilitation"*. Typically, rehabilitation projects include:

- Cover replacements.
- Grade adjustments.
- Frame and chimney repair.
- Grouting.
- Bench and flow channel restoration.
- Protective or structural coating and lining.

Determine the level of manhole rehabilitation condition rating based on the MACP Level 2 Inspection and Assessment Report. Consider the following when selecting rehabilitation methods:

- Existing structural deterioration and failure risk.
- Inflow and infiltration.
- Root intrusion.
- Required flow control.
- Accessibility.
- Traffic control.
- Downtime available for the rehabilitation process.
- Substrate material and condition.
- Moisture.
- Low oxygen levels or high hydrogen sulfide levels.
- Surface conditions near the manhole.
- Costs of different options.
- Availability of qualified contractors.
- Compatibility of rehabilitation methods to repair multiple defects.

Potential recommendations for different rehabilitation activities are provided below. These recommendations are not exhaustive of options but are common rehabilitation options. Evaluate each manhole and determine the appropriate rehabilitation recommendations from this list or other available rehabilitation methods.

5.8.8.2 Manhole Frame and Cover Rehabilitation

Potential design recommendations for manhole frame and cover rehabilitation include:

- Replace sanitary manhole covers located in areas susceptible to inflow with non-perforated covers.
- Replace cracked or defective covers.
- Repair other deficiencies as identified.

5.8.8.3 Manhole Grade Adjusting Ring Rehabilitation

Potential design recommendations for manhole grade adjusting ring rehabilitation include:

- Add or removed adjusting rings when manhole covers are not level with finished surface if in paved or traffic area.
- Replace, grout, or seal adjusting rings that are leaking, cracked, or broken.
- Install external fitted over the entire adjustment section from frame to cone before backfilling. Sleeves may be banded, shrink wrapped, or hand applied.
- Install internal rubber sleeves when excavation needs to be avoided. Require internal sleeves to be held in place with stainless steel bands, hand or spray applied flexible coatings, or cured-in-place liners.

5.8.8.4 Manhole Chimney Rehabilitation

Potential design recommendations for manhole chimney rehabilitation include:

- Installing a chimney seal to prevent deterioration and leakage from the chimney area of the manhole.
- Installing rubber sealing gaskets that are held in place with stainless steel expansion rings.
- Polymer chimney seals specifically designed to sustain some minor movement of the casting during its service life without cracking or failing.
- Cured-in-place liners specifically designed to seal the chimney area.

5.8.8.5 Manhole Bench and Flow Channel Rehabilitation

Potential design recommendations for manhole bench and flow channel rehabilitation include:

- Leaking or deteriorated manhole benches and flow channels shall be repaired.
- Flow channels shall be constructed for sanitary and combined sewer manholes which do not have flow channels.
- The manhole bench and flow channel are non-structural and can be renewed using a variety of cementitious and polymer coating products. Typically, the same coating that is applied to the wall and cone of the manhole shall also be applied to the bench and flow channel.
- Precast plastic manhole inserts may be installed as flow channel replacements.

5.8.8.6 Manhole Sealing

Potential design recommendations for sealing manholes include:

- Grouting leaks in manholes before resurfacing, repair, or installing lining materials.
- Sealing manholes using chemical grout meeting ASTM F2414 – *"Standard Practice for Sealing Sewer Manholes Using Chemical Grouting"*.
- Sealing manholes using flexible material that is designed for freeze/thaw and moving load conditions.

5.8.8.7 Manhole Cementitious Lining

Potential design recommendations for cementitious linings include:

- Restoring the overall manhole condition by eliminating infiltration, exfiltration, root intrusions, and minor defects.
- Being applied when bypass pumping or flow control is limited, or where the surface is damp and moisture is present within the atmosphere.
- Being applied if the surface can be prepared using high pressure and/or detergent cleaning.

- Being installed in accordance with ASTM F2551 – *"Standard Practice for Installing a Protective Cementitious Liner System in Sanitary Sewer Manholes"*.

Specify cementitious linings that:

- Have corrosion resistant properties to reduce the rate of concrete degradation. Additives such as fiberglass flakes may be used to help protect against corrosion and to increase structural integrity.
- May be spray applied, pumped and troweled, or spin cast.
- Can be applied with a smooth finish to reduce microbiological-induced corrosion.

The following references may be used when designing manhole liners:

- *"A New Design Method for Non-Circular Sewer Linings"*, paper by Olivier Thépot, 2001.
- *"Structural Mechanics of Buried Pipes"* by Reynold King Watkins and Loren Runar Anderson, CRC Press, 1999.

The design formulas provided in the appendix of ASTM F1216 are for designing pipe liners and shall not be used for designing manhole liners.

Design requirements for manhole liners include:

- Calculating the minimum thickness of the liner by assuming that there is no bonding between the liner and manhole.
- The liners shall be flexible so that they do not crack, fracture, or break over time. Design the manhole liners to withstand stresses such as freeze thaw cycles acting on the manhole structure.
- Epoxy liners shall be installed in manholes in corrosive environments.
- Cured-in-place liners made of stretchable epoxy coated polyester may be used to eliminate inflow and infiltration and provide structural reinforcement.
- Polymer modified coatings may be applied by spray, trowel, or spin cast. However, spray application is preferred because the spray allows for better coverage, especially for angles or nooks and crannies.
- Require all existing steps and ladders to be cut off, flush, and removed prior to lining manholes. Install new steps and ladders after installation of liner.
- Require interior drop pipes to be removed prior to installation of the liner and reinstalled after installation is complete.

5.8.8.8 Manhole Mechanical Seals and Inserts

Design of manhole mechanical seals and inserts shall:

- Provide a physical barrier against corrosion.
- Specify materials to be PVC, fiberglass, or HDPE unless approved otherwise by DC Water.
- Require seals and inserts to be grouted in place after installation by applying mortar with a minimum thickness of 0.5 inches. The mortar shall fill the annular space and lock the liner into place by adhesion.

5.8.8.9 Repair of Deteriorated Manhole Liners

When a section of the existing liner needs to be repaired, the new liner material shall be designed to be compatible with the existing liner material and the new liner shall mechanically or chemically adhere to the deteriorated or failing liner.

When the existing liner needs to be replaced with a new liner, the failing liner shall be required to be cut out and the concrete beneath coated prior to installing the new liner. New liners shall be structurally reinforced cure-in-place liner.

5.8.9 Service Lateral Rehabilitation and Replacement

5.8.9.1 General

Service laterals shall typically be rehabilitated or replaced up to the property line when mainline sewers are rehabilitated or replaced. Consider the following during for design:

- Replace service laterals where heavy roots cannot be removed or where the structural integrity of the lateral is compromised.
- Designate on the Contract Drawings, which service laterals are to be rehabilitated and which are to be replaced.
- Design shall permit the Contractor to use open cut or trenchless methods to be used to rehabilitate or replace service laterals.
- Require cleanouts to be installed at the property line on all laterals being replaced. The design shall require:
- The lateral pipes to be located with a sewer camera prior to excavation.
- New sewer cleanouts to be constructed over existing laterals using vacuum or hydro-excavation technology to minimize disturbance on private property.
- The connection between the cleanout and lateral to be sealed to prevent infiltration.

5.8.9.2 Service Lateral Reinstatement Post Sewer Lining

The design for sewer lining shall require:

- The Contractor to measure the location of laterals before lining sewers to ensure the laterals can be located if dimples are not visible after being lining.
- A remote operated pneumatic cutting tool be used to cut lateral openings and ground the edges smooth after the liner has cooled and set.
- Laterals to be reinstated immediately after the liner has cooled.
- The Contractor to have a working backup cutter and camera at all times.

5.8.9.3 Lateral Pipe Bursting

Potential consideration for when the design may allow pipe bursting to be used to replace laterals include:

- Replacing structurally damaged laterals on the verge of collapse.
- Replacing laterals with one (1) or two (2) 90-degree bends and there is sufficient space for the bursting head to cut through the soil and install the replacement pipe with larger bending radius than the original installation.
- Not using pipe bursting if there are multiple sharp bends in the pipe requiring separate bursting setups.

The design for pipe bursting shall include:

- Using HDPE pipe as the primary replacement material. However, DIP or PVC pipe may be considered.
- The locations of the access pits [minimum two (2) foot by four (4) foot] on the Contract Design drawings.

5.8.9.4 Cured-in-Place Lateral Liners (CIPL)

The design for CIPL liners shall require:

- Compliance with the requirements of ASTM F1216 - *"Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube"*.
- A minimum installed thickness of three millimeter (3mm).
- The pipe to be mechanically cleaned and roots removed prior to lining.
- A PVC pre-liner and chemical grouting be applied to stop heavy leaks prior to installing CIPL liners.

- Plugs to be inserted in all active service lateral connections prior to lining to prevent flow from entering the sewer during liner insertion.
- A CCTV or other approved inspection method after installation to verify that lateral lining has been properly installed.
- Removal of excessive resin at the end of the lateral lining.

CIPL liners shall not be used for pipes with:

- Severe offset joints.
- Severe corrosion.
- Mineral buildup that has badly reduced the hydraulic capacity unless the mineral buildup can be mechanically removed to reinstate the inside diameter to at least 95% of its original dimension.
- Laterals with bends greater than 45 degrees.

The following CIPL liner systems may be used to rehabilitate laterals as needed or directed:

- Standard liners shaped as simple tubes that are used to reline the entire length of the lateral or a part of it.
- Connection Liners or T-liners with a full circle mainline seal about 12 to 16 inches long that is stitched and fused onto the CIPL liner extending up into the lateral at a minimum 12 inches or the full length to the property line.

5.8.9.5 Lateral Chemical Grouting

The design of chemical grouting for laterals shall require:

- Chemical grouting to comply with ASTM standards.
- The service lateral to be cleaned and televised prior to grouting.
- Roots and grease be removed from the service lateral prior to grouting.
- The use acrylamide, acrylate, acrylic resins, and urethane gels for grouting.
- Void pressure to be monitored while grouting.
- A post-grouting air test and/or visual confirmation of the sealed leak.
- Fill voids on the outside of the pipe.
- Stabilize the soil around the structures.
- Stop infiltration.
- Seal the lateral connection with the mainline and the first one (1) to six (6) feet of the lateral.
- Include the use of additives to chemical grouts to add protection against freezing and drying out (ethylene glycol), inhibit root growth (Dichlobenil), and increase compressive and tensile strength of the grout (latex emulsion/reinforcing agent).

Chemical grouting shall not be used as a structural repair.

5.8.9.6 Lateral Flood Grouting

Under special circumstances, DC Water may consider flood grouting as a method to eliminate infiltration and exfiltration for structurally sound sewer systems with significant sources of inflow and infiltration. Flood grouting is a geotechnical method of sealing manholes, mainlines, and laterals simultaneously in one (1) setup. Flood grouting also improves the bedding and the soil around the pipes and manholes, stops biogenic sulfur corrosion, and prevents future root growth into the sewer.

Design of lateral flood grouting shall include requiring:

- Environmentally friendly chemical solutions to be applied to "flood" an isolated section of sewer and exfiltrate through defects in pipes and manholes into the soil, where they will chemically react with each other. The cured grout with the soil aggregate shall create a watertight, sandstone-like silicate envelope around the leaks.

- Service laterals to be temporarily plugged at the cleanout during flood grouting.
- Customer service to be restored within approximately eight (8) hours.

5.8.9.7 Lateral Robotic Repairs

Design may permit robotic repairs to be used to provide a full structural repair of damaged connections between the sewer and service laterals, and to stabilize the soil envelope around the pipes and stop infiltration. Lateral robotic repairs will include positioning a cutting robot at the lateral opening in the mainline to remove a small portion of the lateral pipe so that a silica or epoxy based resin can be injected under pressure to penetrate the soil and voids behind the pipe and fill pipe cavity removed during cutting. Resin may be injected in the presence of high groundwater infiltration. Robotic repairs typically extend up to two (2) feet into the lateral depending on the resin compound used.

5.8.10 Bypass Pumping

Calculate flows in existing piping to determine the projected flow rates that will be required to be bypass pumped. Calculations shall include sufficient detail to allow a constructability review to be performed and:

- The hydraulic grade line (HGL) in calculations for pipes with diameters of 24 inches and larger.
- When measured flow data is available, validation of the calculation to the flow data.
- Calculations for peak flows under dry and wet conditions.

5.9 AERIAL PIPE CROSSINGS

Sewers laid on piers across ravines or streams may be permitted when it can be demonstrated that no other practical alternative exists. The design of aerial crossing shall include:

- An evaluation of the impact of flood waters and debris.
- Pipe elevation above the 25 year flood elevation.
- Use of DIP with thickest wall available for the size of pipe.
- Corrosion protection.
- Mechanical restrained joints unless otherwise approved by DC Water.
- Joints and supports shall be designed to prevent excessive flexion, overturning, and settlement.
- Precautions against freezing.
- Evaluation for expansion and contraction.
- Evaluation of special construction requirements to minimize heaving where buried sewers change to aerial sewers.
- Expansion joints between above and below ground piping.

5.10 PIPELINE DRAWINGS

Plans and profiles shall be prepared in accordance with Paragraph 4.3.5 except when the requirement is specifically identified for water mains. In addition, information shown on the sewer pipeline drawings include, but is not limited to, showing station and elevation for sewers of each change in horizontal alignment on the plan.

5.11 CROSS CONNECTIONS

Any cross connections found between sanitary sewers and storm sewers shall be reported to DC Water immediately.

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6. EARTH BACKFILL AND LATERAL SUPPORT FOR BURIED PIPES

6.1 MODULUS OF SOIL REACTION (E')

The E' of the in-situ material shall be estimated in the field by conducting standard penetration, cone penetrometer or dilatometer tests. In the absence of field tested data to define E', assume the in-situ E' is 100 psi.

If the E' value of the in-situ soil is higher than the E' value of the backfill material, then the former should be used in the design. If, on the other hand, the E' value of in-situ soil is lower than the E' value of the backfill material, the latter should be used in the design. Alternatively, a finite element analysis may be done using the corresponding E' values for in-situ and backfill soil.

6.2 SOIL ENHANCEMENT FOR LOW MODULUS OF SOIL REACTION E'

If the in-situ soil has a standard penetration test blow count of four (4) or less, general purpose CLSM shall be placed throughout the embedment zone.

Alternatively, the width of the trench backfill material may be increased to reduce the amount of pressure transmitted to the in-situ soil. If used, this method shall be evaluated by a finite element analysis.

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7. ABANDONMENT AND REMOVAL OF SEWER AND WATER SYSTEMS

Abandonment of existing pipe shall comply with DC Water Standard Specifications. Clearly designate on the Contract Drawings which sewer and water systems are to be removed and abandoned.

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8. CORROSION CONTROL

Perform corrosion control design on ductile iron, pre-stressed concrete, steel, and other ferric metal pipelines as well as the metallic fittings/components of non-metallic pipelines and other structures in the water distribution network when required by a DC Water scope of work. All corrosion control design shall be overseen by a Corrosion Engineer, a National Association of Corrosion Engineers (NACE) certified Senior Corrosion Technologist, or a NACE certified Cathodic Protection (CP) or Corrosion Specialist. Corrosion control design is also required if new sources of stray currents are introduced near an existing water or sewer asset.

Corrosion control design will include:

- **Phase 1 – Preliminary Corrosion Analysis:** A desktop analysis to determine whether corrosion control may be required.
- **Phase 2 – Testing:** A field study to determine what corrosion control measures are required.
- **Phase 3 – Design and Cost Estimate:** A design and cost estimate of the recommended corrosion control measures.

8.1 REFERENCES AND STANDARDS

The current editions of the following NACE International practices and recommendations references are acceptable and shall be considered primary sources of information:

- SP0169*: "Control of External Corrosion on Underground or Submerged Metallic Piping Systems".*
- SP0177*: "Standard Recommended Practice – Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems".*
- SP0285: *"External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection".*
- SP0388*: "Standard Practice – Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks".*
- SP0187: *"Design Considerations for Corrosion Control of Reinforcing Steel in Concrete".*
- SP0196: *"Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks".*
- SP0286: *"Standard Recommended Practice – Electrical Isolation of Cathodically Protected Pipelines".*
- TM0497: *"Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Piping Systems".*

The current editions of the following ASTM practices and recommendations references are acceptable and shall be considered primary sources of information:

- ASTM D257*: "Standard Test Methods for DC Resistance or Conductance of Insulating Materials".*
- ASTM D512*: "Standard Test Methods for Chloride Ion in Water".*
- ASTM D513*: "Standard Test Methods for Total and Dissolved Carbon Dioxide in Water".*
- ASTM D516*: "Standard Test Method for Sulfate Ion in Water".*
- ASTM D1293*: "Standard Test Methods for pH of Water".*
- ASTM D1452*: "Standard Practice for Soil Exploration and Sampling by Auger Borings".*
- ASTM D1498*: "Standard Test Method for Oxidation-Reduction Potential of Water".*
- ASTM D2488*: "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)".*
- ASTM D4220*: "Standard Practices for Preserving and Transporting Soil Samples".*

- ASTM D4327: *"Standard Test Method for Anions in Water by Suppressed Ion Chromatography"*.
- ASTM D4373: *"Standard Test Method for Rapid Determination of Carbonate Content of Soils"*.
- ASTM D4658: *"Standard Test Method for Sulfide Ion in Water"*.
- ASTM G51: *"Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing"*.
- ASTM G57: *"Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method"*.
- ASTM G187: *"Standard Test Method for Measurement of Soil Resistivity Using the Two-Electrode Soil Box Method"*.
- ASTM G200: *"Standard Test Method for Measurement of Oxidation-Reduction Potential (ORP) of Soil"*.

Additionally, the designer may also rely on AWWA M27: *"External Corrosion Control for Infrastructure Sustainability"*.

8.2 PHASE 1 ‑ PRELIMINARY CORROSION ANALYSIS

The corrosion analysis of buried utilities shall evaluate:

- Corrosion issues and the potential impact of a corrosion related pipe failure when considering pipeline alignment.
- The need for corrosion control testing when an existing pipeline is exposed for construction or a new pipeline is planned for installation.
- The relevant items in the Phase 1 Checklist included in Appendix B. The Phase 1 Checklist shall include:
- Special circumstances (e.g. the project is on DC Water property) shall be noted and relevant attachments.
- Demonstrate the need or lack thereof to proceed to Phase 2.
- Separate checklists for each pipeline or section of pipeline.
- Attachments copies of reports, maps, correspondence, etc. showing locations of stray current sources, break locations, and other circumstances that confirm the conclusions obtained in the analysis.

Identify, and where possible avoid, stray current sources which may require special corrosion control measures. Potential stray current sources include, but are not limited to:

- WMATA existing or proposed transit lines, especially surface routes.
- Natural gas, fuel oil, gasoline, and other petroleum product pipelines with impressed current cathodic protection systems.
- Telephone and other communication lines or high voltage electrical lines encased in metal conduits with impressed current cathodic protection systems.
- Service stations with impressed current cathodic protection systems from buried fuel tanks and pipes.
- Welding shops or other industrial facilities.

Upon approval by DC Water, proceed to Phase 2 if:

- Based on visual inspection of the pipeline alignment or a record search along the alignment, one (1) or more of the potential stray current sources is suspected within 2,000 ft of the pipeline.
- Existing alignments in high consequence areas show a history of breaks.
- The project includes water mains sixteen inches (16") and larger in diameter.

If Phase 2 is unnecessary then the pipe will not require corrosion control.

8.3 PHASE 2 - TESTING

The need for Cathodic Protection (CP) and the design of CP is determined by field and laboratory tests assessing the environmental conditions at the site. Classify soil samples according to ASTM D2488 and test for:

- Soil resistivity (ohm-cm).
- ORP (mV).
- pH.
- Chloride concentration (ppm).

Soil samples from the anticipated pipe depth shall be obtained by a qualified geotechnical engineer at a maximum spacing of 1000 ft along the final alignment, unless the pipeline alignment is less than 2000 ft in length, then the intervals shall not exceed seven hundred feet (700ft). Shorter spacing between soil borings may be used if required for the corrosion control analysis. The proposed boring locations shall be reviewed by the Corrosion Engineer before any samples are obtained. Each soil sample shall total at least one (1) quart in volume. All samples shall be preserved and transported in accordance with ASTM D4220.

8.3.1 Field Testing

Take in-situ soil resistivity measurements, using the *Wenner Four-Electrode Method* in accordance with ASTM G57, at a maximum of 500 foot spacing along the alignment. In-situ resistivity shall be reported as resistivity between the depths containing the pipeline.

Take in-situ stray direct current (DC) measurements near natural gas and petroleum pipelines as well as at other locations determined to be necessary to evaluate stray current activity along the alignment. Testing shall include measurement of cell-to-cell earth gradients in select areas and structure-to-earth DC potential measurements on existing utilities where available.

Take in-situ induced alternating current (AC) voltage measurements near high voltage overhead electric lines as well as at other locations determined to be necessary to evaluate induced AC voltage impacts along the alignment. Testing shall include measurement of the strength of electric fields in select areas and structure-to-earth AC potential measurements on existing utilities where available.

8.3.2 Laboratory Testing of Soils

Collect soil samples from borings or test pits and transport to the relevant laboratory in accordance with ASTM D4220. In addition to classification per ASTM D2488, test each soil sample for pH, ORP, chloride concentration, and soil resistivity per accepted DC Water standards.

Refer to the saturated soil box resistivity measurement for the soil condition analysis. The soil sample with the highest value in the system shall be taken as representative for everything connected to the given system.

8.3.3 Evaluation of Results

Complete the Phase 2 Checklist, evaluate test results, and recommend corrosion control measures to DC Water. Provide information on any existing pipelines to which the proposed CP system will be connected, including pipe material, coatings, and existing CP measures (if any). Include any as-built information or related documentation. Give a reference for groundwater depth based upon the water table height from the county soil survey or a test boring if it is higher.

Refer to Table 8-1 for stray current analysis and Table 8-2 for soil condition analysis.

Based on the site condition analyses, determine the corrosion control measures that are required using Figure 8-1 for existing pipe and Figure 8-2 for new pipe. For the existing pipe analyses, address the existing pipeline as it is exposed for construction and submit a separate checklist for each location where the existing pipe is exposed. New pipe shall address the entire proposed pipe alignment based upon the worst case.

Any joints should be bonded and cathodic protection installed to the existing pipeline as they are available. Existing CIP should be analyzed as if it were DIP.

Table 8-1: Stray Current Analysis

Level	Survey and Field Test Results
Severe	• If a 2-hr stray current test results in ≥ 50 mV potential variation (from any source), or • Existing or future WMATA Metrorail lines, DDOT Streetcar lines, or welding shops are within 200 feet of the pipeline, or • Existing or future structures with ICCP (impressed current cathodic protection) or cables that are < 100 feet from the pipeline and have a ground bed within 2,000 feet.
Moderate	• If a 2-hr stray current test results in < 50 mV potential variation (from any source), or • existing or future WMATA Metrorail lines, DDOT Streetcar lines, or welding shops are < 500 feet from the pipeline, or • Existing or future buried structures with ICCP that are < 500 feet from the pipeline, and have a ground bed within 2,000 feet, or that are < 100 feet from the pipeline.
Negligible	• If a 2-hr stray current test results in no evidence of stray current from any source, or • Existing or future WMATA Metrorail lines, DDOT Streetcar lines, or welding shops are ≥ 500 feet from the pipeline, or • Existing CP system or cables that are ≥ 500 feet from the pipeline.

Table 8-2: Soil Condition Analysis

Parameter	Range	Points
pH	0 – 2	5
	>2 – 4	3
	>4 – 8.5	0
	>8.5	3
[Cl$^-$]	>1000 ppm	10
	>500 – 1000 ppm	6
	>200 – 500 ppm	4
	>50 – 200 ppm	2
	0 – 50 ppm	0
ORP	Negative	5
	0 – 100 mV	4
	>100mV	0
Soil Description	Clay (Blue-Gray)	10
	Clay/Stone	5
	Clay	3
	Silt	2
	Clean Sand	0
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Soil Resistivity	< 1,000 Ω-cm	10
	>1,000 – 1,500 Ω-cm	8
	>1,500 – 2,500 Ω-cm	6
	>2,500 – 5,000 Ω-cm	4
	>5,000 - 10,000 Ω-cm	2
	>10,000 Ω-cm	0

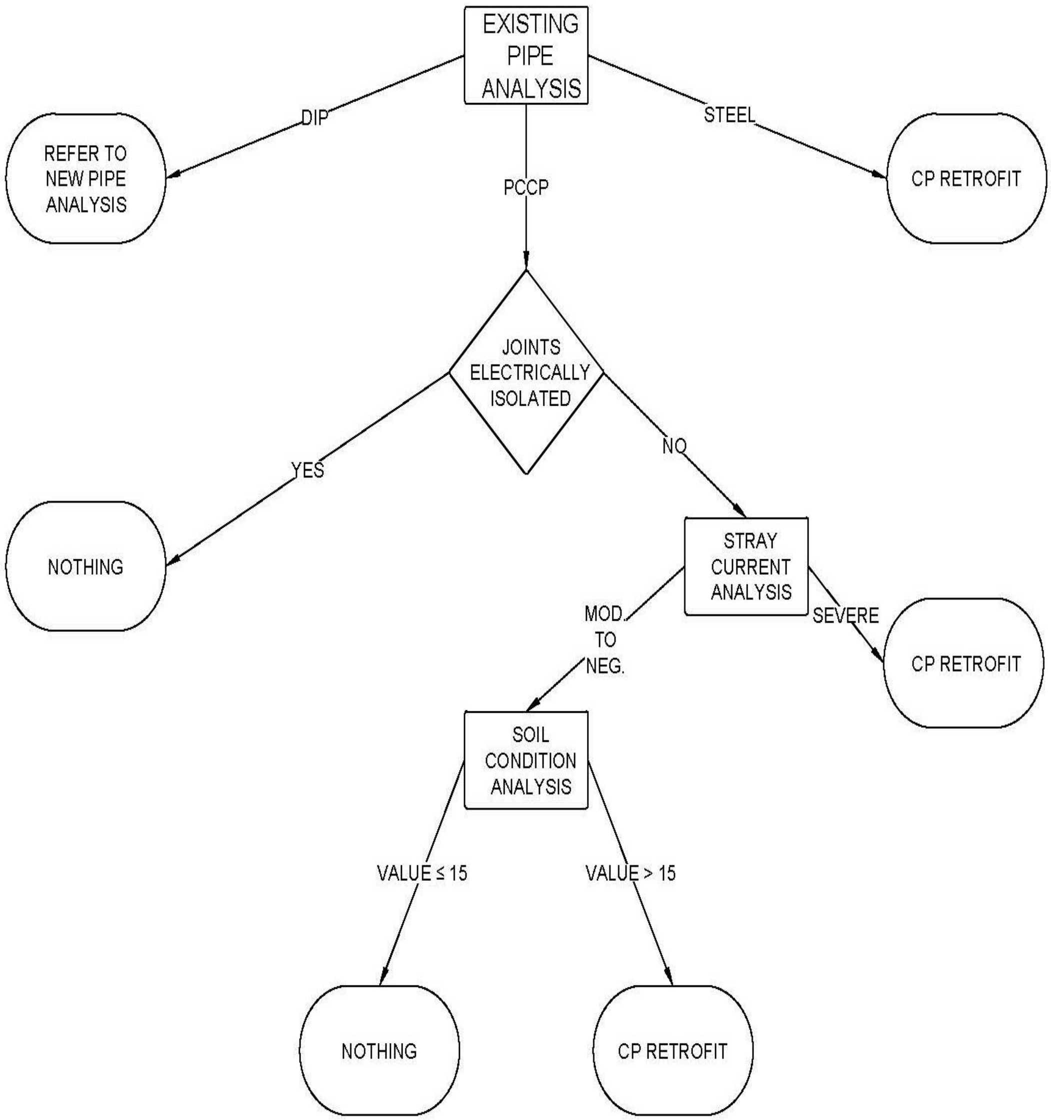

Figure 8-1: Existing Pipe Analysis

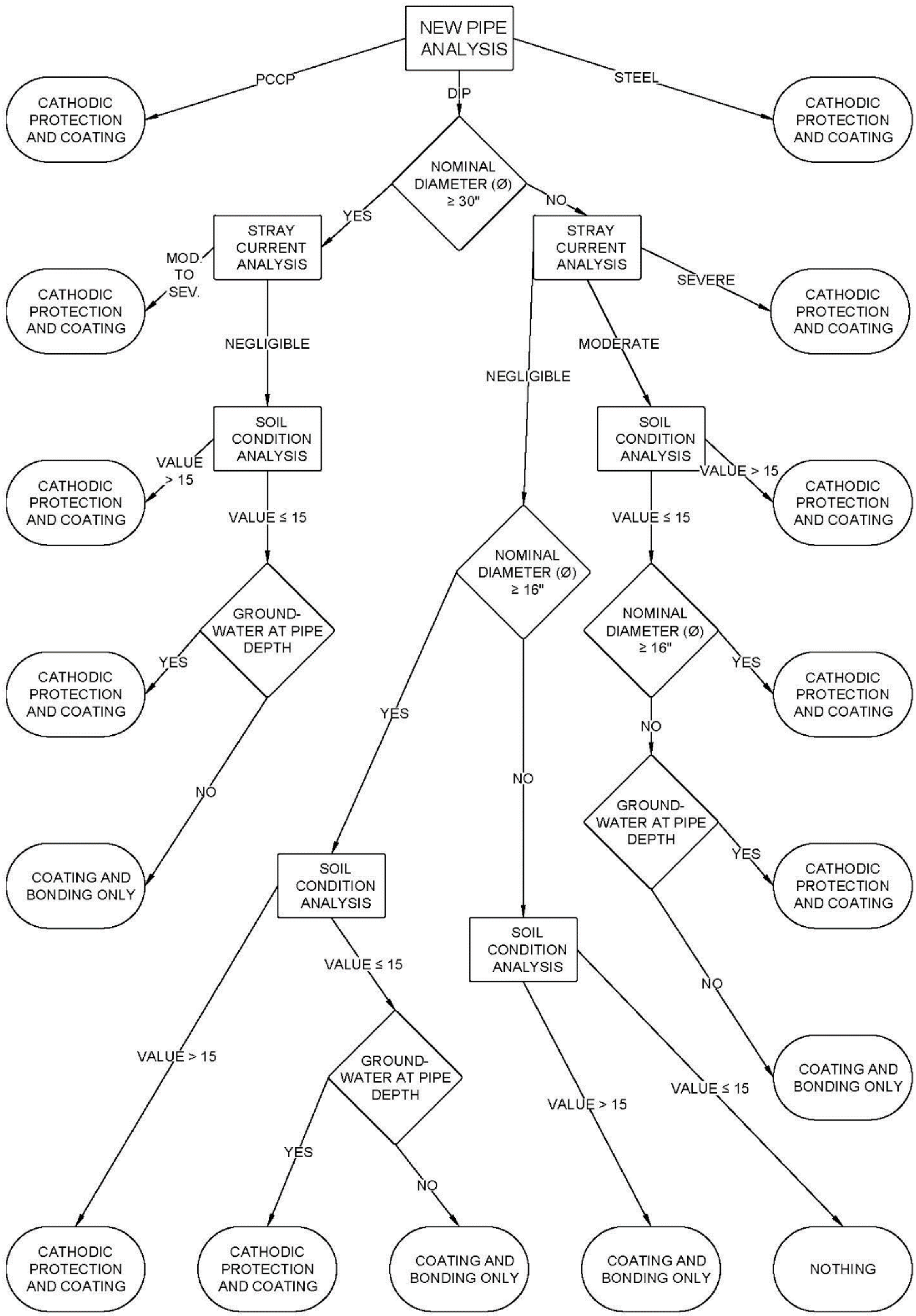

Figure 8-2: New Pipe Analysis

Given the minimum requirements determined from these figures propose corrosion control measures while considering the following:

- Fly ash shall not be used in backfill or where it may contact metal pipelines.
- Polyethylene encasement shall not be utilized as a corrosion control measure.
- Metallic fittings of non-metallic pipelines shall be provided with positive corrosion control (this may include cathodic protection in corrosive soils).
- In all cases, proper bedding shall be provided for the piping. (Piping shall not be placed on undisturbed earth).
- In all cases, new piping shall be electrically isolated from existing piping.
- In all cases, piping made of different metals shall be electrically isolated from each other.
- Stray DC mitigation systems shall be provided in areas where existing piping is protected with impressed current CP systems.
- Induced AC voltage mitigation shall be provided in areas where the pipeline crosses or runs immediately parallel to high voltage, overhead electric lines.
- Casings shall be electrically isolated from the pipeline.
- Generally, the annular space between the casing pipe and carrier pipe shall not be filled.
    - In special instances where casings must be filled, casings shall only be filled with a general purpose CLSM with a minimum pH of ten (10).
    - CLSM with fly ash shall not be used to fill casings.
    - Casings that are filled with general purpose CLSM shall be provided with a corrosion rate monitoring system that is installed within the casing between the pipeline and the casing.

Present these recommendations in a report submitted to DC Water. This report shall include the Phase 2 Checklist included in Appendix B along with any relevant supporting references.

Upon approval from DC Water, proceed to Phase 3 if the pipeline is to be bonded.

8.4 PHASE 3 – DESIGN AND COST ESTIMATE

The design of cathodic protection or corrosion monitoring systems for projects shall include the following considerations:

- Recognition of hazardous conditions prevailing at the proposed installation site(s) and the selection and specification of materials and installation practices that ensure safe installation and operation.
- Coordination with the structural design to ensure that the CP system is fully compatible with the design of the structure to be protected or monitored and include:
- Coordination between the Corrosion Engineer and the specifiers of the materials of construction and coatings.
- Identification of locations and configurations of appurtenant facilities such as valve vaults, service laterals, instrumentation, and connections to other structures.
- Test stations shall not be located in the roadway, unless otherwise approved by DC Water. Locations of monitoring equipment, devices, outlets and appurtenances shall be shown on the approved drawings and located on the as-builts.
- Test stations shall be numbered and recorded on control cards on file at DC Water. Show the location and number of new and existing test stations on drawings.
- Locations of systems shall be selected to minimize currents or earth potential gradients which can cause detrimental effects on foreign buried or submerged metallic structures.
- CP systems shall be designed to provide adequate current to polarize the structures to be protected to levels generally accepted for complete protection. Additionally, the system coating and CP shall be optimized to achieve the most cost-effective corrosion protection system.

- Avoid using excessive levels of CP that may break the bond between the external coating and steel and allow hydrogen evolution to damage the steel.
- The CP system shall be designed to provide a minimal service life of 30 years or shall be commensurate with the required life of the protected structure as approved by DC Water.
- The designer shall provide for periodic rehabilitation of the anode system.
- The CP system shall provide a means for testing and mitigating potential stray current.
- The CP system shall be coordinated and consistent with electrical grounding needs of the facilities to mitigate induced voltage from high-voltage power transmission lines.

Based on the design requirements the cost estimate shall include:

- A cost estimate for installing and maintaining the corrosion control system.
- The life cycle cost analysis.
- A cost to benefit analysis.
- The bill of materials.
- Design drawings for the entire pipe alignment, per DC Water standards.
- Design computations.
- All relevant references.

9. PROTECTION OF UTILITIES

This section provides the requirements when DC Water's facilities or infrastructure will be within the ZOI of any construction activity or when construction activities as defined in Section 9.2 are performed. Contact DC Water before designing or performing work near DC Water facilities and infrastructure. Analysis required by this Section will be reviewed and approved by DC Water prior to permitting construction activities to be performed.

9.1 ZONE OF INFLUENCE

DC Water utilities are affected by construction or an applied load when the utility is located within the ZOI of that construction or applied load. The ZOI is a zone of soil that is influenced by an applied load or excavation. ZOI includes, but is not limited to, any of the following conditions:

- For open-cut excavations in sandy materials the zone of influence is a slope of 2H:1V behind the edge of an excavation pit or if within 25 feet (horizontally) of a DC Water facility.
- An envelope starting at a point two (2) feet below the lowest point of the structure or excavation continuing upward at a 45 degree angle from the horizontal.
- For rock-blasting, the ZOI is 100 feet in all directions of the blasting activity.
- Any area that experiences more than quarter inch (¼") settlement when subjected to ground improvement or dewatering.

Perform and submit to DC Water a pipe condition inspection and assessment if an existing water or sewer pipeline of any diameter is located within the construction ZOI. The technology used for this condition inspection and assessment will vary depending on the water/sewer assets within the ZOI, but may include CCTV per NASSCO standards, lidar/sonar inspection, smart ball inspection, and other similar techniques. The condition inspection and assessment will be used to determine if additional protective measures are required for the pipe.

9.2 CONSTRUCTION IMPACT REPORT

A Construction Impact Report (CIR) is required when construction activities include any of the following:

- Excavation within the ZOI of an existing unreinforced masonry/concrete sewer or an existing water main 24 inches in diameter or greater.
- Driving piles or tiebacks within 40 ft of an existing water or sewer asset.
- Blasting within 100 ft of an existing water or sewer asset.
- Ground freezing within 50 ft of an existing water of sewer asset.
- Temporary excavation creating an unbalanced load on unreinforced masonry/concrete sewers at any distance.
- New surcharge loads (for example, a new building, bridge abutment, spoil piles, or roadway, etc.) are introduced within ten (10) ft of an existing unreinforced masonry/concrete sewer or an existing water main 24 inches in diameter or greater.
- Any percussive tunneling methods (such as pipe jacking or ramming) within 40 ft of any water/sewer asset. Moling used for gas, water, or other service lines less than four (4) inches in diameter do not need to submit a CIR.
- Pipe bursting within ten (10) feet of any water/sewer asset.

A simple load-for-load comparison is typically not acceptable. The CIR shall include an evaluation of every phase of the adjacent construction in all possible weather conditions.

The CIR adjacent to an existing unreinforced masonry/concrete sewer shall include CCTV, or other approved inspection method, of the sewer taken prior and after construction.

The CIR shall include a Finite Element Model (FEM) analysis, with DC Water pre-approved boundary and loading conditions:

- Excavation induced unbalanced loads:
  - Higher at-rest pressure on one side and less at-rest pressure on the other side, when excavation is above the crown within ZOI.
  - At-rest pressure on one side and active pressure on the other side, when excavation is below spring line of the pipe within ZOI.
  - Active pressure on both side of the pipe, when excavation on both side of the pipe within ZOI at the same time.
- Tunneling under pipeline:
  - If pits are within ZOI on both size of the pipe, see above.
  - If pits are outside ZOI, a ground settlement beneath the pipe invert shall be modeled conservatively, along with a remote accessible instrumentation plan for DC Water approval.
- A custom FEM with realistic ground settlement or heaving requires DC Water approval.
- 3D Finite Element Method analysis shall account for shoring that may impact the water and sewer lines that are sensitive to soil relaxation on the side and bottom of the excavation.

9.3 GEOTECHNICAL ASPECT OF EARTH PRESSURE CRITERIA

9.3.1 Support of Excavation - General Requirements and Provisions

This section includes the minimum design and construction requirements for excavation when the DC Water utilities and facilities are within the ZOI.

Temporary structures may be designed with laid back slopes provided the soil loads are assumed to be equivalent to the full height of the excavation from the subgrade under the working slab to the original street grade or surface elevation of the soil before excavation.

If design criteria and/or methods given in any of the reference standards differ with a criteria and/or method explicitly stated in these guidelines, then these guidelines criteria and/or method shall govern.

9.3.2 Basic Lateral Earth Pressure

Basic lateral earth pressure shall be assumed to be linearly proportional to the depth of earth and taken as:

$P=k\gamma_s z.$

Where:

P = basic lateral earth pressure (KSF).
k = coefficient of lateral earth pressure taken as, ko, for walls that do not deflect or move, or, ka, for walls that deflect or move sufficiently to reach minimum active conditions.
γ_s = unit weight of soil (KCF).
z = depth below the surface of earth at pressure surface (FT).

The resultant lateral earth load(s) due to the weight of the backfill shall be assumed to act at a height of h/3 above the base of the wall, where h is the height of the pressure surface, measured from the surface of the ground to the base of the wall.

The location of the resultant lateral earth load on the h pressure surface at above the base of the pressure h/3 surface is applicable when the backfill surface is planar and the backfill is completely above or completely below the ground water table. For those situations where the backfill surface is non-planar and/or the ground water table is located within the backfill, a trial wedge method of analysis may be used for the determination of the resultant lateral earth load in which case the location of the resultant lateral earth load may be determined by the intersection of a line that is parallel to the failure surface of the wedge projected from the centroid of the weight of the failure wedge to the plane of the wall pressure surface. If the projected line is above the top of the pressure surface, the resultant lateral earth load may be assumed to act at the top of the pressure surface.

The at-rest coefficient of earth pressure (K_o) is expressed as:

$K_o = 1\text{-}\sin\Phi.$

The active coefficient of earth pressure (K_a) is expressed as:

$K_a = \tan2\ (45 - \Phi/2).$

The passive coefficient of earth pressure (K_p) is expressed as:

$K_p = \tan2\ (45 + \Phi/2)$.

In these equations the effective friction angle (Φ) should be taken from the actual lab testing, and cohesion "c", shall be considered zero (0). If a geotechnical report is prepared, and submitted to DC Water, based on sufficient job specific borings and other geotechnical investigation, other values of effective friction angle (Φ) may be used at the sole discretion of DC Water.

Due to ineffective soil retaining features that lead to relaxation, lateral soil pressure on the side of construction is prone to decrease, resulting in unbalanced boundary condition that is detrimental but usually neglected.

Down-drag incurred lateral soil pressure shall be addressed individually to satisfaction of DC Water Engineer.

9.3.3 Design Requirements for Construction Within the ZOI

Perform the following analyses for DC Water review and approval:

- Establish diagrams illustrating the pressures used in the design, including the long term, existing pressures on the underground DC Water structures. Illustrate the variation in the existing pressures due to the various construction phases, including full excavation to subgrade and when the structure is complete. A structural evaluation will not be required if the proposed pressures and loads on DC Water structures are within the limits of DC Water's initial structural design.
- If the proposed pressures and loads on DC Water's structures fall outside initial design limitations (of DC Water structures), then perform a structural analysis to verify that the anticipated earth pressures will not cause over stressing or cracking. DC Water may, at its sole discretion, waive such an analysis based on the amount of variation in pressures and loads acting on DC Water structures.
- The design for the excavation support system shall include consideration of a deep-seated slope stability analysis of the soldier pile or sheeting wall.
- If required by DC Water, perform a 3D geo-mechanical finite element model analysis of the existing DC Water structure for the anticipated loads for both as-is and retrofitted conditions.
- Provide details of any proposed construction dewatering or groundwater drawdown planned during the adjacent construction. Perform a settlement analysis of the existing DC Water facilities if the foundations are founded in subsurface strata of loose material with a thickness of more than five (5) feet.
- If laid back slopes are used at the top of excavation support system, and if they are steeper than one (1) vertical to one and a half (1-1/2) horizontal, perform a slope stability analysis.

9.3.4 Lateral Earth Pressure and Groundwater Pressure

Compute the basic horizontal earth pressures using the active earth pressure. Multiple the resultant or total active earth pressure by a stiffness factor depending upon the required stiffness. Redistribute the resulting load on the cofferdam in a trapezoidal pressure. Apply the stiffness factors to both the cofferdam design and the bracing system.

Assign stiffness factors as follows:

- Use stiffness factor = 1.25 for a soldier pile and lagging or a sheet pile support system.
- Use stiffness factor = 1.5 for a slurry wall, secant and tangent pile wall support system.

If the water table is above the subgrade, and if de-watering is not done, consider the effect of the lateral water pressure and modify the active earth pressure accordingly.

Depending upon the type of soil, the ordinate of the resultant trapezoidal pressure diagram in pounds per square foot shall be at least equal to:

- 25H for a soil with Φ=38 degrees, and a stiffness factor of 1.25.
- 29H for a soil with Φ=38 degrees, and a stiffness factor of 1.50.

Where H = the height in feet of the excavation between the subgrade under the working slab and the surface of the ground. The bottom of a laid-back slope at the top of the cofferdam shall not be used as the upper limit in determining the value of H.

Estimate ground water pressures based upon the existing water levels or on permissible drawdown levels, plus an allowance for seasonal variation. Where soldier beams with wood lagging are to be used, ground water may be assumed to be below the level of the interior excavation subgrade. When the shoring wall is intended to prevent all leakage of ground water the exterior water level shall be used and accounted for in the design.

Compute the passive earth pressure available to resist the forces placed upon the temporary support structure using the conventional expressions for passive earth pressure. Friction forces on the cofferdam shall be ignored. Use a safety factor of 1.5 when computing the theoretical passive resistance. The passive earth pressure should be reduced with consideration of slopes and berms in front of the support system.

Consider frictional forces only on the embedded soldier pile length below the subgrade when balancing the vertical forces imparted to the support structure by rakers or tiebacks. Determine the allowable bearing capacity by applying a safety factor of 3.0 to the ultimate bearing capacity.

The structural support system design shall consider the effects of all loads resulting from construction equipment, construction trailers, supported utilities, stockpiled materials, cranes, concrete trucks, and non-underpinned buildings adjacent to the excavation. For more severe construction loading, conduct a special analysis.

Evaluate the stability of the base of the excavation for all excavation support systems. The evaluation shall consider piping due to seepage, unbalanced external forces, base stability of cohesive soils, etc. An acceptable method of evaluating the stability of the base of the excavation shall be in accordance with the procedures presented in the US Navy Design Manual 7.02, "*Foundations and Earth Structures*".

9.3.5 Structural Excavation Support Elements

Evaluate the excavation construction sequence and its effect on the struts, corner braces or diagonal struts, rakers, walers and soldier piles for the various stages of partial excavation. The condition where the soldier pile is assumed to be continuous over the brace immediately above the excavated level may produce a condition of maximum loading in the support structure. Size the excavation support members accordingly. For raker bracing system use reduced passive pressure acting on the soldier beams due to the soil sloping down from the edge of berms, for the partially excavated conditions.

When the support of excavation is closer than ten (10) feet to the DC Water facilities or underground tunnel sections, DC Water may require a stiff support system (e.g. slurry walls, tangent walls, etc.) and other means of support of excavation (such as soil grouting). The requirement may also include restricting the spacing of soldier piles to four (4) feet maximum, and restricting the spacing of supports (rakers, tiebacks, etc.) to eight (8) feet maximum. Discuss the support of excavation within ten (10) feet of structures with DC Water before commencing such support design.

Design soldier piles as simply supported beams, spanning between points of support. In analyzing intermediate stages of excavation, assume the soldier pile is continuous across the lowest level of bracing. Analyze the embedment length of soldier piles below the design subgrade for the horizontal resistance required to provide a support point below the subgrade. The maximum horizontal resistance on the soldier beams flange may be assumed to be three (3) times the ordinary passive pressure computed for the width of the flange, or the width/diameter of pre-augured hole when filled with a minimum of 3500 psi concrete, but not to exceed the passive pressure based on the spacing of soldier piles. The minimum embedment length shall be ten (10) feet.

All structural steel members in the excavation support structure should be sized using Allowable Stress Design (Working Stress Method) in the "*AISC Steel Construction Manual*". Neither the design axial stress can be reduced nor the permissible allowable bending stress and combined stress ratio be increased for the excavation support structure. Support of excavation design calculations shall consider the effects of combined axial, torsional, and flexural loads in the structure and its elements.

Bracing members, such as struts, corner braces, cross struts, rakers, etc., should be designed, other than self-weight, for an additional lateral load, equal to two percent (2%) of maximum design axial load and imposed on bracing members in both lateral directions, applied to produce maximum flexure on the members.

Consider the stability of laterally unsupported members and unsupported span lengths in the design of the supporting members. The use of pin piles or lacing may be required if the above stress requirement is not satisfactory.

The pin pile design is presumed as two percent (2%) of maximum design axial load of abutted bracings in both horizontal and vertical directions. The lacing design load is assumed to be two percent (2%) maximum axial load of abutted main support members.

The structural support system design shall recognize the effects of all loads resulting from construction equipment, construction trailers, supported utilities, stockpiled materials, cranes, concrete trucks, and non-underpinned buildings adjacent to the excavation.

Soldier piles shall ordinarily be spaced from four (4) to seven (7) feet on centers. A maximum spacing of eight (8) feet on centers will be allowed where soil conditions are granular. Timber lagging shall have a minimum flexural stress of 1100 pounds per square inch and three (3) inches minimum thickness for soldier piles spaced seven (7) feet apart and for excavated depths of up to 25 feet. Timber lagging, four (4) inches thick, shall be used in excavations below 25 feet. For other pile spacing conditions and types of lagging, submit design details for approval.

The vertical spacing of bracing tiers shall not exceed 12 feet center to center. The maximum length of unsupported soldier pile between the surface of the ground and the first brace shall not exceed six (6) feet. Deflections in the soldier piles shall not exceed half inch (½”). The soldier pile bearing capacity and the soldier pile deflections shall be calculated and included in the calculations.

Cantilevered soldier piles may be used for shallow excavation provided the maximum cantilever length does not exceed seven (7) feet and the maximum deflection does not exceed half inch (½”).

Design struts and rakers for axial load, torsional and flexural loads as appropriate. Brace struts and rakers in accordance with the requirements of the current edition of the “*AISC Steel Construction Manual”*. Select strut and raker sections that limit deflections to the above requirements. In addition, for support systems in which braces are installed between opposite sides of excavation (cross-lot struts), design and construct support on both sides to obtain comparable restraint and rigidity.

Tiebacks shall be deformed steel bars with a minimum guaranteed ultimate tensile strength (GUTS) of 150,000 pounds per square inch or seven (7) wire stress relieved steel strand for pre-stressed concrete with a GUTS of 270,000 pounds per square inch.

Require minimum clearances of tiebacks free length and the anchored length is at least five (5) feet and ten (10) feet, respectively from existing DC Water facilities. Require tieback construction procedures to include all precautions to minimize ground loss. Notify DC Water, prior to construction, of any changes to the tiebacks or anchors which are made to clear existing utilities.

When using corner or diagonal bracing, and when the wales do not transfer the load to the other end, analysis shall include calculations required to determine reaction dissipation into the support of excavation wall (soldier piles, slurry walls etc.) on the sides of excavation. If corner bracing is proposed with wales connected at the corners, the corner connection of the wales shall be completed after preloading the corner/diagonal bracing.

Require Contractor to provide details on shop or working drawings indicating how the tieback, strut, or raker loads are to be transmitted from the supporting member through the waler to the soldier pile. Include bolted and welded connections, web stiffeners and brackets, dimensions of raker heel blocks, strut lacing, pin piles, jacking lugs and other special details of construction. Illustrate connection details indicating how the forces from the corner braces will be transmitted and dissipated or balanced through the soldier piles and/or walers. Calculations are required for each listed item.

Require the Contractor to include the sequence and method of construction on shop or working drawings. Include procedures for wedging or jacking rakers, loading tiebacks and preloading struts. Details of wedging and jacking to maintain tight contact for all bracing members shall be as follows:

- Tiebacks shall be preloaded to 140% of the maximum design load and locked off at 100% of the maximum design load.
- Struts and rakers not used for slurry walls, tangent and secant piles, shall be preloaded to 50% of the maximum design load.

- Struts and rakers used to support slurry walls, tangent and secant piles, shall be preloaded to 100% of the maximum design load.
- Tieback, raker, and strut loads shall be shown on the shop drawings.
- Excavation shall not be allowed to proceed for more than two (2) feet below the point of lateral support before the main bracing members are installed and preloaded.
- Earth berms are permitted when required for the installation of rakers and heel blocks. Slopes on the berms are to be no steeper than one (1) vertical to one and one half (1-1/2) horizontal.

Analyze bearing capacity for heel blocks based on accepted methods of analysis of inclined footings. A minimum safety factor of three (3) shall be applied to obtain the allowable bearing capacity. The heel block spacing and design shall consider the interaction of the heel blocks on the supporting soil. Suitable reductions in the allowable bearing capacity of the soil shall be made to account for any overlapping soil stresses.

Steel sheet piles used adjacent to DC Water structures shall be hot-rolled, steel sheet piles. Lateral soil pressures for sheet piles shall be based on undrained condition. For adequate stiffness Z-profile sheet piles are recommended. For sheet piles terminating at top of rock above the base of excavations, the sheet piles shall be laterally supported in an approved manner before the start of rock excavation. Sheet pile deflections shall be calculated and included in the submissions; maximum allowable deflection of sheet piles is half inch (½”).

Slurry (diaphragm) walls consist of structural cast in place concrete walls constructed by tremie placement of concrete in a pre-excavated, slurry filled trench. Slurry wall panels excavated adjacent to DC Water structures shall have a minimum thickness of three (3) feet and maximum length of ten (10) feet. Slurry wall bearing capacity and slurry wall deflections shall be calculated and included in the submissions. Slurry walls shall be analyzed in accordance with the requirements presented herein. For slurry walls terminating at top of rock above the base of excavations, the slurry wall shall be keyed into the rock and laterally supported in an approved manner before the start of rock excavation.

Secant or tangent pile walls consist of a line of bored piles to form a continuous wall. If the bored piles are tangent or contiguous to each other the wall is tangent pile wall. If the bored pile elements overlap to form an interlocking wall, the wall is called a secant pile wall. Piles shall be reinforced with reinforcing bar cages or structural steel shapes. Secant or tangent pile wall bearing capacity and deflections shall be calculated and included in the submissions. Secant and tangent pile walls shall be analyzed in accordance with the requirements presented herein. For secant and tangent pile walls terminating at top of rock above the base of excavations, the pile wall shall be laterally supported in an approved manner before the start of rock excavation.

New Austrian Tunneling Method (NATM) Shafts may be used with prior approval of DC Water. NATM shafts are shafts constructed using the NATM. NATM shafts can be constructed in soil and in rock. NATM shaft construction in soil entails excavation in lifts ranging from three to five (5) feet in height. Each lift is supported by a lining girder(s), normally lattice girders, embedded in shotcrete (sprayed concrete). For all NATM shafts submit supporting design calculations; proposed excavation and support procedures; proposed groundwater control measures; shotcrete design mix and field trial information; shop drawings for lattice girders, including connection details, rock reinforcement, and welded wire fabric, including details for intermediate anchors between rock reinforcement and lattice girders; concrete mix; formwork design; and concrete placement and consolidation methods.

9.3.6 Support Systems with Tiebacks

Design tieback systems such that they will be installed in soil no closer than a plane extending upward at an angle of 45 degrees to the horizontal from outer limit of lowest depth of excavation. Certify that the boundary survey for the proposed tieback support systems have been tied into DC Water’s control coordinates.

The design shall require the Contractor to:

- Stress tiebacks to proof loads equal to 140% of maximum design load and maintain proof load for 30 minutes prior to reducing to design load. Reject tiebacks which lose more than five percent (5%) of proof load.

- Apply proof loads in increments of five (5) tons at one (1) minute intervals and provide means to measure load application within accuracy of plus-or-minus five percent (5%).
- After reducing tieback load to design load, encase anchors in grout maintaining design load until anchors are fixed in place.
- In transfer of loads from jacks to support system, use fixation method which will limit load loss to no more than five percent (5%) of design load.
- Provide and maintain convenient access and appropriate means to accomplish these observations.

9.3.6.1 Preliminary and Creep Tests On Tiebacks:

Design shall require the Contractor to:

- Reapply proof loads equal to 140% of design load at each level of support in excavation on first installation on each side of excavation at horizontal intervals not exceeding 500 feet and wherever there is significant difference in soil in which tiebacks are installed.
- As specified for proof loading, apply proof loads in increments of five (5) tons at one (1) minute intervals. Provide means to measure load applications with an accuracy of plus-or-minus five percent (5%) of design load. Maintain proof load for 24 hours prior to reducing it to design load.
- Make records of axial movement with incremental applications of load as well as the amount and time of load fall-off with no pumping of jack or axial movement during the 24 hours the proof load is applied to the tieback.
- Redesign the tieback system if during the period of 24 hours:
    - Axial deformation of the tieback system occurs and exceeds 0.02 inches, or
    - The decrease in jack pressure without pumping is more than five percent (5%) after correcting for temperature changes.

9.4 LIMITATIONS ON CONSTRUCTION

The design shall prohibit the following construction activities within the specified limits of existing DC Water facilities, without a detailed engineering design approved by DC Water.

- Excavation under DC Water structures, except for access for underpinning.
- Tunneling under DC Water structures or facilities, unless prior documented approval of DC Water is obtained.
- Installation of pre-augured piles within five (5) feet of DC Water assets.
- Pile driving within 25 feet of DC Water structures, and tracks.
- Blasting within 100 feet of DC Water structures without prior approval from DC Water.

9.5 BLASTING

9.5.1 Requirements

When blasting is used, the design shall require the Contractor to:

- Verify the blasting impact with DC Water through shop drawing submittals and a blasting plan.
- The blasting plan shall include but not be limited to:
- Continuous acoustic monitoring of DC Water mains.
- The size, depth and spacing of the blast holes.
- The blasting agent.
- The average charge per hole.
- The blast monitoring program.
- The blast monitoring equipment and seismographs.

- A limitation of no more than one (1) hole being fired in the same delay period.
- Limit the peak particle velocity imparted to existing DC Water facilities caused by blasting to not more than two (2) inches per second in all cases.
- Provide DC Water with a site plan illustrating the blasting impact relative to DC Water structures if a proposed rock blasting operation is within DC Water's ZOI (100 feet).
- Perform test blasting in DC Water's ZOI, starting at 100 feet horizontal distance from DC Water's facilities or utilities.
- A test blast must start with a low weight per charge for the initial blast, which will serve as a "test blast".
- Depending on results of the seismograph reading after the test blast, an increase in the weight of the charge may be allowed.
- The maximum weight of charge shall not exceed five (5) pounds /hole/delay.

9.5.2 Certification and Documentation When Blasting

The design shall require the Contractor to:

- Request utility companies or agencies that own or control services and appurtenances affected by demolition work for a discontinuance of services.
- Provide evidence of requests for discontinuance along with certificates of severance.
- Ensure that DC Water's facilities are not impacted by demolition operations whether due to adjacent utility damage and/or temporary service discontinuation.
- Provide copies of the demolition permit to DC Water.

9.6 FIELD INSTRUMENTATION

The design shall require the Contractor to monitor DC Water assets with field instrumentation for the following conditions as required by DC Water:

- Groundwater Level and Pore Pressure.
- Lateral Ground Movement and Deformation.
- Settlement/Heave.
- Tilt/Rotation.
- Load/Stress on Structural Members.
- Earth Pressure.
- Vibration.
- Ground Temperature.

9.6.1 Use of Instrumentation

On projects where the DC Water utility is within the ZOI, the design shall require the Contractor to monitor movement of the utility soil support system. The following list describes possible instrumentation monitoring that may be needed:

- The effects of blasting or heavy construction (vibration monitoring of adjacent facilities).
- Movements in adjacent slopes and structures (survey hubs, tilt-meters).
- Ground stability during and after construction (piezometers, survey hubs/stakes, and inclinometers).
- Applied loads in reinforced wall systems, such as ground anchors, soil nails, and MSE wall reinforcing strips (load cells, strain gauges, extensometers).

- Deflection, displacement, and loads of flexible wall systems, such as sheet piles (inclinometers, survey points, earth pressure cells).
- Loads and deflections at the base of drilled shafts (load cells, extensometers).
- The effects of dewatering (piezometers or observation wells to determine drawdown at various distances from the dewatering wells).
- Temporary stability during excavations for landslide stabilization (survey hubs, stake lines, inclinometers).
- Stability of tunnel cuts, rock slopes, and rock bolts (extensometers, load cells, strain gauges).

9.6.2 Lateral Ground Movement Instrumentation

On projects where the DC Water utility is within the ZOI, the design shall require the Contractor to monitor lateral ground movement. DC Water may require movements be monitored by:

- Visual observations.
- Surveying equipment to monitor tag lines comprised of hubs/stakes, or permanently/temporarily installed reflectors.
- Inclinometers.
- Other similar devices.

9.6.3 Portable Crack/Deformation Gauges

On projects where the DC Water utility is within the ZOI, the design shall require the Contractor to monitor cracks and fractures on DC Water unreinforced masonry/concrete sewers using a strain measuring tool. Tools include:

- A transparent graduated grid/scale.
- Calipers.
- Survey tape.
- Micrometer.
- Dial gauge.
- Mechanical strain gauge.
- Electrical crack gauge.

9.7 REQUIREMENTS FOR EXCEPTIONS TO CONSTRUCTING OVER WATER AND SEWER ASSETS

DC Water does not permit constructing structures over water mains and sewers unless an exception is granted. This section defines requirements, which will be considered by DC Water in determining if an exception can be granted. Completing the requirements does not guarantee an exception will be granted. It only ensures that DC Water has the necessary information to determine the impact of the proposed construction. The owner of the property and proposed construction shall:

- Perform a CIR as required by Section 9.2
- Provide necessary evaluations described in Section 3.5. Obtain and grant to DC Water an easement of the size deemed necessary by DC Water per Section 3.5.6.
- Sign an agreement or covenant which holds DC Water harmless for any damages caused by a break or collapse of the pipeline, including damages that may occur due to maintenance and repairs required to be performed on the pipeline.
- Construct access points to the pipeline for future maintenance and repairs as determined by DC Water.

- Provide and maintain 24 hour access to the pipeline to allow DC Water to perform maintenance and repairs.
- Construct facilities that allow DC Water access for repair, rehabilitation, or replacement of the pipeline in the future. This may require a “knock out” portion on floor slabs.
- Construct access pits to pipe if necessary to perform pipe inspections.
- Perform an inspection on the pipe before and after construction using a firm that specializes in pipeline inspections and is acceptable to DC Water. Submit the inspection and condition assessments to DC Water so DC Water can determine if any damage occurred during construction.
- Protect the pipeline during construction and repair any damages caused by the construction, including replacement of the pipeline if necessary.
- Repair, rehabilitate, or replace any pipe damaged during construction. Pipe inspections performed prior to and after construction will be basis for determining changed conditions.
- Design the additional applied load (structure, fill, etc.) so that it does not impose loads on the pipeline, including designing the structure to bridge or cantilever over the pipeline, using piles to deliver loads below the pipeline, ensuring footings are outside the pipeline ZOI, or other methods acceptable to DC Water.
- Implement construction restrictions that prevent heavy and/or dynamic loads from being applied to the pipeline during construction.
- Maintain a minimum of three (3) feet of cover over the pipeline during construction.
- Predrill piles when pile foundation is installed within the ZOI.
- Design footings to be outside the ZOI.
- If excavation around the pipe line is required, excavate evenly around the pipe to maintain uniform lateral pressure on the pipe.
- Design the building to withstand a catastrophic failure caused by a break or collapse of the pipeline.
- Take multiple borings along the pipeline, provide a geotechnical analysis, and develop recommendations specific to protecting the structure from a collapse of the pipeline as well as soil loading conditions to the pipeline. If geotechnical recommendations warrant design less stringent than required by this Manual and the results of the CIR, DC Water will determine which requirements need to be followed.
- Install a structural lining (CIPP, geopolymer, or carbon-fiber wrap) inside the pipe to extend the life expectancy of the pipe and reduce near-term maintenance requirements.
- Follow other requirements that are specific to the proposed construction site and proposed structure as determined by DC Water.

10. WATER BODY CROSSINGS

10.1 HORIZONTAL ALIGNMENT OF LINEAR INFRASTRUCTURE NEAR WATER BODIES

Design linear infrastructure at stream crossings to:

- Minimize the number of stream crossings.
- Cross the stream as nearly perpendicular to the stream flow as possible.

Design linear infrastructure running parallel to a stream such that:

- It is located outside of the stream bed at a distance which allows for future possible channel widening by either naturally or human-made means.
- A minimum distance of 50 feet is maintained between utilities and the horizontal limits of the Ordinary High Water Mark (OHWM) or tide elevation.
- A minimum distance equal to one (1) pipe diameter is maintained between the pipe and top of bank of any ephemeral streams, drainage swales and similar drain channels.
- A minimum of ten (10) horizontal feet is maintained between the linear infrastructure and the top of bank of any perennial streams.

10.2 DEPTH OF COVER OVER LINEAR INFRASTRUCTURE NEAR WATER BODIES

Design the tops of sewer entering or crossing streams such that:

- There is a sufficient depth below the natural bottom of the stream bed to protect the sewer line.
- A minimum of one (1) foot of suitable cover is provided where the stream is in rock.
- A minimum of three (3) feet of suitable cover is provided when the stream bed is an unconsolidated material except that cover may be one (1) foot if the proposed crossing is encased in concrete and future geomorphology of the stream channel will not undercut the bank, encasement, or infrastructure.

Show the invert of the stream channel in profile on the Contract Drawings.

10.3 PROTECTION OF LINEAR INFRASTRUCTURE FOR STORM EVENTS

Protect linear infrastructure and their appurtenances located along streams against the 100 year flood by:

- Designing the elevation of manhole rims at least one (1) foot higher than the 100 year flood elevation.
- Performing a location specific design to prevent inflow when manhole rims cannot be located at an elevation at least one (1) foot higher than the 100 year flood elevation (for example a roadway within the floodplain).
- Designing flood protection specific to the project location.

Show FEMA 100 year flood elevation contours on the Contract Drawing plan sheets.

10.4 CONCRETE ENCASEMENT NEAR WATER BODIES

Gravity sewers crossing streams shall be encased in concrete across the stream and extend at least 15 feet beyond the bank on each side of the stream.

10.5 LINEAR INFRASTRUCTURE NEAR WETLANDS

Show wetland boundaries within the limits of disturbance on project plans. The design shall insure compliance with all permit requirements and regulations for work/near wetlands.

10.6 OTHER CONSIDERATIONS

The design shall include the following additional construction requirements when utilities cross water bodies.

- Refer to Section 5.6.8 for additional requirements for inverted siphons.
- Protect pipe and joints against anticipated hydraulic and physical horizontal and vertical loads.
- Protect pipe against erosion.
- Require the pipe to be air-tested with zero (0) infiltration/exfiltration.
- Require backfill material to be stone, coarse aggregate, washed gravel, or other materials which will not readily erode, cause siltation, damage the pipe during placement, or corrode the pipe.
- Protecting the stream and sewer by designing flow diverters, energy dissipaters, drop structures or v-notch weirs.
- Prevent downstream erosion that will cause the asset to be undermined in the future.
- For force mains, install a valve on each side of a stream crossing. The valve shall be located to allow ease of operation and maintenance.

11. BRIDGE CROSSINGS

11.1 GENERAL

The design of a pipeline crossing on a bridge structure is considered a special design in every case due to the varied nature of bridge designs. The preferred design of a pipeline bridge crossing consists of:

- A straight alignment using a restrained DIP system on saddle or roller type supports.
- Pipe expansion joints, as determined by analysis, which allow the pipeline to act independently of the bridge superstructure.
- Lateral supports, particularly if a roller support system is used.

This scenario is preferred because it does not include fittings and it minimizes pipe joint deflections that create thrust forces. However, if required because of the bridge configuration, other scenarios can be designed with DC Water approval.

If metric dimensions are required for the design and contract drawings (typically due to requirements of the bridge Owner), provide both English and metric dimensions for the pipeline.

Obtain written approval from the bridge owner and/or DDOT for bridge crossings. The written approval shall include:

- Existing Bridge Structures: A letter from the bridge owner and/or DDOT stating it has reviewed the pipeline designs which allow the pipeline to be attached to its structures and that loading from the pipeline will not have a detrimental effect on the bridge.
- Proposed Bridge Structures: A letter from the bridge owner and/or DDOT and the bridge PDE, stating they have reviewed the designs and will allow the pipeline to be attached to their structures and the bridge structure will be designed for the additional pipe loads.

11.2 FITTINGS AND JOINT DEFLECTIONS ON BRIDGE STRUCTURES

11.2.1 Fittings

Avoid aerial bridge designs that use fittings. Provide justification to DC Water and obtain approval if fittings are necessary. Use of fittings requires a dedicated thrust restraint system. No fittings or connections shall be located under the approach slab.

11.2.2 Joint Deflection

Small vertical joint deflections typically are counteracted by the weight of the pipe or the support system. Horizontal joint deflections however, create a lateral force which may require a special support design. In either case, avoid joint deflections, where possible. If joint deflection is required, evaluate the thrust forces at joint deflections and design the support system accordingly. The following considerations shall be used in design:

- Minimize joint deflections.
- A maximum of 80% of the manufacturer's recommended allowable deflection is permitted.
- Bracing, sufficient to resist thrust forces developed by maximum allowable joint deflection, is required at each joint.

11.3 PIPELINE COATING SYSTEM

The pipeline, its appurtenances, and the pipe support system shall be designed to have an exterior coating comparable with the life expectancy of the bridge. The coating shall be suitable for the corrosive effects of road salts and atmospheric and weather conditions.

Metal piping suspended under the bridge-deck expansion joints tend to receive excessive "salty" spray from corrosive deicing compound, resulting in expedited exterior corrosion faster than the rest of bridge components. A wax wrap tape shall be included in the design for this segment of the pipe to guard against such higher risk of external corrosion.

The contract specifications shall include installation precautions and special provisions for the protection, application and repair of the exterior coating during construction.

11.4 PIPELINE IDENTIFICATION

Include the requirement to label the pipeline with identification markings on the exterior of the pipeline. Locate markings such that they are legible from access locations. Markings shall include:

- The utility name (DC Water).
- Pipeline working pressure (psi).
- Contents (water, sewer, etc.).

Pipeline lettering shall:

- Be one third (1/3) of the pipe outside diameter, but not larger than four (4) inches in height.
- Consist of stenciling with a high-quality paint.
- Begin within 50 feet of the bridge abutments and repeat at differential intervals of no more than 200 feet.
- Have one (1) identification marking in every bay bounded by beams and diaphragms through which the pipeline passes.

11.5 ISOLATION, AIR RELEASE, AND DEWATERING VALVES

Design valves to include the following requirements:

- One (1) valve on each side of the bridge for isolating the pipeline on the bridge.
- Storm and gravity sanitary sewers shall also have vaults with structures to isolate the pipe on each side of the bridge.
- Locate and design valves for thrust restraint in the closed position.
- Locate valves far enough away from the bridge abutment/backwall to prevent disturbing the valves or compromising the valve restraint system during bridge maintenance.
- Provide a dewatering valve at a location that permits the pipeline, when isolate, to be fully drained by gravity.
- Install an air release at high points and other locations if determined appropriate during hydraulic analysis.

11.6 LOCATION OF PIPELINE ON BRIDGE STRUCTURE

There are three (3) general locations on bridges where a pipeline could be located. They include:

- Under the bridge between two (2) adjacent girders.
- On the exterior side of the bridge, and
- Within a designated utility corridor.

The location chosen for design will depend on factors such as the configuration and material construction of the bridge, accessibility for maintenance of the pipeline, and the bridge, etc. In any case, the following guidelines apply.

- Vertical clearance between the bridge and the roadway below, railroad, etc. must not be reduced. Entire installation (pipeline, pipe supports, supporting brackets, etc.), must be above the bottom of the highest adjacent bridge stringer.

- Vertical clearance between the top of the pipe or pipe bells/flanges and the underside of the bridge deck or structural members shall be a minimum of six (6) inches. Evaluate the possible vertical travel of the pipe due to deflection of the bridge structure and provide adequate clearance accordingly.

11.7 PIPE THRUST

The pipeline design shall prevent thrust forces from the buried pipeline to be transferred to the bridge structure. Thrust forces should pass through the bridge back wall/abutment in a sleeve. The design shall include:

- A ductile iron sleeve, sized large enough to allow for installation and removal of the pipeline.
- A sleeve large enough to allow the largest pipe joint to pass through without touching the casing.
- The void between the pipeline and the sleeve to have a using a mechanical means such as “Link Seal” that is made water tight.

Design the pipeline to include the following:

- A minimum of four (4) feet of cover over the top of the pipe is required beyond the back wall/abutment.
- The first and subsequent buried pipe joints beyond the back wall/abutment shall have vertical deflections down, so that four (4) feet of cover over the pipeline is achieved as soon as possible.
- At the bridge back wall/abutment, the minimum cover can be reduced to three (3) feet.
- Withstand differential settlement of the backfill behind the bridge abutment wall.
- Fully restrained joints.
- Lateral supports designed to allow for expansion and contraction along the pipe.

The minimum lateral support to be provided at each joint of the pipeline is given by:

$F = 0.1PA$ or
$F = S_f\, 2PA\, (\sin Ø/2)$ (whichever is larger).

Where:

F = Thrust force (lb).
S_f = Safety factor (1.5).
P = Design pressure (psi).
A = Cross section area of pipe (use OD of pipe) (in^2).
$Ø$ = maximum permissible pipe joint deflection (degrees).

11.8 PIPE LOAD ON BRIDGE STRUCTURE

Design for pipeline loading on the bridge. Loads include but are not limited:

- The pipe being full of water.
- The weight of the pipe appurtenances (expansion joints, couplings, etc.).
- The pipe support system.
- Other pipe loads per AASHTO (wind, earthquake, shock, impact, etc.).

11.9 ATTACHING PIPELINE TO BRIDGE STRUCTURE

Coordinate the pipeline support system with DDOT and any other applicable agency. The pipeline support system design shall:

- Include supports that are independent from other loads, utilities, etc.
- Not include welding to the bridge structural members, unless otherwise approved by DDOT and any other applicable agency.
- Shall take into consideration the various components of the bridge structure and shall be located without interference to the bridge components.

- The design of the support system shall be based on the following standards:
- DIPRA, *"Design of ductile iron pipe on Supports"*.
- ANSI/MSS SP-58, Pipe Hangers and Supports – *"Materials, Design, Manufacture, Selection Application, and Installation"*.
- ASTM F708, *"Standard Practice for Design and Installation of Rigid Pipe Hangers"*.
- Account for any movements due to thermal expansion and contraction of the pipeline on the supports so that damage will not occur to the pipe coatings or linings.
- Be designed for free axial movement of the pipeline, unless the pipeline is designed to be restrained by the supports, (i.e., fixed to the bridge at each pipe joint).
- Shall inhibit galvanic action.
- Electrically insulate the pipeline from the pipe supports.
- Prevent lateral and vertical movement.
- Consider any anticipated shock or impact loading when selecting and specifying the pipe hangers, rollers, supports, etc.
- Require a minimum of two (2) vertical supports per pipe length and at least one (1) lateral support per pipe joint shall also be provided.

11.10 DESIGN OF PIPELINE FOR EXPANSION AND CONTRACTION

Fluid flow inside a pipeline as well as ambient temperature changes throughout the year will affect expansion and contraction of the pipeline with respect to the bridge. The bridge and the pipeline expansion could differ for the following reasons:

- Differences between the pipeline and bridge temperature due to the pipe temperature being affected by the temperature of its contents (water and sewage).
- Differences in the coefficients of thermal expansion between the pipeline and bridge materials.
- The location of the bridge expansion joint may concentrate movement relative to the pipeline.
- Expansion and contraction in conjunction with thrust forces could introduce excessive stresses on the pipeline, pipe joints and/or the pipeline supports.

Evaluate thermal expansion and contraction of the pipeline and the bridge and provide the necessary provisions in the design as follows:

- The design change in temperature (ΔT) shall be a minimum of 120°F.
- When lining a pipe on a bridge crossing, the liner shall accommodate the bridge movement.
- The axial thrust forces are not transmitted across the pipe expansion joints.
- Where practical and permissible, locate the expansion joints where they can be easily accessed for inspection and maintenance the expansion joints.

Include on Contract Drawings:

- A table or a formula which specifies expansion joint gap widths to be set in the field at ambient temperature at the time of installation.
- The requirement for the Contractor to obtain the pulling force necessary to actuate the expansion joint from the pipe manufacturer, and restrain or anchor the pipe accordingly.

11.11 DESIGN OF PIPELINE TO PREVENT FREEZING

Evaluate all pipeline bridge crossings for freezing. Clearly indicate the assumptions and method used for analysis in calculations. If required, design insulation and/or heat tracing for the required thermal protection. Design shall consider requirements for shielding, support and protection from damage, shielding, and future maintenance requirements.

11.12 DESIGN OF CATWALK

Design the pipeline to be accessible for inspection and maintenance. If a catwalk is required, the catwalk shall be designed as follows:

- With two and a half feet (2’-6”) minimum width, safety handrails on both sides, and fixed ladder for access.
- With a minimum live load of 100 psf.
- Constructed of welded galvanized steel or aluminum bar grating.
- Railings and supports may be hot dipped galvanized steel or aluminum.
- The catwalk and all appurtenances shall meet all requirements of OSHA and other regulatory agencies.

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12. EROSION AND SEDIMENT CONTROL

Evaluate the need for erosion and sediment control in every project. Ensure requirements for sediment and erosion control are clearly stated in the Contract Documents.

Sediment and erosion control guidelines are set by DOEE. The documents to be used for reference are the Standards and Specifications for Soil Erosion and Sediment Control, "*Erosion and Sediment Control Handbook"* by DCRA.

For work on DC Water infrastructure outside the District of Columbia, sediment and erosion control guidelines are set by the appropriate jurisdiction (such as the MDE or DEQ).

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13. STANDARD SPECIFICATIONS AND DETAILS

13.1 USE OF STANDARD SPECIFICATIONS AND DETAILS IN DESIGN

DC Water has developed standard specifications and details for use in constructing projects. There are several purposes for using standards including:

- Consistency between finished projects.
- Improved construction quality.
- Reduced costs compared to “one-on” designs.
- Consistency in inspection requirements.
- Sets minimum standards for the constructed project.

It is expected that the PDE will have a comprehensive knowledge of the standard specifications and details and will implement them into the design to the greatest extent possible. If a conflict between necessary design requirements and the standards is identified or if the PDE determines that the standards do not provide the level of construction quality and integrity necessary for the design, notify DC Water in writing. DC Water will work with the PDE to resolve the conflict and develop a solution that meets the necessary design requirements.

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APPENDIX A

PRESSURE ZONE MAP

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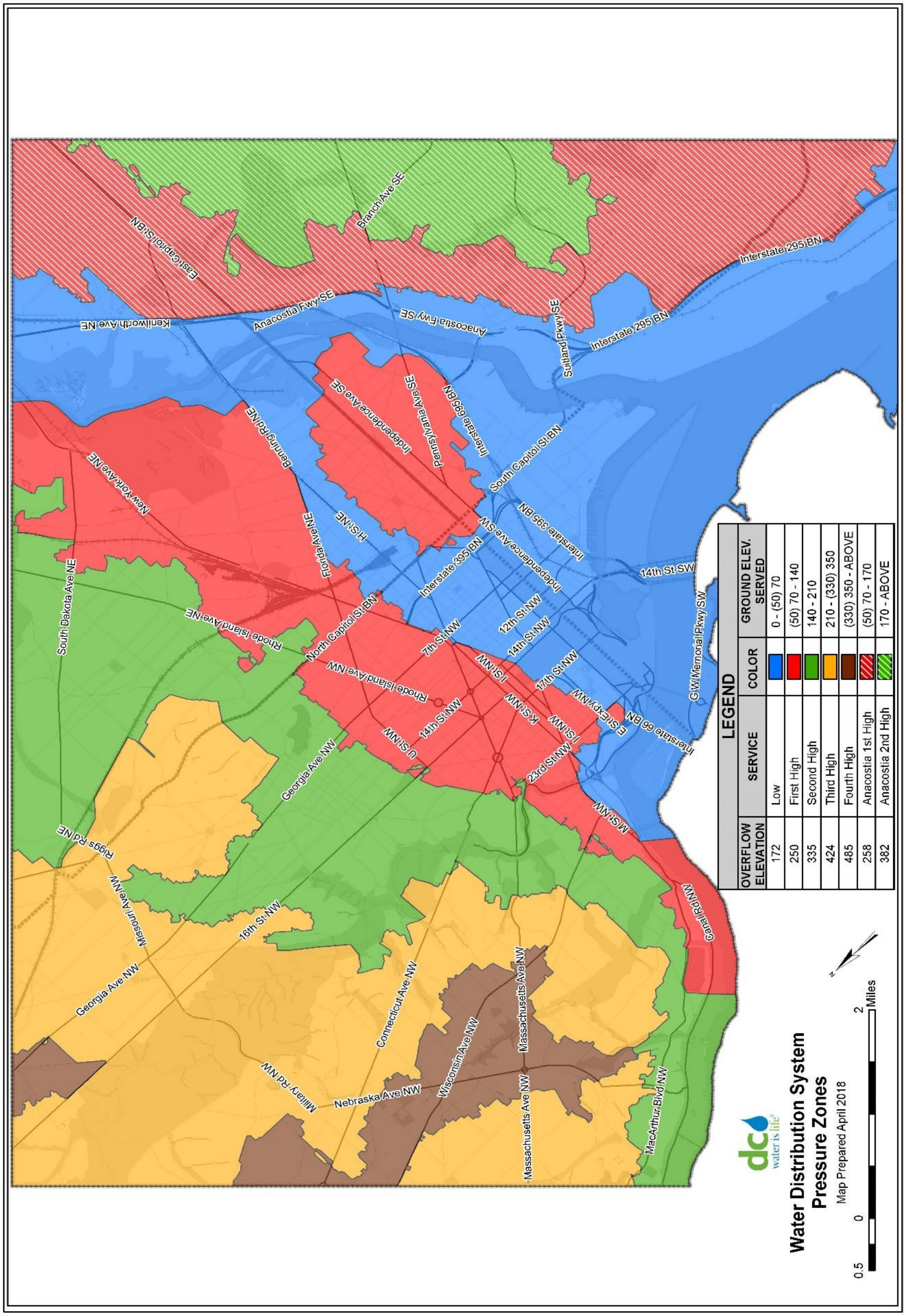
Water Distribution System
Pressure Zones
Map Prepared April 2018
water is life
LEGEND
OVERFLOW ELEVATION | SERVICE | COLOR | GROUND ELEV. SERVED
172 | Low | 0 - (50) 70
250 | First High | (50) 70 - 140
335 | Second High | 140 - 210
424 | Third High | 210 - (330) 350
485 | Fourth High | (330) 350 - ABOVE
258 | Anacostia 1st High | (50) 70 - 170
382 | Anacostia 2nd High | 170 - ABOVE
0.5
0
2
Miles
East Capitol St BN
Branch Ave SE
Kenilworth Ave NE
Anacostia Fwy SE
Suitland Pkwy SE
Interstate 295 BN
Independence Ave SE
Pennsylvania Ave SE
Interstate 695 BN
South Capitol St BN
Interstate 395 BN
Independence Ave SW
14th St SW
G W Memorial Pkwy SW
Interstate 66 BN
E St Expy NW
17th St NW
14th St NW
12th St NW
H St NE
Florida Ave NE
Benning Rd NE
New York Ave NE
South Dakota Ave NE
Rhode Island Ave NE
North Capitol St BN
7th St NW
Rhode Island Ave NW
14th St NW
U St NW
K St NW
I St NW
23rd St NW
M St NW
Canal Rd NW
Georgia Ave NW
Riggs Rd NE
Missouri Ave NW
16th St NW
Connecticut Ave NW
Massachusetts Ave NW
Wisconsin Ave NW
Nebraska Ave NW
Military Rd NW
MacArthur Blvd NW

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APPENDIX B

CORROSION CONTROL CHECKLISTS

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FORM PDM VOL 3 - 01

PHASE 1 – PRELIMINARY CORROSION ANALYSIS CHECKLIST

Contract: ____

Project: ____

Project Design Engineer (PDE): ____

Preparer (Print):_________________________ **Reviewer (Print):**_______________________________

Preparer (Signature): ______________________ **Reviewer (Signature):**_________________________

Date: ________________

Section of Pipeline Analyzed: ____

Additional Sections of Pipe and Checklists: ☐ - Yes ☐ - No

Instructions:

Complete this checklist and submit it with the relevant references to DC Water. Analyze each section of pipeline using a separate checklist. When piping is separated by existing piping to remain, each portion of piping is considered an independent section. Additionally, major changes in alignment, line branches, and significant long lengths of pipe through different lay conditions are considered independent sections of pipeline. Indicate in the space above if additional sections of pipe are analyzed.

Respond to each of the following questions. Refer to Section 8 Corrosion Control of the Project Design Manual Volume 3 – Linear Infrastructure Design for information on conducting the Phase 1 - Preliminary Corrosion Analysis. If any of the following criteria are satisfactorily met, include the proposed boring plan with the submittal and then, upon approval from DC Water, proceed to Phase 2 – Testing.

Analysis:

1. Is the proposed pipe diameter 16 inches or greater?

   ☐ - Yes ☐ - No Reference: _________________________

2. Are any of the listed potential stray current sources within 2,000 feet of the section of pipe?

WMATA transit line:	☐ - Yes	☐ - No	Reference: _______________________
Anode ground bed:	☐ - Yes	☐ - No	Reference: _______________________
High voltage structure:	☐ - Yes	☐ - No	Reference: _______________________
Welding shop:	☐ - Yes	☐ - No	Reference: _______________________
Other potential source:	☐ - Yes	☐ - No	Reference: _______________________

3. Will this section of pipe be installed within a “High Consequence” area with a history of breaks?

   ☐ - Yes ☐ - No Reference: _________________________

4. Are there special circumstances for this section of pipe that need to be considered?

   ☐ - Yes ☐ - No Reference: _________________________

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FORM PDM VOL 3 - 02

PHASE 2 – TESTING CHECKLIST

Contract: ____

Project: ____

Project Design Engineer (PDE): ____

Preparer (Print):________________________ **Reviewer (Print):**______________________________

Preparer (Signature): ____________________ **Reviewer (Signature):**___________________________

Date: ________________

Additional Sections of Pipe and Checklists: ☐ - Yes ☐ - No

Instructions:

Complete this checklist and submit it with the relevant references to DC Water. Analyze each section of pipeline using a separate checklist. When piping is separated by existing piping to remain, each portion of piping is considered an independent section. Additionally, major changes in alignment, line branches, and significant long lengths of pipe through different lay conditions are considered independent sections of pipeline. Indicate in the space above if additional sections of pipe are analyzed.

Respond to each of the following questions. Refer to Section 8 Corrosion Control of the Project Design Manual Volume 3 – Linear Infrastructure Design for information on conducting the Phase 2 - Testing. If proposed corrosion control measures include a CP system, proceed to Phase 3 after obtaining approval from DC Water.

Analysis:

1. What pipe materials will the proposed pipe attach to?
   ☐ - Ductile Iron ☐ - Cast Iron ☐ - PCCP ☐ - Steel ☐ - Other
   Reference: ____

2. What corrosion control system will the proposed pipe attach to?
   ☐ - None ☐ - Coated ☐ - Bonded ☐ - CP ☐ - Other
   Reference: ____

3. Is there groundwater at pipe depth?
   ☐ - Yes ☐ - No Reference: ____

4. Stray current exposure is:
   ☐ - Negligible ☐ - Moderate ☐ - Severe Reference: ______________________________

5. Is the Soil Condition Analysis Value > 15?
   ☐ - Yes ☐ - No Reference: ____

6. Based upon these results, what corrosion control measures are recommended?
   ☐ - Coating ☐ - Bonding ☐ - CP ☐ - None
   Reference: ____

7. What corrosion control measures are proposed?
   ☐ - Coating ☐ - Bonding ☐ - CP ☐ - None
   Reference: ____

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