District Department of Transportation

Design and Engineering Manual

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District Department of Transportation

DISTRICT OF COLUMBIA

DEPARTMENT OF TRANSPORTATION

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DEPARTMENT OF TRANSPORTATION

FOREWORD

Washington, DC is a thriving and growing city with a rich history whose continued success relies on its transportation infrastructure. Our transportation solutions require engineered designs that are thoughtful of all users, contexts and the environments.

The District of Columbia Department of Transportation (DDOT) Design and Engineering Manual has not been updated since 2009. This edition updates critical aspects of the manual to reflect advances in industry guidance, provides information on topics that were not previously covered, eliminates inconsistencies and redundancies, and updates references and coordination with other DDOT manuals. The transportation field is dynamic and continues to evolve, and therefore, this manual will be updated on a recurring schedule to stay current.

The users of this manual will notice several meaningful improvements to key areas. For example, Green Infrastructure has been incorporated into a newly formed, comprehensive Drainage, Stormwater Management and Hydraulics chapter. Chapters on structures and geotechnical engineering have been clarified and simplified, while new chapters such as Value Engineering, Project Deliverables, Bridge Load Rating Analysis and Reporting, and Intelligent Transportation Systems have been added.

DDOT believes in fair and equitable transportation decisions for all of the traveling public and all users of the public space. DC is robust in supporting a variety of transportation infrastructure, public realm amenities, sustainable practices, and multimodal accommodations. We hope with this revision, engineers, designers and consultants find an improved resource at their fingertips to enhance the quality and livability for all residents and users. We also value your feedback should you identify potential improvements or recommendations that may be considered during future revisions.

Respectfully,

Leif Dormsjo
Director

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1 Overview

1.1. Introduction

The District of Columbia Department of Transportation (DDOT) Design and Engineering Manual describes the Department's procedures and standards for preparing project construction documents. The primary purpose of the manual is to enable engineers, consultants and private developers to efficiently and effectively develop projects that meet the District's policies and standards, while providing sufficient flexibility to allow creative solutions and the application of engineering judgment to deliver a context-sensitive, multimodal public realm. Designers who use this manual are encouraged to form partnerships with urban planners, landscape architects, environmental specialists, historic preservation specialists, residents and others whose perspectives will enhance the quality of the District's public spaces, roadways, and the communities served by them.

The DDOT Design and Engineering Manual (hereinafter called "manual" or "standards") consists of three parts: PART I – Process and Procedures, PART II – Project Development and PART III – Engineering and Design. This manual defines the policies, procedures and requirements for the benefit of all parties in order to develop and construct safe, efficient, sustainable and easily maintained projects. Therefore, it is the objective of this manual to:

- Improve the safety of pedestrians, cyclists and drivers throughout the District.
- Increase non-vehicular transportation modes to meet the mobility and economic development needs of the District.
- Maintain and enhance the District's transportation infrastructure and streetscapes, while balancing the needs of all users.
- Minimize adverse impacts on natural and environmental resources, and promote energy efficiency.
- Respect the unique character of the District and its many historic districts. Encourage flexibility in design. Ensure that public safety is maintained at all times and that public inconvenience is minimized to the maximum extent possible.
- Support the principles of Crime Prevention through Environmental Design.
- Preserve the limited physical capacity of public rights-of-way.
- Protect private property from damage that could occur as a result of construction and repair projects in the transportation network.
- Protect the District's infrastructure investment by establishing criteria for public improvements.

DDOT's Chief Engineer oversees all phases of transportation infrastructure improvement projects in the District of Columbia.

1.2. Authority and Applicability

This manual will be the main source of information and guidance for proposed construction projects in the District. Standards, including revisions and amendments, will apply to all proposed construction in public space. This manual also augments the latest edition of the **DDOT Standard Specifications for Highways and Structures**, and the **DDOT Standard Drawings.**

1.3. Document Language

This manual has been prepared in accordance with the Federal Plain Language Guidelines; therefore, the following terms are used and intended as defined below:

- "must" for an obligation
- "must not" for a prohibition
- "may" for a discretionary action
- "should" for a recommendation

1.4. Definitions

Refer to Appendices A and B respectively for a glossary of terms and a list of acronyms used in this manual.

1.5. Future Changes and Revisions

DDOT recognizes that the regulations, codes, standards and policies affecting the funding, development and design of its projects are continuously changing. Therefore, these standards will be periodically updated as necessary to add clarity or to reflect changes generally recognized as best practice in the appropriate professional and trade industries.

Comments and recommendations for revisions to the current manual may be submitted to DDOT_DEM_Suggestions@dc.gov for consideration. Any such suggestions should include the number and name of the relevant section(s) and the justification for the recommendation. Upon receipt of the suggestion, it will be reviewed by the appropriate DDOT department who will, if appropriate, recommend proposed changes for consideration by the Chief Engineer, and other potentially affected departments. All amendments and revisions must be reviewed and approved by the Chief Engineer.

1.5.1. Policy Revisions

The Director of the Department of Transportation or the Chief Engineer of the Infrastructure Project Management Administration may revise policy, but not regulations and legal provisions adopted by an act of law.

1.5.2. Technical Revisions

Technical revisions and corrections to these DDOT standards will be made in accordance with good engineering standards and practice. Technical revisions require the approval of the Chief Engineer. If technical revisions are deemed necessary, the revisions may be made through one of the two processes explained below.

1.5.2.1. Normal Technical Revision Process

The normal process occurs during a planned revision. These standards are periodically revised as determined necessary.

1.5.2.2. Accelerated Technical Revision Process

The process may be accelerated when it is determined that an immediate revision is necessary.

1.6. Governing Standards

Governing standards clarify the issue of interpreting and applying the provisions of the DDOT standards.

The primary references for this manual include:

1. American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets (Green Book, current version)
2. AASHTO, Load and Resistance Factor Design [AASHTO LRFD] Bridge Design Specifications
3. AASHTO, Guide for Design of Pavement Structures
4. AASHTO, Guide to the Development of Bicycle Facilities
5. AASHTO, Guide for Planning, Design and Operation of Pedestrian Facilities
6. AASHTO, Roadside Design Guide
7. *American Society for Testing and Materials (ASTM)*
8. District Department of Energy and the Environment (DOEE), Stormwater Management Guidebook (current version)
9. DOEE, Standards and Specifications for Soil Erosion and Sediment Control (current version)
10. *DDOT, Public Realm Design Manual*
11. DDOT, Green Infrastructure Standards (latest edition)

12. Applicable requirements of the Federal Highway Administration (FHWA)
13. FHWA, Manual on Uniform Traffic Control Devices (MUTCD)
14. *National Association of City Transportation Officials (NACTO) Urban Street Design Guideline*
15. *NACTO, Urban Bikeway Design Guide*
16. Transportation Research Board (TRB), Highway Capacity Manual

Whenever these standards, or any provision in any law, ordinance, resolution, rule or regulation of any kind, contains any restrictions covering any of the same subject matter, the more restrictive or higher standards or requirements will govern. Whenever it is not clear which standard, provision, ordinance, resolution, rule or regulation applies because of a conflict between the regulation or guidance on the same subject matter, the Director of the Department of Transportation or Chief Engineer of the Infrastructure Project Management Administration shall decide the standard or provision that governs and, or controls for a specific project.

1.7. Design Exceptions

The District of Columbia is a well-established, historic and dynamic urban environment. Often the existing infrastructure does not meet current AASHTO design criteria, and reconfiguring the public space to meet these standards would be both cost-prohibitive and also contrary to the overall objectives of this manual as outlined in **Section 1.1**.

That said, it is important to document and record the reasons exceptions from standards are necessary. Properly documenting exceptions is as important to successful design delivery as developing plans, specifications and estimates themselves.

The detailed procedures for documenting exceptions is are included in **Chapter 12, Project Deliverables,** along with all other deign submittal requirements.

2 Project Development

2.1. Introduction

Transportation is an integral part of nearly every aspect of the District of Columbia's highly competitive, increasingly global and largely service-oriented economy. Contemporary cultural values emphasize mobility, independence and immediate access to an ever-expanding range of products, services and activities. The District of Columbia's economic growth and overall quality of life are directly dependent on a transportation system that can move people and products safely and efficiently. Such a network must be flexible and responsive, interconnecting various modes of transportation and land uses. The transportation network and surrounding land uses need to be integrated to manage capacity, user expectations and behaviors, community health needs, crime prevention and environmental considerations.

The District Department of Transportation (DDOT) is the lead agency responsible for developing, maintaining and enhancing the District's transportation system, a system that includes multi-modal roadways, bridges, premium transit facilities, recreational trails, bicycle/pedestrian facilities, recreational watercraft and water taxis. Rapidly changing trends in development patterns, transportation funding, mobility needs and economic conditions place high demands on the District's transportation network. To adapt to a changing environment where land use and community needs are becoming even more dependent on transportation and vice versa, DDOT has implemented a Transportation Program Development and Project Development Process (see Figure 2-1) that will ensure transportation funding is:

- Used to maintain existing infrastructure first
- Applied in a manner that supports smart land-use decisions
- Focused on better use of existing capacity, realizing that adding capacity is not always the answer
- Programmed based on realistic project (design and construction) cost estimates

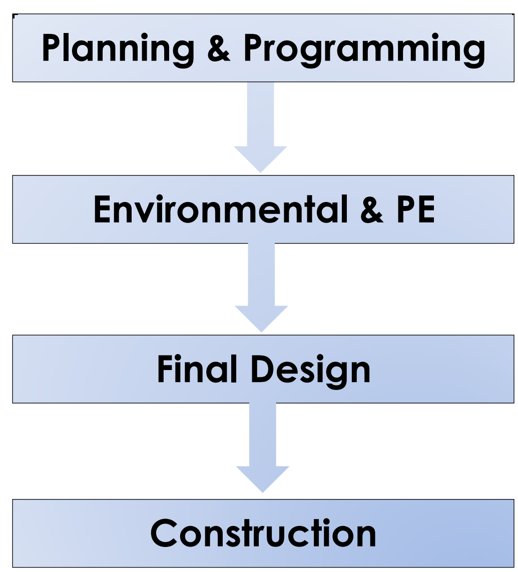

Figure 2-1 | Project Development Process

During the initial transportation planning phases, DDOT and applicable project owners and stakeholders (refer to **Appendix C**) take responsibility for identifying potential transportation problems. This group identifies project needs, develops potential alternatives, ensures environmental responsibility and creates a fundable transportation plan, which contains proposals and potential projects that will sustain and enhance the transportation network and the District's communities.

DDOT should work collaboratively with project owners and stakeholders prior to and during Transportation Improvement Program (TIP) development. Participants should be aware of DDOT's processes and guiding principles (discussed later in this chapter) and consider these concepts when evaluating proposals to move forward with TIP development.

Once the proposals become projects to be developed and delivered, information gathered before and during the TIP process will be used in the project delivery process. During Post-TIP activities, DDOT's processes and other supporting principles (e.g., context-sensitive solutions, flexibility in highway design and smart growth) will be used to develop an efficient, affordable and sustainable transportation network.

Before developing a transportation program, DDOT must clearly lay out the goals and objectives of the District of Columbia's transportation system, which set the District's transportation direction for a 20-year period and define the direction of the Department. These goals are supported by the Transportation Program Development and Project Delivery Process. Transportation projects being considered (or proposed) for inclusion in the TIP/Statewide Transportation Improvement Program (STIP) must support the District's transportation system goals before they can evolve into projects and eventually be constructed. The process defines the steps required to systematically identify problems, shape conceptual solutions into proposals, and eventually advance projects through the planning, design and construction phases. The process is an effective mechanism through which DDOT responds to the District's diverse transportation needs. The plan and process were developed to provide a sustainable transportation system and adhere to the 10 core principles explained in **Section 2.2**.

The project development process consists of four steps, the first three of which are iterative, in that proposals that do not make it into the TIP are not necessarily dismissed from consideration. Proposals that are not included in the TIP, but are still in the Long-Range Transportation Plan (LRTP), may go through the first three steps multiple times before being put on the TIP as a project to advance to construction.

2.2. DDOT Core Principles

All DDOT projects should be evaluated in the context of the following core principles:

1. Capital Assets

- A baseline project cost estimate should be prepared as early as possible in the process; the project will eventually be designed to this baseline cost. Updated estimates should be compared to this baseline throughout project delivery. Projects must be fundable to be constructible.

2. Choose Projects with High Value-to-Price Ratios

- The goal is to find the best solution that:
  - Meets the identified project needs
  - Fits within the transportation, community, land use, environmental and fiscal context
  - Is community-supported
  - Is affordable based on fiscal constraints
  - Can be implemented in a reasonable time frame
  - Achieves the greatest benefits for the money spent compared to other projects
- The degree of improvement must be justified by the total required investment; actual metrics for making this determination will need to be developed on a project-by-project basis.

3. Enhance the Local Network

- Encourage solutions that utilize current roadway alignments
- Reduce the number of environmentally impactful projects
- Use existing rights-of-way
- Emphasize network connectivity
- Better manage capacity by integrating land use and transportation planning
- Strive for access and corridor management

4. Look Beyond Level of Service

- Project approach should fit the project need, type and complexity, and provide a full range of affordable, cost-effective solutions
- Concepts should be filtered through the best judgment of a multi-disciplinary team
- Design exceptions and waivers may be appropriate depending on the project

- Achieve balance between design speed, desired operating (running) speed and posted speed
- Use Measures of Success (Performance Measures)

5. **Safety First, and Maybe Safety Only**

- All projects require a safety review; projects above a certain dollar threshold require a safety audit
- Safety projects must provide documentation on the expected performance of the proposed improvements (Measures of Success or Performance Measures)
- Crash fatality reduction is always a goal; implement the mayor's Vision Zero Initiative
- Procedures from the Transportation Research Board's **Highway Safety Manual** should be incorporated as appropriate

6. **Accommodate All Modes**

- Conform with the DDOT Complete Streets Policy
- Consider pedestrian needs (walkable communities program, well-connected sidewalks, Americans with Disabilities Act requirements).
- Consider needs of bicyclists
- Incorporate public transit (bus, rail or street car) where applicable
- Use a multi-disciplinary team that includes members with expertise in each transportation mode, as appropriate for the project

7. **Leverage and Preserve Existing Investments**

- Focus should be on the overall transportation network and how the project fits into that network, not only on the individual roadway
- Prioritize redevelopment (maintenance/preservation) of existing infrastructure first (asset management)

8. **Build Communities and Neighborhoods**

- Ensure consistency with local planning
- Develop transportation networks that serve all modes of travel: pedestrian, bicycle, public transit and motor vehicle
- Consider:
    - Local streets and Safe Routes to School programs

- Land use, transportation and economic development

9. Understand the Context; Plan and Design Within the Context

- Respect the community character
- Understand the full context (transportation, environmental, community, land use and fiscal)
- Understand place (suburban network, urban neighborhood, urban core) and how it affects design
- Respect existing and future land use
- Match vehicular speeds (desired operating speed/design speed) to the local context and place
- Identify opportunities to change facilities (lanes and lane widths, sidewalks, environment-friendly streetscape, improved drainage) to better reflect the local context

10. Develop Regional and Other District Government Agencies as Strong Land Use Partners

- DDOT's Transportation Program Development and Project Delivery Process encourages more meaningful participation from local and regional transportation planning agencies in project development
- Integrate land use planning with transportation planning (existing and future)

More details on each of DDOT's 10 Core Principles are contained throughout this manual. It is imperative that DDOT Project Managers, Planners, and Designers, along with the project owners and stakeholders, follow these principles and DDOT's processes.

2.3. Project Development Purpose and Objectives

This manual was developed as a guide for DDOT and its stakeholders, consultants and contractors who are responsible for advancing transportation projects. Familiarity with the process will contribute greatly to improved efficiency in the coordination and advancement of District transportation projects.

This manual is not intended to be a substitute for experience or sound judgment. Because every project offers different challenges, creative application or modification of the procedures described in this manual may be necessary to advance a project and achieve project-specific objectives.

The flexibility allowed by current laws, policy, and this process, coupled with DDOT's goal to improve the quality of projects delivered in terms of scope, cost and schedule, has led to the establishment of seven primary objectives for this process:

1. Focus available funds and resources on the most necessary transportation needs

Establish project purpose and need, and eliminate unnecessary projects and unrealistic alternatives, during the Planning (Pre-TIP) phase, which may require identification of appropriate funding for the Planning phase.

2. Improve cost estimating for potential projects

Undertake all appropriate engineering and environmental analyses prior to TIP/STIP activities, conduct a review of preliminary project cost estimates before placing projects in the TIP, develop metrics for each TIP to compare actual project costs to TIP/STIP estimates, and when developing preliminary costs, remember to carefully consider inflation factors so that Year of Expenditure dollars are used for the estimates.

3. Increase accuracy in project scheduling and improve predictability for project delivery

Develop a better understanding of engineering, environmental and public constraints early in project planning to facilitate development of realistic schedules that will lead to more timely delivery of projects.

4. Develop better and more accurate project scopes

Evaluate project alternatives and project design criteria, conduct preliminary studies during planning, and collect ample project-specific data during planning to better understand potential project issues.

5. Reflect DDOT's goals in project selection

Select projects that promote the integration of the District's transportation system goals and other initiatives into project planning, and develop consistent criteria for identifying and prioritizing potential projects.

6. Improve communication, coordination and cooperation within and among DDOT, the Federal Highway Administration (FHWA), Federal Transit Administration (FTA), other transportation planning entities and the resource agencies

Integrate DDOT staff into LRTP and TIP development, form a Programming Advisory Committee to review project proposals (emphasizing integrated membership), and work with agencies (including FHWA and FTA, as appropriate) earlier in the process.

7. Promote early public participation and public involvement

Provide opportunities for participation by the agencies and the public in the early stages, beginning with the development of the LRTP and continuing through prioritization and project delivery.

2.4. Project Development Process

Project development involves several distinct phases from concept to completion. Departments of transportation have different terms for how they describe these phases and define the project development process. DDOT projects are developed and executed through the following four steps:

- Planning and Programming
- Environmental Approval and Preliminary Engineering (PE)
- Final Design
- Construction

Although specific tasks may vary from project to project, the general tasks and requirements remain consistent across projects.

From planning through the design phase, and eventually to construction, more detail is added through each consecutive step, and the field of vision narrows until the focus is on a single element or improvement concept. The Planning and Programming process identifies that there is a need for an improvement. The Environmental Approval and PE process focuses on identifying what should be built. Design focuses on how something should be built. Construction, of course, builds the design, focusing on how the pieces fit together in the field.

It is important to consider Context Sensitive Solutions (CSS) in the project development process to ensure that all DDOT projects are in harmony with respect to cultural characteristics, aesthetics, community values, social needs, natural environment and transportation needs. Public involvement is not identified as a separate step in the project development process because regular public involvement occurs at every phase of project development.

2.4.1. Step 1: Planning and Programming

Planning and Programming is the first step in the project development process. Project-level planning normally occurs after system-level or statewide planning. Statewide transportation planning or system-wide transportation planning involves a higher level of planning that incorporates metropolitan and regional planning. During this phase, the "Constrained Long Range Transportation Plan," STIP and TIP are developed based on DDOT's LRTP (moveDC). During this phase, the need for a project is determined.

This determination may be a result of several different types of input: engineering studies, infrastructure condition analyses, public input or legislative input, among others. System planning is followed by the programming step in which the STIP and TIP are developed.

Following system planning and programming is project-level planning, up to the 15 percent level. This generally includes document research, data collection, problem assessment, identification of deficiencies, feasibility studies, concept studies and public involvement. Other tasks in this step may include developing a problem statement; defining the project purpose and goals; identifying key stakeholders, partners and project team members; determining project limiting factors and constraints; determining impacts to the right-of-way (ROW); and preparing a budget estimate. It is during this phase that the transportation problem that needs to be addressed is established and a project begins to take shape. The project need can be identified through various sources such as a pavement condition index, bridge condition reports, asset management reports, transportation studies, community requests, Advisory Neighborhood Commission (ANC) requests, agency or government initiatives, safety reports, the Washington Metropolitan Area Transit Authority and other agency requests and LRTPs, including specific modal elements.

2.4.2. Step 2: Environmental Approval and Preliminary Engineering

The next step of project development is Environmental Approval and Preliminary Engineering, up to the 30 percent level. This phase is sometimes also called the "Project Development" phase. The DDOT Environmental Program Branch is responsible for project development. During this phase, alternatives with the potential to solve the transportation problem are investigated, including their engineering requirements and environmental impacts. This phase typically entails public involvement, agency coordination, preliminary engineering, conceptual design, transportation engineering studies, survey work and the preparation of environmental studies and documents, including any ROW approvals.

For routine maintenance and reconstruction projects, preliminary design may occur in a separate phase; however, for large or complex projects, preliminary design is needed to identify the preferred alternative and its details that may affect traffic and neighborhoods, as well as built and natural environments. CSS values, which include being in harmony with respect to cultural characteristics, aesthetics, community values, social needs, natural environment and transportation needs, must be incorporated into all projects.

It is important to note that Final Design cannot start before Environmental Approvals are obtained, though Preliminary Design can begin. Title 23 of the Code of Federal Regulations, Section 636.103 defines "Preliminary Design" as follows: "Preliminary design defines the general project location and design concepts. It includes, but is not limited to, preliminary engineering and other activities and analyses, such as environmental assessments, topographic surveys, metes and bounds surveys, geotechnical investigations, hydrologic analysis, hydraulic analysis, stormwater management assessments, utility engineering, traffic studies, financial plans, revenue estimates, hazardous materials assessments, general estimates of the types and quantities of materials, and other work needed to establish parameters for the final design. Prior to completion of the NEPA [National Environmental Policy Act] review process, any such preliminary engineering and other activities and analyses must not materially affect the objective consideration of alternatives in the NEPA review process."

2.4.3. Step 3: Final Design

The third phase of project development is Final Design. During this phase, plan documents are developed, including engineering drawings, specifications and special provisions needed to guide construction, and detailed construction estimates. Even though any requirements for ROWs are established and approved in the Environmental Approval and PE phase, the actual ROW acquisition occurs in the Final Design stage before construction can start. Refer to **Chapter 8** of this manual for details on ROWs.

2.4.4. Step 4: Construction

The final step of project development is construction—bringing all the hard work of planning and design to reality. This step, which in many ways is the most visible phase of a project, requires follow-through on commitments that have been made to agencies and the public during earlier phases of project development.

3 Project Management

Project management and coordination are critical to the success of the project development process and the efficient delivery of projects that solve transportation problems. Effective project management and coordination require the participation of all stakeholders, partners and the community.

This chapter is intended to explain DDOT's expectations for managing the design project. The information presented is not all-inclusive, but must be used in conjunction with information found in other chapters of this manual and other DDOT documents to tailor the Consultant's project management approach to the requirements, circumstances, goals and objectives of the specific design and construction project.

This chapter discusses DDOT's minimum expectations for design project management related to:

- Design Team Structure
- Risk Management
- Quality Assurance and Quality Control
- Major Project Considerations
- Design Schedule Management

3.1. Design Team Structure

The Design Consultant must provide a staffing plan that identifies and documents project roles, responsibilities, required skills and reporting relationships for all key professionals assigned to the project. These key professionals must be the same as those proposed by the Consultant at the time of contract award unless otherwise approved by the DDOT Project Manager.

<u>Design Team Structure Deliverables</u>

- Staffing plan identifying key personnel by title, role and responsibility
- Resumes of key personnel
- Organizational chart showing reporting relationships of all key personnel
- Point of contact

3.2. Risk Management

Risk management is critical to the success of the project development process and needs to be integrated into the Consultant's project management plan. Effective risk management occurs throughout the design planning and delivery process and includes communication and coordination with all stakeholders to ensure that risks are identified and mitigation strategies are acceptable.

A risk is any factor that may negatively affect successful completion of the construction project within the approved schedule and budget. Risk management is the systematic and disciplined implementation of the Design Consultant's internal processes and procedures for identifying, measuring and controlling events that minimize DDOT's exposure to delays and unanticipated costs through the careful management of those risks.

Risk is inherent in every project. It is the possibility, not the certainty, of delays and unanticipated and uninsured costs to which DDOT is exposed. This exposure could be anything from diminished quality of an end product to increased cost, missed deadlines or project failure. DDOT expects Design Consultants to present a clear plan for minimizing uncertainty by proactively identifying and addressing each risk.

DDOT expects the Design Consultant to develop a risk mitigation plan that includes, at a minimum:

- Identifying and assessing the probability and severity of potential risks throughout the design and construction of the project. A risk register, as defined by the Project Management Institute, could be used to list, categorize and rank the risks in terms of their likelihood and severity.
- Incorporating the risk assessments into design deliverables, where applicable.
- Communicating and coordinating the results of the risk assessment with the DDOT Project Manager to ensure that proposed mitigation strategies and their trade-offs are acceptable to DDOT.
- Developing a risk management approach involving key people and processes that is understood and used by the team.

<u>Risk Management Deliverable:</u>

- A Risk Management Plan is to be incorporated into the Consultant's project management plan and must include the following:
    - Identification of all risks
    - Probability of occurrence
    - Severity (cost, schedule and scope impacts)
    - Mitigation plan for each identified risk

3.3. Quality Assurance / Quality Control Plan

At the beginning of the project, develop a Design Quality Assurance / Quality Control (QA/QC) Plan and submit the QA/QC Plan to the Program Manager for approval. During the project kickoff, discuss the QA/QC Plan with the DDOT Project Manager, and revise as necessary. The QA/QC plan must ensure errors and omissions are minimized, contract documents are technically accurate and easily understood, and that all staff members, either from the firm or from affiliated organizations, are aware of the QA/QC Plan and its implementation.

The QA/QC Plan will include and ensure the following:

- Identify the person responsible for the overall QA/QC Plan for the specific contract and the individual responsible for Quality Assurance for each discipline, and correspondingly for Quality Control.
- Perform design analysis and computations in a planned, controlled and orderly manner; document the findings so that they can be reviewed easily.
- Establish a procedure that includes cross-discipline plan reviews for conflicts that will ensure adequate inter-disciplinary coordination.
- Develop uniform methods for checking and back-checking calculations, designs, drafting and other contract document elements that do not rely on review and comments from the DDOT Project Manager.
- Establish a system of independent checking such that the original designer is at no time responsible for verifying his or her own work.
- Develop a flow chart showing the proposed process of checking, revision, back checking and coordination between the different disciplines.
- Retain and file all marked plans, draft specifications, calculations, review comments, etc. used in the checking process until completion of design. Files may be requested by the DDOT Project Manager at any time.
- Develop a system to ensure that the latest design criteria and standard drawings are being used.
- Ensure that the pay items, quantities and units of measurement are not in contradiction on contract plans, special provisions, pay item schedule and cost estimates.
- Ensure pay item completeness and that estimated quantities are accurate and costs are reasonable.
- Format and ensure completeness of Special Provision Specifications for non-standard items.
- Ensure plan clarity and completeness of details and dimensioning.
- Ensure conformance with DDOT specifications, guidelines and standards.

QA/QC Deliverables

- QA/QC Plan
- Documentation and records-related QA/QC, constructability reviews, and post-design services

3.3.1. Quality Assurance Statement

With each review submittal, the Professional Engineer whose signature and seal will appear on the contract drawings must submit a statement with the transmittal letter that:

- The standards, codes and criteria applicable to the design have been observed.
- The QA/QC Plan has been implemented, and the designs, computations, drawings and other contract elements have been checked thoroughly and back-checked.

3.3.2. Documentation

Maintain current Quality Assurance and Quality Control records on approved forms and/or format appropriate for Quality Assurance and Quality Control operations, activities and checks performed, including the work of joint-venture firms and subconsultants.

3.4. Independent Constructability Review

During constructability review, the Consultant reviews the design submitted by DDOT or by another consultant and engages in the following activities:

- Attend a design briefing by the Program Manager or his/her designee outlining project background and details.
- Accompany the Program Manager or his/her designee on a site visit to become familiar with field conditions.
- Collect information and prepare individual reports as specified in the latest constructability review.
- Read results of preliminary reviews and provide recommendations.
- Modify individual reports to reflect the recommendations.
- Prepare a draft constructability report and submit it to DDOT for review.
- Revise the report per comments received and resubmit it to the DDOT as a final constructability report.

3.5. Post-Design Support Services

The Consultant will provide support services consisting of altering designs in response to unanticipated or changed field conditions, analyzing and participating in proposed design changes, and ongoing interpretation and classification of design plans.

The Consultant will perform the following tasks in response to specific DDOT directives:

- In response to unanticipated and varying field conditions or changes in construction procedures, the Consultant will conduct on-site field reconnaissance and, where required, prepare Field Change Sheets modifying pertinent contract plan sheets.
- The Consultant will analyze and make recommendations on the implementation of design changes proposed by DDOT or the Construction Contractor and provided by DDOT. This includes Maintenance and Protection of Traffic plans.
- The Consultant will interpret and clarify design concepts, plans and specifications.
- The Consultant will review structural shop drawings for construction and release upon acceptance.
- The Consultant will attend progress meetings with DDOT when requested.

3.6. Major Project Considerations

The DDOT Project Manager will confer with the DDOT Chief Engineer as to the extent of construction required for the project. The Design Consultant will validate and advise the DDOT Project Manager as to the extent of construction required for the project.

It is important to note that terminology related to repair and replacement considerations differ for roadway and bridge projects. For roadway projects, considerations range from resurfacing to streetscape and rehabilitation to reconstruction. For a bridge project, options range from repair to rehabilitation to full replacement.

Roadway and bridge projects generally have limited environmental and right-of-way (ROW) issues. However, rehabilitation projects do offer opportunities to make streetscape improvements, including landscaping; introducing aesthetic and structural enhancement; upgrading intersections, crosswalks, streetlights, sidewalks, traffic signals, wheelchair ramps, curbs, gutters and utility systems; and improving alternative modes of transportation.

Specific considerations for rehabilitation must be determined on a project-by-project basis. For bridges, the Designer will consider whether to rehabilitate or replace the structure prior to beginning design engineering. Roadway reconstruction and bridge replacement projects involve the total reconstruction of the pavement and bridge, respectively, and all other necessary improvements.

Prior to starting design work, the Design Consultant, in coordination with the DDOT Project Manager, should consider the following items, where applicable:

- Environmental documentation requirements
- ROW acquisitions and clearances
- Traffic issues
- Street lights
- Structures
- Materials for pavement
- Trees and landscaping
- Utilities
- Drainage/stormwater structure upgrade and management
- Agreements and approvals
- Community involvement
- Maintenance (required involvement of the appropriate DDOT maintenance divisions including Asset Management, Traffic, Street Light, Urban Forestry, Stormwater Management, etc.)
- L'Enfant Plan
- Capitol Hill
- Project in a historic district, on a historic bridge or on historic property (boundary markers)
- Business Improvement Districts
- Streetscape enhancement
- Bike/pedestrian improvements
- Federal Lands Clearance (National Park Service, etc.)

3.6.1. Environmental

Project-specific environmental commitments made during project development, whether in Environmental Impact Statements, Environmental Assessments, Categorical Exclusion documentation or National Historic Preservation Act Section 106 memoranda of agreement or other relevant documents, must be incorporated into the design plans. Environmental commitments can involve historic preservation issues, Clean Water Act requirements and park land requirements, as well as air and noise issues. Refer to the **DDOT Environmental Policy and Process Manual** for details. Project-specific mitigation commitments generally involve avoidance, protection, minimization or replacement of protected resources.

Refer to **Chapter 5** of this manual or the **DDOT Environmental Policy and Process Manual** for more details.

3.6.2. ROW Acquisition and Clearances

ROW acquisition and clearance considerations on a project generally include:

- ROW acquisition procedures
- Government land permission/permits
- National Parks Service/Other Federal Lands acquisition and Special Use permits
- ROW certifications
- Utilities clearance
- Railroad clearance
- Airport/heliport clearance
- Coast Guard (Navigation) clearance
- Special Flood Hazard Area clearance

Refer to **Chapter 8** of this manual for more specific information on ROW acquisition and clearance processes.

3.6.3. Traffic

Traffic considerations on a project generally include a review of the following:

- Traffic design data
- Traffic accident analysis (see DDOT's Traffic Accident Reporting and Analysis System)
- Turning movements/access issue signal warrants
- Traffic movement diagrams
- Intersection/interchange design
- Traffic issues
- Bike/pedestrian issues
- ADA accommodations
- Transit accommodations
- Traffic calming
- Traffic signal plan

- Lighting plan
- Permanent signs and markings
- Construction traffic control plans

The Program Manager or his/her designee must confer with Transportation Operations Administration (TOA) staff for their approval on traffic issues. The design of safer public streets and highways begins at the Design Scoping Review and continues through construction advertisement. Highway safety improvements can be divided into three areas:

1. Roadway safety improvements (visibility and operation characteristics)
2. Roadside hazard elimination (forgiving roadside concepts)
3. Traffic engineering and operations (improving traffic regulations, warnings and directions)

The Program Manager is responsible for providing a design with safety as a primary objective. In many instances, benefits gained from a specific safety design or treatment can equal or exceed additional cost.

The Program Manager can best utilize limited design funds by conducting a benefit/cost analysis and preparing safety reports detailing feasible alternatives and recommendations.

The Program Manager or his/her designee should document the safety issues and any benefit/cost analysis that include the following:

- Encroachments
- Roadside geometry
- Accident costs

Refer to **Chapters 38** through **45** of this manual for more specific information on project traffic considerations and processes.

3.6.4. Structures

Structural considerations on a project include a review of the following:

- Major structure – bridge
- Major structure – culvertMajor structure – unusual
- Pedestrian overpass/underpass
- Architectural/aesthetic treatments
- Foundation investigation/recommendations
- Structure condition reports

- Hydraulic design
- Retaining walls
- Noise barrier walls
- Guiderail/barrier design and review
- Crashworthy bridge rail
- Vertical and horizontal clearances

Refer to **Chapters 13** through **24** of this manual for more specific information and procedures for structural considerations.

3.6.5. Materials for Pavement

Selection of the pavement types listed below must be in accordance with the criteria in **Chapter 27** of this manual.

- Rigid pavement
- Flexible pavement
- Composite pavement
- Special material pavement (cobblestone, etc.)

Pavement materials considerations on a project generally include:

- Pavement analysis/distress review
- Geotechnical studies
- Foundation investigation/drilling
- Pavement material selection

Refer to **Chapter 27** of this manual for more specific information and procedures related to materials and to American Association of State Highway and Transportation Officials guidelines for skid-resistant pavement design.

3.6.6. Drainage and Stormwater Management

Stormwater considerations on a project include a review of the following:

- Drainage capacity analysis and design
- Stormwater management and water quality enhancement measures
- Erosion and sediment control measures

Refer to **Chapter 28** of this manual for more specific information and procedures related to drainage and stormwater management.

3.6.7. Trees and Landscaping

The removal, addition or modification of the landscaping or types of trees in a project area requires the approval of the DDOT Urban Forestry Administration.

The Program Manager or his/her designee should include the Urban Forestry Administration in the design reviews and meetings. The Program Manager or his/her designee must confer with the Urban Forestry Administration for issues relating to trees and landscaping.

Landscaping considerations on a project generally relate to tree species, spacing of trees, other facility conflicts, seeding/sodding, tree pruning, stump removal, and sight distance requirements at intersections when required.

Refer to the **Chapter 37** of this manual for more information on landscape considerations.

3.6.8. Utilities

Utility considerations generally include reviewing existing utility easements, conducting visual inspections to identify utility structures, and establishing procedures for utility clearance. Early coordination with utility companies will minimize conflicts and avoid unnecessary delays. DC Water and Sewer Authority (DC Water) has an existing arrangement with DDOT, whereby DDOT's Design Consultant and Construction Contractor can perform the services needed to design and upgrade the water lines and other DC Water facilities within a DDOT ROW. The Design Consultant must coordinate with DC Water representatives at the beginning of the design phase to discuss the scope of work and schedule. DC Water should participate in the negotiation of consultant fees and submit written agreement of funding for the associated increase in project design cost. DC Water will also participate in design reviews.

Refer to **Chapter 9** of this manual for more information on addressing dry utilities considerations.

3.6.9. Agreement and Approval

Agreement and approval requirements will vary from project to project. The Design Consultant should validate with the DDOT Project Manager whether there are any applicable agreements or approvals that will affect the project.

Refer to **Chapter 4** of this manual for agreement procedures and guidelines.

3.6.10. Community Involvement

Generally, community involvement will occur at the following milestones of the project development process:

- Planning
- Concept design
- Preliminary design
- Final design

The Design Consultant will be a key participant in the community involvement process. In conjunction with the DDOT Project Manager, the Consultant should plan for community involvement throughout all phases of design. The draft public involvement plan must be submitted within 10 days after the project kickoff meeting.

Refer to **Chapter 7** of this manual for guidelines and procedures for developing and implementing effective community involvement programs for DDOT projects.

3.6.11. Maintenance Input

The Design Consultant will work with the DDOT Project Manager to obtain input from the appropriate DDOT maintenance divisions, including Asset Management, TOA, Urban Forestry, and Stormwater Management, during the design phase. The maintenance representative should review the project plans and provide comments in writing to the Design Consultant and DDOT Project Manager.

3.6.12. Bike/Pedestrian Improvements

The Design Consultant will work with the DDOT Project Manager to obtain input from the bike and pedestrian planners, as well as traffic engineers, on bike- and pedestrian-related issues during the design phase. The proper placement and design of bike and pedestrian facilities is an important element of design on all applicable projects. For more specifics on bike/pedestrian improvement procedures, refer to **Chapter 29** of this manual.

3.6.13. Federal Lands Affected

For projects that affect federal land, refer to the clearance requirements of the owners of the affected properties.

3.7. Design Schedule Management

After notice to proceed, the Consultant should submit a preliminary design schedule and final schedule in which all submissions are defined.

3.7.1. Preliminary Design Review (30 Percent)

The Consultant will submit the preliminary plan to the DDOT Project Manager for review and approval. The submission must include a description of all potential design exceptions. The DDOT Project Manager will verify the design criteria/standards, review for potential design exception requirements, consider environmental issues, and check that input from stakeholders and the community involvement process is incorporated into the design. The DDOT Project Manager will conduct the review process using a Project Checklist form in **Appendix D** of this manual. If the submittal requirements for the 30 percent submittal are met, then the DDOT Program Manager will prepare submittal letters for distribution to all stakeholders. The Design Consultant will distribute the construction documents to the stakeholders on the list prepared by the DDOT Project Manager.

The Consultant is required to provide a preliminary engineering report justifying the methods and approach to the design. The report will outline the design alternatives, potential design exceptions, preliminary cost estimates, issues, resolutions, findings, and all public involvement results and conclusions. Comments are to be resolved before design proceeds.

Please refer to **Chapter 12** for 30 percent submittal requirements.

3.7.2. Value Engineering

Value Engineering (VE) is a systematic analysis by a multi-disciplined team to find effective and efficient ways to satisfy the full purpose and need of the project, not a process to reduce or eliminate scope.

Ideally, VE studies will be performed on projects when they are between the 30 percent and 65 percent design phases. While the Design Consultant is precluded from performing the VE analysis, the Design Consultant will support the analysis by providing all requested information regarding its design and approach.

Please refer to **Chapter 6** for a full discussion on this topic.

3.7.3. Intermediate Design Review (65 Percent)

At this stage of design, the Consultant will inform the DDOT Project Manager of the need to obtain approval from the Federal Highway Administration (FHWA) for any design exceptions. The Consultant will prepare the required documents. FHWA approval must be obtained before design proceeds.

Please refer to **Chapter 12** for 65 percent submittal requirements.

3.7.4. Final Design Review (100 Percent)

At this milestone, the Design Consultant, in conjunction with the DDOT Project Manager, will resolve the comments from the 65 percent reviews of the detailed construction plans, special provisions, specifications, pay items and updated cost estimates.

The Design Consultant will submit all design calculations, in addition to documents specified in the contract, to the DDOT Project Manager. Calculations and documents to be submitted include, but are not limited to:

- Drainage and other hydraulic calculations
- Bridge loading and structure analysis and design calculations
- Quantity takeoffs
- Construction cost estimate
- Construction schedule

Please refer to **Chapter 12** for 100 percent submittal requirements.

3.7.5. Plans, Specifications and Estimates

Once all issues have been resolved and the necessary utility clearances and permits have been obtained, the Plans, Specifications and Estimates (PS&E) submission can be made for obligation of construction funds.

Please refer to **Chapter 12** for PS&E submittal requirements.

3.7.6. Final Bid Documents

At the conclusion of final design, the obligation of funds for construction moves the project forward to the bid process. The Consultant will finalize all bid documents and support the DDOT Project Manager until the project is successfully advertised for bid.

4 Agreements

4.1. Entity Agreements

An agreement is required when DDOT and an entity or public agency have a shared interest in a transportation project. The Project Manager should work with the appropriate District authority to determine the parameters of an agreement whenever an entity or public agency needs to:

- Maintain or construct a project affecting the District Highway System
- Provide funds and determine the shared responsibility of funds for such a project
- Comply with other interests that require the entity to coordinate with DDOT on such a project

The following steps for implementing an original entity agreement or an amendment to an entity agreement for a transportation project are performed by the Program Manager unless otherwise noted:

- Ensure that the proposed service or project is consistent with DDOT's procedures
- Determine roles and responsibilities for the project between DDOT and the other entity
- Review and analyze the request, prepare a draft Memorandum of Agreement (MOA) when a non-District entity is involved and a Memorandum of Understanding (MOU) when a District agency is involved, and forward a draft to the Chief Engineer
- Review and comment on the draft contract (and coordinate with the Chief Engineer);
- After approval of draft from Chief Engineer, provide the draft agreement to the Office of the General Counsel (OGC)
- After approval from the OGC, transmit the draft agreement to the entity for review and consideration
- Revise the draft agreement, if requested and as appropriate to address the entity's concerns, and coordinate with the Chief Engineer and the Department's Attorney on the requested changes
- Check the authorization document to ensure funding commitment and signature authority for the agreement
- Route the final agreement, signed by the entity for execution
- Distribute the executed agreement as needed
- Issue a Notice to Proceed to the entity

4.2. Utility Agreements

If the project requires the relocation of existing facilities or installation of new services, the Program Manager must coordinate with the utility company's engineer (this will be required for any work by the utility). In general, no separate agreement with the utility company or DC Water will be required if the utility pays the entire cost directly to the consultants/contractors for their work. However, the Program Manager must include provisions in the construction contract for the contractor to coordinate the work with the utility company.

The utility company or DC Water may request the Program Manager to incorporate the design into the District project for which the utility company will pay the cost to the District after the bids are opened. Before the project is opened for bidding, DC Water is required to establish an escrow account for the project with sufficient funds to cover the estimated construction cost for DC Water work. The document for the escrow account must be submitted to the DDOT Program Manager for the record. If the bid prices are not acceptable to DC Water, DC Water will have an option to withdraw its request and hire a contractor do the proposed work.

In the event the proposed DDOT projects will be impacted by an existing utility structure, the cost for relocating existing utilities will be borne by the utility company. Please refer to **Chapter 9, Utilities**.

The final agreement must be presented to the Chief Engineer for approval. The agreement may be an informal document, but should be in place prior to advertisement of the project for construction. Copies of the documents will be filed with the Program Manager.

Part II – Project Development
Chapters 5 through 12

5 Environmental

5.1. Introduction

This chapter summarizes the various environmental laws and regulations with which DDOT projects must comply. A brief overview of the process carried out to comply with these laws and regulations is also provided in this chapter. However, the details on these laws, regulations, processes, and procedures are provided in the **DDOT Environmental Manual**. Please refer to the **DDOT Environmental Manual** for more details.

One of the earliest decisions DDOT must make concerning a transportation project is the appropriate class of action. For federal projects, this decision is to be made in conjunction with the lead federal agency. This decision is important because the class of action determines the level of documentation necessary to comply with the National Environmental Policy Act of 1969 (NEPA) and the District of Columbia Environmental Policy Act (DCEPA). The DDOT Environmental Program Branch (EPB), in coordination with the lead federal agency, if appropriate, makes the decision for the level of action required.

If the project is using federal funding or requires federal action (approval, permit, etc.), then the project will have to comply with NEPA. Projects that comply with NEPA automatically comply with DCEPA, as an exemption is provided under DC Municipal Regulations (DCMR) Chapter 72, section 7202.1(b). If a project is using only local funding and no federal action is required, then the project has to comply with DCEPA only. However, the project must comply with other environmental laws in addition to NEPA and DCEPA, regardless of class action.

For projects where NEPA applies, whether the project will need a Categorical Exclusion (CE), an Environmental Assessment (EA), or an Environmental Impact Statement (EIS) level of documentation depends on the project's potential effects to the human and natural environment pursuant to the Council on Environmental Quality (CEQ) regulations (Title 40 of the Code of Federal Regulations [CFR] Sections 1500 through 1508) and whether significant impacts are anticipated.

For projects where DCEPA applies (i.e., uses local funding), whether the project is an exemption or requires an Environmental Impact Screening Form (EISF) depends on the project impacts.

This section describes the different NEPA and DCEPA actions and document types that DDOT will use to process its transportation projects. For details please refer to the **DDOT Environmental Manual**. The DDOT Project Manager must coordinate with the EPB for all such environmental actions.

5.2. Determination of Environmental Action Types

For projects using federal funding or requiring a federal action, in accordance with CEQ regulations under NEPA, the lead federal agency and DDOT must identify those typical classes of action that:

- Require an EIS – An EIS must be prepared for any proposed major action significantly affecting the environment.
- Require an EA, but not necessarily an EIS – These actions require that an EA be prepared to determine the significance of the impacts. If it is concluded from the EA that the project's impacts will be significant, an EIS is required; if not, a Finding of No Significant Impact (FONSI) is prepared.
- Require the preparation of a CE – Actions that are clearly Categorical Exclusions and do not normally affect activities or resources under the jurisdiction of other agencies. The need for environmental documentation and agency coordination on CE projects depends on the level of impacts associated with the project. If no significant impacts are anticipated, then a CE is prepared.

The Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) environmental regulations and action list can be found in 23 CFR 771. Occasionally, a project is proposed that does not appear to fit any of the action categories, in which case the DDOT Project Manager and EPB will coordinate with the lead federal agency to make this determination.

DDOT uses the Federal Aid Highway Program to fund the majority of its projects. Projects that use Federal Aid Highway Program funds or require an approval action from FHWA have to comply with FHWA requirements. FHWA environmental regulations are codified in 23 CFR 771. Currently, FHWA and FTA have joint environmental regulations in 23 CFR 771. To streamline the NEPA review process, DDOT has established a Programmatic Agreement (PA) with FHWA for CE projects that require FHWA's action, provided the CE projects meet the requirements under CEQ 40 CFR 1508.4 and FHWA 23 CFR 771. This PA allows the DDOT EPB to approve certain actions that qualify for a NEPA CE using specially developed forms. The following sections in this chapter briefly discuss this process. For details, please refer to the **DDOT Environmental Manual**.

For projects that use only local funding, in accordance with the District of Columbia regulations under DCEPA, DDOT/EPB has to identify whether a project will:

- Be an exemption per 72 DCMR 7202 – Actions for which no EISF or EIS is required. A list of actions that do not require the preparation of an EISF or EIS is provided in 72 DCMR 7202.

- Require the preparation of an EISF per 72 DCMR 7201 – Major actions for which an EISF is required. A list of actions that require the preparation of an EISF is provided in 72 DCMR 7201.
- Require the preparation of an EIS – Projects that do not qualify for an exemption or projects for which an EISF was submitted and the lead agency concluded that an EIS is required need an EIS.

The DDOT EPB makes the environmental action determination. It should be noted that the DC Department of Consumer and Regulatory Affairs (DCRA) is the lead on the DCEPA process, and forms have to be submitted to DCRA for local projects to be approved. For details, please refer to the **DDOT Environmental Manual**.

5.3. NEPA Action Types

For projects using federal funding or requiring a federal action, in accordance with NEPA regulations, each federal agency must identify those typical classes of action that:

- Require an EIS
- Require an EA
- Require the preparation of a CE

The FHWA and FTA environmental action list can be found in 23 CFR 771. Most DDOT projects require NEPA compliance. The different types of NEPA actions are summarized below. For further details, please refer to the **DDOT Environmental Manual**.

5.3.1. EIS Action – Environmental Impact Statement

A proposed action known to have significant environmental impacts will require the preparation of an EIS.

A decision to prepare an EIS for a proposed action may be made when:

- That action clearly involves significant impacts on the human environment, or
- Environmental studies and the results of early coordination indicate significant impacts, or
- The review of an EA concludes that significant impacts would result from a proposed action.

An EIS concludes with the issuance of a Record of Decision (ROD). Please contact the EPB to determine whether an EIS is required. The EPB team will work with FHWA or the appropriate federal agency to make the determination.

Please refer to the **DDOT Environmental Manual** for details.

5.3.2. EA/FONSI Action – Environmental Assessment / Finding of No Significant Impact

An EA is a public document that serves to provide sufficient evidence and environmental analysis to determine whether to prepare an EIS or to prepare a FONSI. An EA is prepared when the significance of a project's impacts cannot be clearly determined. All actions that do not readily fall into an EIS action or meet the qualifications of a CE are evaluated as an EA.

Based on the review and findings of an EA and any public comments, an EIS is prepared if FHWA (or another federal lead agency) determines that significant impacts would occur as a result of implementing DDOT's project. A FONSI is prepared if the study concludes that the proposed action will not cause significant impacts. The FONSI is the conclusion to the EA process. The Project Manager must coordinate with the EPB, in cooperation with FHWA or the appropriate federal agency, to determine whether an EA is required.

Please refer to the **DDOT Environmental Manual** for details.

5.3.3. CE Action – Categorical Exclusions

CE actions and activities meet the definition of Categorical Exclusion in CEQ NEPA regulations in 40 CFR 1508.4. For FHWA actions, these also have to meet 23 CFR 771.117, and for FTA projects they have to meet 23 CFR 771.118.

CE actions require some information to be provided by DDOT to determine whether the proposed action meets the requirements of a CE and to determine the appropriate CE classification. The level of information to be provided should be commensurate with the complexity of the project or action. Since FHWA and FTA have joint environmental regulations in 23 CFR 771, to streamline the NEPA review process, DDOT has established a PA for NEPA review. This PA gives DDOT authority to approve certain NEPA actions, Categorical Exclusions in particular. The Project Manager must coordinate with the EPB for all NEPA actions as to what form is to be used for these NEPA actions. For details, please refer to the **DDOT Environmental Manual**.

5.4. DCEPA Action Types

For projects that use only local funding, in accordance with the District of Columbia regulations under DCEPA, DDOT/EPB has to identify whether a project will:

- Be an exemption
- Require the preparation of an EISF
- Require the preparation of an EIS

5.4.1. Exemption

Exemptions are the class of actions that are exempt from (do not require) preparation of an EISF or EIS. The 1997 rule for the implementing DCEPA Act of 1989 includes a list of actions that are exempt from preparing an EISF or EIS for DCEPA compliance.

Most DDOT reconstruction, replacement and maintenance projects in a DDOT right-of-way are covered in the exemptions. See the **DDOT Environmental Manual** for details on exemptions.

5.4.2. Environmental Impact Screening Form

An EISF is required for actions that are not exempted by the DCEPA. The EISF has to be completed by the applicant and submitted to DCRA for approval.

See the **DDOT Environmental Manual** for details on the format and content of EISF.

5.4.3. Environmental Impact Statement

An EIS is required under DCEPA for actions that are not exempted by the DCEPA, not covered in the EISF section (20 DCMR 7201), or for which the lead agency has made a determination that an EIS is required.

See the **DDOT Environmental Manual** for details on the format and content of the EIS.

5.5. Environmental Process

Environmental documents (CE, EA, EIS) are prepared by either DDOT or a qualified consultant under the direction of the DDOT Project Manager. The DDOT Environmental Process consists of the steps below. For details, please refer to the **DDOT Environmental Manual**.

Step 1: A project is identified and included in the DDOT Constrained Long-Range Plan (CLRP), State Transportation Improvement Program (STIP), and the National Capital Region Transportation Planning Board's Transportation Improvement Program (TIP).

Step 2: After the project is identified in the CLRP/STIP/TIP, the DDOT Project Manager and EPB staff meet to review the project and potential requirements.

Step 3: Based on input received during the project review meeting, the EPB staff recommends the level of environmental action/documentation and resource studies that will be required for the project.

Step 4: The EPB provides recommendations on the requirements for coordination with the District of Columbia State Historic Preservation Office (DC SHPO), the National Park Service, or other federal and local agencies.

Step 5: Prior to obligation of funds, the Project Manager is responsible for completing Form I of the Project Development and Environmental Evaluation Form. The form has to be submitted to the EPB for review and approval. Comments and guidance or assistance from the EPB will direct the next steps based on the information provided in Form I. It is important to note that some projects/actions require only Form I, while some will also require Form II or Form III. The EPB makes the determination and can provide the most recent version of Forms I, II and III.

Step 6: The Project Manager, Infrastructure Project Management Administration (IPMA) Ward-based team, and EPB will conduct a joint field review and hold an environmental compliance review meeting. If, based on the findings of the field review and the Form I review, there are no further changes to the scope of the project, the NEPA recommendations, or the coordination requirements of the project, the EPB will approve Form I and the NEPA action, and the project can proceed to obligation.

Step 7: However, if the EPB determines more information is needed, the DDOT Project Manager will be directed to complete Form II of the Project Development and Environment Evaluation Form and submit it for approval. After review, if all requirements are met and complete information is provided, approved Forms I and II will be provided to the DDOT Project Manager.

Step 8: When the action does not meet the requirements and information needed in Forms I and II, EPB will identify the necessary level of NEPA action on Form I, which can be CE-Level III in the FHWA-DDOT PA, an EA, or an EIS. The Project Manager will then start developing the identified NEPA document. The EPB will provide oversight and approvals of the documents as they move forward. All NEPA documents (CE, EA, and EIS) have to be approved by the EPB before they go to the DDOT Director, FHWA, or any other federal agency for approval. The EPB is responsible for determining the appropriate level of NEPA action and for providing oversight and approval of all NEPA documents produced by DDOT.

Step 9: Once Form I or both Forms I and II are approved, and if the project is federally funded through the Federal Aid Highway Program, the project funding can be obligated in the Financial Management Information System (FMIS).

Step 10: Once federal funds have been obligated (and Notice to Proceed issued for any needed contractual documents) and the project is initiated, intensive field surveys and data collection may begin. This includes the development of functional-level engineering studies, study reports and documentation, and continuing public involvement.

During the course of project development, sometimes changes can occur in the scope of a project. When these changes are substantive, a re-evaluation of potential impacts to resources is usually required. More often, however, the changes to a project are minor and do not immediately prompt a Project Manager to reconsider potential resource impacts. If there are changes in the project scope, the EPB must be notified to determine whether additional information or re-evaluation of a document may be needed. The EPB also audits projects routinely to ensure the project scopes remain consistent with NEPA approvals.

As project design proceeds, the DDOT Project Manager ensures mitigation commitments made during the project development process and defined in environmental documents (CE forms, EA, or EIS) are included in the plans and completed in the field during construction. When completing preliminary and final design, the DDOT Project Manager is responsible for ensuring the scope of work and project limits do not exceed the scope and limits as described and analyzed in the approved environmental documents. It should be noted that for CE-level projects, forms should be updated for the study/preliminary engineering work, final design, and construction phases.

Changes outside the previously approved environmental documentation will require new environmental clearances. The DDOT Project Manager is responsible for coordinating directly with the EPB regarding all changes to the scope or project limits so that appropriate environmental clearances can be obtained. It is also the responsibility of the DDOT Project Manager to include the EPB in the design scoping process for all projects.

5.6. Other Environmental Laws and Regulations

In addition to NEPA, DDOT projects requiring federal funding, approvals, permits, or actions have to comply with all other laws, regulations, guidelines, executive orders, etc. Some of the most important and relevant include:

- National Historic Preservation Act – Section 106
- Clean Air Act and Amendments
- Clean Water Act
- Section 4(f) of the U.S. Department of Transportation Act
- Civil Rights Act
- Endangered Species Act
- FHWA Noise Regulations

Please refer to the **DDOT Environmental Manual** for details on these laws and processes.

6 DDOT Design Phase Value Engineering (VE) Program

6.1. Introduction

Value Engineering (VE) is a methodical approach for focusing on the value of a complex or high-cost project and its final product by either improving the function or reducing the cost. It is a process that requires a multi-disciplined team of subject matter experts to develop concepts based on project purpose and needs. The intent is to improve the value of a project during the early design stages.

The main objectives of a VE study are to add value to the project by making recommendations on how to minimize costs, improve the life cycle, reduce construction time, make the project easier to construct, improve quality, and ensure safe operations and environmental/ecological goals. The VE team looks for the optimum blend of scheduling, performance, constructability, maintainability, environmental awareness, safety, and cost consciousness.

The VE process incorporates, to the extent possible, the values of the major stakeholders. These generally include the designer, construction engineer, maintenance engineer, contractor, state and federal approval agencies, local agencies, and the public.

VE has been formally recognized as an acceptable review process in highway development by both American Association of State Highway and Transportation Officials (AASHTO) and the Federal Highway Administration (FHWA) since the 1980s. The **AASHTO Guidelines for Value Engineering** is the main reference to be used in all applicable DDOT projects.

6.2. Definitions

6.2.1. Value

Value is the comparison of the true cost of a feature to its worth to those involved, including owners, users and others. The Value Index (VI) is mathematically expressed as:

$$VI = \frac{worth}{cost}$$

The value of project features whose value index is less than 1 ($VI < 1$) is questionable, and these features would be candidates for further investigation in a Value Engineering Study.

Project features whose value index is greater than or equal to 1 ($VI \geq 1$) have favorable value; the larger the value index, the higher the value is to project stakeholders. Features with a large value index would not typically be investigated further in a Value Engineering Study.

It should be noted that increasing the value of a project does not always equate to cutting the cost.

6.2.2. Value Engineering in Design (VE Studies)

It is best to perform VE during the early phases of design. Starting the VE study at the 30 percent design stage is highly recommended. The VE team is a group of multi-disciplined individuals who are not directly involved in the design of the project. Their objective is to ensure that transportation safety, District long-range comprehensive plans, and the communities' needs are met in an efficient and cost-effective way. VE studies culminate in a formal report outlining the study team's recommendations.

VE studies should incorporate seven characteristics:

4. A multi-disciplinary team approach
5. The systematic application of a recognized technique (VE Job Plan)
6. The identification and evaluation of function, cost and worth
7. Creative speculation on alternatives that can serve the required functions (search for solutions from new and unusual sources)
8. Evaluation of the best alternatives with the lowest life-cycle costs
9. Development of acceptable alternatives into fully supported recommendations
10. The presentation/formal reporting of all VE recommendations to management for review, approval and implementation

6.2.3. Value Engineering Change Proposals (VECPs)

After contract award, contractors may devise innovative methods and means or develop an alternative construction proposal that allows the District to benefit from a contractor's "fresh look" and experience. This will not be part of the VE study. Refer to the VECP section of the **DDOT Standard Specifications for Highways and Structures** for detailed information about the VECP process and procedures.

6.3. Applicability

6.3.1. Federally Mandated VE Studies

Title 23 of the Code of Federal Regulations Part 627 contains a mandate requiring all departments of transportation to carry out a minimum of one VE study for each federally funded design-bid-build project on the National Highway System (NHS) for highway projects valued in excess of $50 million and for bridge projects costing more than $40 million. These threshold amounts are for the project's overall cost, including costs associated with environmental studies, preliminary engineering, final design, right-of-way (ROW) acquisition and construction, and should consider all funding sources, federal and local. Design-build projects are exempt from this requirement.

A VE study is required for projects that originally did not receive federal funding but later received federal assistance, provided the other mandated criteria apply. Similarly, federally funded NHS projects with overall project costs estimated at less than the threshold amount will require a VE study if the total project costs unexpectedly increases to a level exceeding the threshold.

In the event that a study is not conducted on a project meeting or surpassing the federally mandated threshold, the FHWA can withhold Federal-Aid Highway Program funds on any eligible project. Therefore, to prevent a loss in funding, NHS projects with total costs near the threshold amount that include or have the potential to include federal participation should have a VE study conducted.

In addition to federal VE regulations, DDOT strongly recommends conducting a VE study on any complex and highly sensitive project with an estimated cost of $15 million or more (which includes project development, design, ROW acquisition, and construction costs), regardless of funding. The VE coordinator and DDOT Program Manager will decide on the applicability of VE studies.

6.3.2. Non-Mandated VE Studies

For any non-mandated projects, the District is encouraged to have VE studies conducted on any project it deems appropriate as a means of improving the overall value of that project. Cost savings is a principal benefit of the VE process; however, other issues that add that complexity to the project should be considered in the VE selection process. Complexities may include critical constraints, difficult technical issues, external influences or complicated functional requirements. The types of projects that have the highest potential for value improvement are:

- High-cost projects
- Projects with alternate solutions that vary the scope and cost
- New alignment or bypass sections
- Widening of existing highways for capacity improvements
- Major structures
- Interchanges on multi-lane facilities
- Projects with costly or extensive environmental or geotechnical requirements
- Major reconstruction of existing highways
- Projects involving extensive traffic control
- Projects with multiple stages

6.4. Initiating a VE Study

For optimum results, a VE study should be conducted after conceptual design elements and preliminary cost information have been developed, which is typically after the preferred alternative has been identified at the 30 percent design stage. This allows VE findings and suggestions to be more readily incorporated into the project. Proper timing helps to ensure that recommendations generated through a VE study do not cause significant impact on the project schedule.

6.5. Team Structure

A VE team is typically composed of a team leader and five to seven individuals with a diverse range of backgrounds relevant to the project. The team members may be selected from the DDOT; other DC agencies; other local, state, or federal agencies; or the private sector. VE teams of fewer than five tend to limit the amount and variety of creative input, while teams of more than seven can be difficult to manage.

VE teams should be structured such that the appropriate areas of expertise are available to evaluate the potential value improvement areas associated with the project. Expertise from the functional areas of design, structures, ROWs, maintenance and traffic operations make for a good team balance. All of these disciplines may not be needed depending on the project scope, while other specialties, such as utilities, environmental analysis or railroad operations, may be applicable. It is important to note that the team must be independent from the project in order to exclude any bias during the process. All team members must be committed to the time required for the study. It is desirable for team members to have attended Value Engineering training before participating in a VE study.

6.5.1. Team Leader

The quality of the VE analysis largely depends on the skills of the VE team leader. The VE team leader is responsible for guiding the team during the study and should be proficient in the VE process. A consultant serving as a VE team leader must be a Certified Value Specialist as defined by the Society of Value Engineers International, the professional society governing the VE industry.

The VE team leader’s responsibilities include the following:

- Leads and facilitates the VE study
- Follows the project plan and ensures the team is moving in the right direction
- Guides the team through the activities needed to complete the pre-study, the VE study and the post-study stages of a VE study
- Manages the schedule and budget for the VE study

6.5.2. VE Coordinator

- Meets periodically with the Project Design Engineer and the Program Manager to identify candidate projects for which a VE study is either required or desired
- Identifies projects for VE analyses with the help of the Program Manager
- Makes recommendations for timing of the VE analysis for each project
- Prepares a list of the identified projects
- Prepares an annual VE report
- Maintains policy documents for the department
- Coordinates studies
- Arranges training for future VE team leaders and members

6.6. Consultant-Run VE Studies

For all studies done by consultants whom DDOT hires, it is the responsibility of the consultant to assemble the VE study team, lead the study, and coordinate the logistics of the study with the VE coordinator.

6.7. VE Process/Methodology

The guidelines for the VE process are based on AASHTO’s **Guidelines for Value Engineering**.

7 Community Involvement

Community involvement is an integral part of the process of designing and constructing transportation projects and is essential for the success of DDOT projects. It is also essential for ensuring that the transportation system makes the city more multimodal, livable and prosperous. Identifying stakeholder interests and concerns is an essential step in the development of context-sensitive solutions and successful construction projects, and is achieved through community involvement activities. Community involvement is also used to ensure that all projects and project teams are in compliance with all aspects of DDOT's Title VI policy on equal opportunity.

DDOT's Title VI policy was developed based on two federal laws: Title VI of the Civil Rights Act of 1964, and Executive Order 12898 entitled "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations." DDOT's Title VI policy ensures that all of its programs and activities will be implemented so that no person, of any race, color, national origin, gender, age, disability or income status is excluded from participating in, denied benefits of, or otherwise subjected to discrimination, particularly as it relates to community and public involvement.

Effective public involvement during the planning, development, design, and construction phases of a project can alert DDOT to community concerns (e.g., Environmental Justice, Title VI) so that they do not result in violations of these laws. Early and continuous interaction between community members and DDOT staff is critical to successfully identify and resolve potential concerns in communities with Environmental Justice and Title VI-protected populations. Although community involvement and outreach programs are not "one-size-fits-all," the following general approach can be customized to develop an effective program for each project.

Refer to **District Department of Transportation Environmental Manual***,* 2012, for information pertaining to community involvement and Environmental Justice regulations that direct DDOT to provide minority and low-income populations greater access to information on a project and opportunities for public participation in matters that may impact human health and the environment.

7.1. Step 1: Planning the Public Involvement Program

This initial step involves gathering information, researching the background and history on the project, identifying major issues and decisions, and collecting and reviewing demographic data to determine identifiable populations (e.g., Limited English Proficient (LEP)/Non-English Proficient (NEP), elderly, disabled, low-income, minority).

This step generally includes:

- Review or develop the project purpose and need statement
- Review or develop project goals
- Review any existing environmental impact studies
- Review any impacts on minority and low-income populations
- Review any impacts from the proposed action, the result of other actions, or cumulatively on groups protected by Environmental Justice laws and groups covered by Title VI and any other nondiscrimination statutes
- Review floodplain issues
- Review any threatened or endangered species issues
- Review any development or redevelopment plans
- Review status of other related District projects or studies
- Review Access Management Plan or goals
- Review and understand District multi-modal objectives
- Review public involvement efforts and outcomes conducted during the project planning phase
- Understand any particular impacts to adjoining landowners
- Identify any known major issues
- Understand key decision points (alignment, cross sections, right-of-way acquisition, alternative mode, access management, etc.)
- Identify key groups (staff, council, commission, stakeholders, partners, advocacy groups, media, public, businesses, developers, etc.). Contact information for groups that DDOT frequently coordinates with can be found on the DDOT website.
- Identify input needed from the public to complete a successful project
- Contact the affected Advisory Neighborhood Commission and other identifiable neighborhood groups and schedule an introductory project meeting
- Identify public participation, challenges and opportunities within minority and low-income populations, as well as those populations protected by DDOT's Title VI policy

7.2. Step 2: Developing the Public Involvement Plan (PIP)

Based on the results of Step 1, the project team must develop a strategy that has a defined purpose and goals, identify the project work group/team, review and select appropriate outreach tools, and create an action plan that will produce an open and credible project.

The outreach effort and appropriate tools may vary depending on the project type (e.g., preliminary design, final design, construction), scale, and location. The PIP will provide tailored goals and tools for outreach depending on objectives agreed upon during project kickoff.

This step generally includes defining goals for the community involvement and outreach program. Examples might include:

- Achieve an acceptable level of awareness and understanding of work to be completed for all stakeholders
- Build public support for the project
- Provide adequate information for decision-makers
- Educate the public and develop user-friendly project information
- Involve a broad range of stakeholders, including low-income populations

Public and Environmental Justice concerns and values should be identified. Examples might include:

- Identify project activities and outcomes that may adversely impact elderly, disabled, or LEP/NEP communities
- Identify potential adverse impacts such as changes in tax base and property values, or diminished quality of life for residents—particularly the elderly, disabled, LEP/NEP, low-income and minority communities

The tools and protocols for the community involvement and outreach program should also be defined during this step. Examples might include:

- Determine public communications protocols with the DDOT Project Manager, including phone, email, website and social media
- Identify and establish a contact database of the various work groups for the project. Examples might include:
    - Project Management Team (key staff, consultants)
    - Community Relations Team (key staff, consultants, community leaders)
    - Technical Working Group (key staff, consultants, developers, Federal Highway Administration (FHWA), Environmental Protection Agency (EPA), City Council representative, District of Columbia Water and Sewer Authority (DC Water), Washington Metropolitan Area Transit Authority (WMATA), alternative modes/Americans with Disabilities Act (ADA) advocates, etc.)

- Focus Groups (key staff, consultants, interest groups)
- Recurring Community Meetings (key staff, general public)

- Review and select community involvement outreach techniques, with a focus on minority and low-income populations. Examples include:
  - Project logo
  - Project fact sheet
  - Newsletters (hard copy and email)
  - Press releases
  - Clipping service (of all news articles and press releases)
  - Project photos, cross sections, and renderings
  - Webpage (with link to DDOT website)
  - Telephone hotline and project email
  - Text message
  - Suggestion/comment forms (hard copy, website and email)
  - Public meetings and open houses
  - Focus groups
  - Stakeholder interviews
  - Meeting notices (hard copy, phone and email)
  - News outlets and cable access channel announcements (media)
  - Non-traditional outreach techniques targeting diverse populations
  - Information signs in the project area
  - Social media (Twitter, Facebook, etc.)
  - Translated outreach materials
  - Foreign language interpreters
  - Commission and Council work session presentations
- Establish outreach timeline (to be revised routinely), including key project milestones, outreach tools, and work group meetings (location, time, and frequency)

Based on the project schedule and decision points, establish a PIP complete with project contacts, public meetings and locations, action items, assigned responsible parties and target dates.

A draft PIP must be submitted to the DDOT Project Manager for comment within 10 days after the project kickoff meeting. Upon receipt of comments, the PIP must be revised and included as part of the project documentation.

7.3. Step 3: Implementing the Public Involvement Program

Implement the public involvement program based on the project type, and outreach tools and protocols established in Steps 1 and 2.

7.3.1. Website Requirements

If a website is required as part of the project, it must be designed to meet current DDOT guidelines for branding provided by the DDOT Project Manager and include the following information at a minimum:

- Agency logo
- Project description
- Project map and photos
- Public involvement information
- Project schedule
- Project updates and milestones
- Contact information

7.3.2. Print Material

All print material must comply with DDOT's branding guidelines, and include the following information regarding Title VI:

> *The District Department of Transportation (DDOT) does not discriminate on the basis of actual or perceived: race, color, national origin, sex, age, marital status, personal appearance, sexual orientation, gender identity or expression, familial status, family responsibilities, matriculation, political affiliation, genetic information, disability, source of income, status as a victim of an intrafamily offense, or place of residence of business as provided by Title VI of the Civil Rights Act of 1964, the Americans with Disabilities Act, the D.C. Human Rights Act of 1977, and other related statutes. If you need special accommodations or language assistance services (translation or interpretation) please contact [**insert project contact information**] 72 hours in advance of the meeting. These services will be provided free of charge.*

7.3.3. Project Documentation

All public and stakeholder communications and responses will be documented throughout the duration of the project, including:

- Emails

- Phone calls
- Outreach material
- Meeting minutes
- Presentation material

7.4. Step 4: Ongoing Evaluation and Modification of the Plan (as needed)

Based on the dynamics of the process and issues that may surface as the project proceeds, the public involvement program must be evaluated on an ongoing basis and adjusted as needed.

For example, the outreach timeline will be a "living" document, with information on the type of public outreach needed and when. Meetings will also be scheduled to determine upcoming milestones and potential hurdles to overcome.

8 Rights-of-Way, Certification and Clearances

8.1. General

The District Department of Transportation's Right-of-Way Program Coordinator (DDOT ROW Program Coordinator) is responsible for coordinating the acquisition of right-of-way (ROW) for federal and District projects and issuing ROW certifications and clearances. Often, both permanent and temporary property rights are needed for projects.

The ROW acquisition process can be lengthy and involve multiple District agencies. In the majority of projects the ROW acquisition process cannot begin until the environmental review(s) are complete as described in Chapter 5 of this Manual and the DDOT Environmental Manual. Part of the environmental process is the identification of the property need for the project and the type of property interest to be acquired. Once the required environmental approvals have been obtained and a preferred alternative has been selected, the ROW acquisition process can begin in earnest. The process includes obtaining title work, surveys, appraisals, and eligibility of owners and/or tenants for relocation. Because of the time and cost involved with property acquisitions, it is important that an adequate amount of right of way be acquired for each project. Project managers must coordinate with the Planning and Sustainability Division on future widening and enhancements. Transportation improvements must be constructed entirely within the ROW. Any time temporary construction easements (TCE) are utilized, the TCE must be restored to its original condition after construction and contain only improvements owned by the property owner.

In limited circumstances private development projects involve the creation of public space that will ultimately be conveyed to DDOT. Prior to acceptance, the property owner must demonstrate that all of the requirements of Chapter 2 of Transportation Systems Article of the DC Code have been satisfied. The street and/or alley will not be opened until the dedication plat has been recorded with the office of the DC Surveyor. Responsibility for new streets and, or the widening of existing streets necessary to provide adequate transportation service to or within a development lies exclusively with the developer until such time as the District has accepted the ROW through the dedication process.

Further more detailed information regarding the ROW acquisition process, please refer to the District Department of Transportation's **Right of Way Policies and Procedures Manual (ROW Manual)**.

8.2. Overview of the ROW Acquisition Process

The right of way process begins early on in the development of DDOT projects. When a transportation need is identified by a project manager, the right of way manager should immediately contact the Right of Way Unit ("ROW Unit"). A primary responsibility of the ROW Unit is to deliver a clear ROW in a timely manner for DDOT's construction program to proceed on schedule. The specific duties of the Right of Way Manager are set out in Chapter 8 of the ROW Manual.

As the Project Manager prepares a scope for their project, they must prepare a cost and budget for the proposed project. The budget must include an estimate to acquire the needed right of way and relocation of occupants that will be displaced by the project as well as consultant fees, appraisals, review appraisals, title reports, surveys. Land costs are initially estimated based on tax assessments and recent sales in the area. Relocation costs are also estimates based on Right of Way's analysis of persons, types of business that will be displaced by the project and the availability of comparable housing and business sites. These estimates are refined as the process moves along. The estimates of these overall right of way costs are included in the initial funding request to FHWA or local funding for the project.

DDOT also must identify the source of funds for the acquisition, e.g., the Federal Highway Administration (FHWA), Multi-Year Capital Budget (DC Code § 1-204.44), or Council Issuance of General Obligation Funds (Public Law 1-168, 103 Stat 1267). The funding source has important implications to the long-term management of the ROW, and impacts, for example, how that ROW can be used and/or disposed of in the future.

Once the initial funding request is approved, a task order can be issued to a Right of Way consultant to perform right of way acquisition services including, but not limited to surveys (See Surveys below), title reports, appraisals and other acquisition related documents. Concurrently the Project Manager must initiate a request to the Chief Engineer and the Director to have an attorney assigned to the project. As tasks are completed the deliverables must be reviewed by the Project Manager, the Right of Way Coordinator and DDOT's Office of General Counsel (OGC). Once the land to be acquired for a project has been surveyed, the OGC attorney will request Department of Governmental Services (DGS) consent to acquire the property pursuant to D.C. Official Code § 50-921.04 (F)(2016). The Right of Way Consultant may also be tasked with evaluation of eligibility for the relocation assistance, services and benefits to ensure, to the maximum extent possible, the timely and successful relocation of displacees and reestablishment of businesses. See generally Chapters 8 and 10 of the ROW Manual.

The Right of Way Consultant submits a draft acquisition packages to the PM who coordinates the review with the Right of Way Section and OGC for review and approval. The offer is based on the appraisal and offer package must comply with the requirements of the ROW Manual.

If the property owner accepts the offer, OGC works with the purchasers' attorney to finalize the purchase agreement. Once the purchase agreement is signed by all parties, the purchase agreement and supporting documentation are submitted to the Office of the Chief Financial Officer for payment (Check Request Package). The Check Request Package must include, at a minimum, a check request memo, copy of the approved 1365, the signed purchase agreement, plat, appraisal, review appraisal, offer letter (counter), estimate of closing costs, contact report, W9. Settlement funds are customarily wired to the settlement company and once receipt is verified, OGC coordinated closing with the settlement company.

If the property owner rejects the offer, the Project Manager prepares a variation of the Check Request Package which includes, at a minimum, a condemnation memo, copy of the approved 1365, plat, appraisal, review appraisal, offer letter (counter), counter offer (if any), rejection of offer and contact report. While the OCFO is processing the condemnation package, the Project Manager should be putting together the condemnation package. Once a check payable to the Clerk of the Superior Court is received by OGC, the check and the condemnation package are transmitted by OGC to the Office of the Attorney General.

Modifications to access to the public right of ways, such as the closure of a curb cut, are also a property right that may, or may not be compensable and the Project Manager must coordinate by the Right of Way Section and OGC to ensure compliance with Federal law.

Surveys:

ROW surveys must be performed by a surveyor licensed in the District of Columbia. These surveys typically tie into Maryland's survey datum and require title searches and analysis of other surveys. If ROW surveys are incorporated into the design plan process, a separate task is not necessary.

8.2.1. Determination of ROW Needs

Determination of ROW needs begins with the design scoping review and continues through ROW clearance. Some considerations and actions necessary in determining ROW needs include:

- Determining proposed typical section
- Investigating existing ROWs and easements, and adjacent property ownerships
- Determining the survey activities required (i.e., boundary, topographic, etc.)
- Determining the access control requirements and issues for the project
- Determining any required utility relocations
- Identifying all required new ROW
- Identifying all required new easements and their purpose
- Preparation of ROW plan

8.2.2. Certification / Clearance

Before a Federal-Aid project can be advertised for construction, the FHWA requires a letter certifying that all right of way interests have been acquired and that DDOT has complied with all Federal and District laws, rules, regulations, and policies in acquiring new land and providing relocation assistance to any displaced occupants. ("ROW Certification"). A ROW Certification cannot be provided until all of the necessary documentation has been provided. In some instances where all of the ROW documentation cannot be provided, a conditional clearance letter may be issued but such conditional clearance letter may require the approval of the Chief Engineer of IPMA or Associate Director of TPPA before a project can be advertised.

In addition to the statement about the right of way interests, the ROW Certification must include a statement that all physical obstructions including utilities and railroads have been or will be removed, relocated, or protected as required for construction, operation, and maintenance of the proposed project. Early coordination with the railroad(s) is critical for ROW projects to eliminate hazards at railroad-highway crossings, and must begin early in the process if the project contemplates the use of railroad properties or requires adjustments to either railroad facilities or facilities jointly owned or used by railroad and utility companies.

For projects that are not federally funded, a similar process is followed for ROW to certify that all right of way interests have been acquired. A clearance or conditional clearance letter is issued for these locally funded projects. In order to certify or clear the right of way for a project to advertise, ROW Program Coordinator must be provided with the supporting documentation evidencing that all of the needed right of way interests have been acquired. See Chapter 14 of the ROW Manual for detailed information what's required for a ROW Certification and when additional approvals may be required.

8.2.2.1. Documentation

The ROW Program requires the following documentation from the Project Manager to initiate certification or clearance process for a project:

- Letter requesting ROW certification or clearance
- A set of half-scale (11" x 17") Right of Way drawings and Design drawings

The Project Manager, *in consultation with* the ROW Program and the OGC, will work with the consultant(s),in accordance with the ROW Manual, to obtain the following:

- Title report(s) for every parcel from which an interest was acquired (fee simple or easement only)

- Appraisals / Waiver Valuations
- Executed documents that secure all property rights needed to construct the project, which may include combinations of any of the following: deed(s), easement(s), temporary construction easements(TCE), condemnation order, memorandums of agreement (MOA)(including railroad agreements)

8.2.2.2. Acquisition

Any land used for the purpose of opening, extending, widening, or straightening any street, minor street, or alley may be acquired by: purchase; condemnation pursuant to Chapter 13 of Title 16; or dedication of land; however, if the land being acquired by dedication is for a Federal Aid Highway project, the person offering to dedicate the land must be informed of his or her right to compensation for the land. See 49 CFR 24.108 (1999). The requirements of the Uniform Relocation Assistance And Real Property Acquisition For Federal And Federally Assisted Programs apply to any acquisition of real property for a Federal program or project, and to programs and projects where there is Federal financial assistance in any part of project costs. See 49 CFR Parts 24. Offers to purchase property shall be made in person whenever possible. The requirements for real property appraisals and their review can be found at 42 U.S.C. § 4651 (1987) and the corresponding regulations at 49 CFR 24.102 *et seq.* and require at a minimum that

- As soon as feasible, the owner shall be notified of the Agency's interest in acquiring the real property and the basic protections, including the agency's obligation to secure an appraisal.
- The owner, or the owner's designated representative, shall be given an opportunity to accompany the appraiser during the appraiser's inspection of the property.
- An identification of the buildings, structures, and other improvements (including removable building equipment and trade fixtures) which are considered to be part of the real property for which the offer of just compensation is made. Where appropriate, the statement shall identify any separately held ownership interest in the property, e.g., a tenant-owned improvement, and indicate that such interest is not covered by the offer.
- The agency must make every reasonable effort to acquire the property by negotiation. The owner must be given reasonable opportunity to consider the agency’s offer and to present any information that is considered relevant to determining the property’s value.

8.2.3. Relocation Assistance

The Uniform Relocation Assistance And Real Property Acquisition For Federal And Federally Assisted Programs provides certain rights to those being displaced by a project utilizing Federal financial assistance for any part of project costs. See 49 CFR Parts 24. As soon as feasible, a person scheduled to be displaced shall be furnished with a general written description of the displacing agency's relocation program. The notice shall at a minimum

- inform the person that he or she may be displaced for the project and generally describes the relocation payment(s) for which the person may be eligible, the basic conditions of eligibility, and the procedures for obtaining the payment(s);
- inform the person that he or she will be given reasonable relocation advisory services, including referrals to replacement properties, help in filing payment claims, and other necessary assistance to help the person successfully relocate;
- Inform the person that he or she will not be required to move without at least 90 days' advance written notice (see paragraph (c) of this section), and informs any person to be displaced from a dwelling that he or she cannot be required to move permanently unless at least one comparable replacement dwelling has been made available.

Eligibility for relocation assistance shall begin on the date of initiation of negotiations (defined in 49 CFR § 24.2) for the occupied property. Relocation benefits provided to displaced people may include relocation payments. Examples of such payments include replacement housing payments, rental supplements, moving cost payments and business reestablishment expense reimbursement. When comparable replacement housing is not available or within the financial means of the person displaced, DDOT may provide such housing under Last Resort Housing provisions, which can entail providing a housing payment in excess of statutory limits, rehabilitating an existing replacement dwelling, or constructing a new replacement dwelling. Under Last Resort Housing regulations, the agency can provide a direct loan, purchase the land or a replacement dwelling and sell or lease to the displaced person, or remove barriers to disabled persons who have been displaced. In some situations, it is possible to change the displaced person's status from tenant to owner.

8.2.4. ROW Changes

If at any time there are changes in the project plans that affect the ROW, it is the Project Manager's responsibility to notify the DDOT ROW Program Coordinator. The Project Manager is responsible for:

- Identifying changes that may require additional survey and ROW needs

- Furnishing comprehensive design information such as embankment toes, structure limits and road approach design ROW requirements to the ROW Program Coordinator as soon as possible after the Field Inspection Review so that new ROW and easement limits can be determined and ROW plans and descriptions prepared

  NOTE: ROW changes are discouraged, as they may adversely affect and delay the ROW clearance and the overall project schedule.

8.3. Permits/Rights of Entry

Temporary rights of access are required whenever DDOT or a contractor is required to do work outside the existing ROW. Typically, the permission is granted in the form of a permit, license or right of entry. The property owner determines the form of the agreement to be used, and for example most federal agencies will only issue permits, but a few issue licenses. Rights of Entry are used most often used to gain access to privately owned land to do preliminary project work such as environmental testing or survey. Temporary rights are very seldom used for construction of transportation facilities because of the risk that the temporary right will expire before the permanent rights are acquired. The process for obtaining permission to work on non-District owned land is as follows:

- The Project Manager, after review by the Right of Way Coordinator, will apply to the agency for the required permit or license. The application must describe with particularity the work to be done (e.g. testing, repairs).
- Draft permits must be reviewed by the OGC for legal sufficiency prior to signature by the Director.
- Non-governmental property owners most often use rights of entry. The Project Manager requests OGC draft a right of entry and provides all the pertinent project information such as the location of the project, the type of work, the duration of the work and the owner of the properties on which the work will be done.

8.4. Federal Lands Acquisitions

D.C. Official Code § 10-111 (2016) authorizes the transfer of jurisdiction of property between the United States and the District for purposes of administration and maintenance under any such conditions as may be mutually agreed upon. The OGC coordinates the transfer, with the support of DDOT's Right of Way Section and Project consultant. DDOT works closely with the Office of the Surveyor (Surveyor) to initiate the Transfer of Jurisdiction. The process for transferring property pursuant to a Transfer of Jurisdiction is as follows:

- DDOT Project Manager works with federal agency to prepare an acceptable Plat of Transfer of Jurisdiction;
- An application and corresponding filing fee are submitted to the DC Surveyor's office;
- NCPC approval for the Transfer of Jurisdiction is obtained before the Surveyor will authorize the transmittal of the legislation to the D.C. City Council;
- The Resolution authorizing the Transfer of Jurisdiction is submitted to the City Council and approved by the Congress.
- The plat cannot be signed until after the Congressional review period has ended.

8.5. Railroad Agreement Requirements for Right of Way Certification/Clearance

Railroad/highway projects follow scoping and review processes similar to those for regular highway projects. An agreement between the railroad and DDOT is required on all projects that will alter an existing railroad facility or encroach on a railroad ROW. The Project Manager is responsible for preparing the draft and final contract railroad/highway agreement and coordinating review by the railroad and other agencies. To ensure an effective railroad clearance process, the Project Manager should adhere to the following guidelines:

- Do not presume an existing contract will cover new work
- Allow adequate lead time, as this process may take up to a year or more
- Make early communication with the railroad company and recognize that railroads have specific rights
- Remember that plans need to be nearly complete before any contract can be successfully executed

8.5.1. Basic Design Requirements for Railroad/Highway Projects

- Develop preliminary and final railroad plans. The Project Manager and the Railroad Engineer must coordinate to prepare preliminary and final plans.
- Prepare documents and specifications to ensure compliance with railroad agreement requirements.
- Prepare railroad flagging, coordination and insurance specifications.
- Obtain approvals and appropriate signatures from the railroad company, DDOT, and other agencies.

- At a minimum, an abbreviated set of project plans must be prepared for the project to include a cost estimate and general plan sheet for the railroad work. Plans for the railroad work may be incorporated into a larger project.

8.5.2. Other Documentation Generally Required for Railroad/Highway Projects

- Executed contracts between DDOT and the railroad owner, as applicable
- Railroad flagging/insurance protection certificate
- Federal-Aid Highway Program data
- Project special provisions
- Estimate and general plan sheet from the involved railroad company
- ROW and utility clearances, as appropriate
- Notice to Proceed letter

8.5.3. Procedures that Generally Apply to Railroad/Highway Projects

- The Project Manager prepares and submits an application to the railroad when required, such as for railroad crossings and over/underpasses.
- The Design Unit develops railroad encroachment plans, defines construction responsibilities between railroad and highway and submits plans for authorization and approval by the railroad.
- The railroad will advise DDOT of any concerns related to the design and construction of the project.
- The Project Manager should request an estimate of the railroad's anticipated costs related to the project work, for DDOT approval.
- The Project Manager prepares and submits a draft agreement, including the estimate of anticipated railroad costs, for approval by the railroad. After the agreement has been approved by the attorney or legal counsel and the controller, it is signed by all involved parties.
- The Contractor is responsible for obtaining Public Liability and Property Damage Insurance for itself and for any subcontractors, as stipulated in the railroad agreement. Evidence of the coverage must be furnished to DDOT and to the railroad.
- The Contractor must also obtain Railroad's Protective Liability and Property Damage Insurance on behalf of the railroad.
- If the railroad/highway agency agreement will provide for direct reimbursement of any costs to the railroad from Federal-Aid Highway Program funds, the Project Manager will coordinate with the budget office to obtain federal authorization.

8.6. Airport and Heliport Clearance

Airway/highway flight area clearances must be adequate for the safe movement of air and highway traffic. Similarly, the expenditure of public funds for any related airport and highway improvement must be in the public interest. Airport flight area clearance should be considered when a highway project is within 20,000 feet of an airport or within 5,000 feet of a heliport.

The Project Manager will seek to eliminate substandard airway/highway clearances on existing and new highway projects considering such objects as overhead signs, lighting standards, moving vehicles on the highway, over-crossing structures and fencing adjacent to the airport/heliport. Construction operation activities such as crane placement should also be considered.

The Project Manager is responsible for notifying the airport/heliport of any conflict that might arise and for coordinating with airport officials in notifying these concerns and findings to the Federal Aviation Administration (FAA). The Project Manager should file an FAA Form 7460-1 per Federal Aviation Regulations (FAR) Part 77 (77.17). (If the Project Manager requires assistance or has questions regarding the FAR Part 77 or the process of filing a FAA Form 7460-1, he/she should contact DDOT.)

Documentation must be from the coordinating airport official to the FAA; all information submitted by the coordinating airport official must be reviewed by the FHWA to determine if clearances provided are sufficient. The FHWA will advise the FAA of its findings and give its concurrence. When conflicts cannot be resolved, the FHWA, D.C. Division Office, will refer its recommendations to the Federal Highway Administrator.

The FHWA issues a Finding in the Public Interest based on compliance with flight area clearances that conform to FAA standards. FAA guidelines also apply to military and private airports with the same rules and regulations as apply to public airports and heliports.

The FAA notifies the Project Manager of acceptable mitigating actions. Form 418a, Federal-Aid Program Data, has a space to enter the airport/heliport in the vicinity and notes when FAA coordination is required.

9 Utilities

Where utilities are involved, existing utility easements should be reviewed, visual inspections/locations should be conducted and utility clearance procedures should be established. The Program Manager/Project Manager should involve representatives from utility companies at the design scoping review, the preliminary design review and the final design review meetings. Coordinating utility issues early in the process is important to minimizing conflicts during the project.

Coordinate the design for new construction with affected utility companies in early stages of the design. Every effort should be made to avoid relocating the existing utilities unless it is deemed necessary to do so. The cost for relocating existing utilities will be borne by the affected utility companies except for utilities relocated on the Interstate Highway System, where the Federal Highway Administration (FHWA) will contribute to the relocation cost.

Utility considerations are discussed below.

9.1. Utility Clearance

District laws and provisions give utility companies the right to construct their lines within a highway right-of-way (ROW), provided they meet DDOT's established criteria. As a result, many utilities are located adjacent to or within the highway ROW.

Before any DDOT construction project is advertised, the Project Manager must obtain a utility clearance in accordance with Title 23 of the Code of Federal Regulations Part 635.309(b), Physical Construction Authorization, from the Utility Manager. This clearance certifies that all conflicts with the utility companies involved with the project have been addressed in the Plans, Specifications and Estimate package or satisfactorily resolved.

Most utility work, and if possible, all of it, should be completed before construction begins. Utilities include sewer and water work, which is included in contractors’ work, and electricity, cable TV, gas and telephone lines, which are not included in DDOT contracts.

The utility clearance letter is prepared by the Project Manager and directed to the FHWA, D.C. Division Office, on projects with FHWA oversight. On projects where DDOT has oversight, the clearance letter is directed to the Chief Engineer.

9.2. Dry Utilities

The Program Manager/Project Manager must consult with the Public Space Office concerning all utilities in public space.

9.2.1. Project Manager Responsibilities

The Project Manager must coordinate with representatives of all dry utilities affected by the project to:

- Ensure that existing utility lines and any relocation requirements are accurately reflected in the Plans, Specification and Estimate package
- In consultation with the dry utilities representative, make further investigations as needed to verify utility conflicts
- Ensure that all utility companies are aware of the full impact of the project on their facilities
- Negotiate necessary utility agreements and/or permits

9.2.2. Utility Company Responsibilities

The utility companies must:

- Identify, verify and locate known utilities within project limits
- Verify utility conflicts
- Coordinate necessary utility relocations
- Provide documentation for project utility clearance
- Ensure that any utility relocation is scoped, programmed, budgeted, and authorized by the utility company

9.3. Water, Sewer and Storm Sewer

The Program Manager/Project Manager must consult with the District of Columbia Water and Sewer Authority (DC Water) concerning all issues related to water and sewer facilities. DDOT has an existing Memorandum of Agreement (MOA) with DC Water that discusses the following:

- DC Water betterments
- Project-initiated relocations

Please refer to the 2002 MOA between DDOT and DC Water for shared projects.

9.3.1. Project Manager Responsibilities

- Ensure that existing DC Water facilities and any relocation requirements are accurately reflected in the Plans, Specification and Estimate package.
- In consultation with the DC Water Engineer, make further investigations as needed to verify utility conflicts.

- Ensure that any DC Water facility relocations are properly scoped, programmed, budgeted, and authorized by DC Water.

9.3.2. DC Water Engineer

The DC Water Engineer's duties include:

- Identifying, verifying and locating known DC Water facilities within project limits
- Verifying utility conflicts
- Coordinating necessary utility relocations
- Negotiating necessary utility agreements and/or permits
- Drafting project utility specifications
- Issuing project utility clearance
- Advising the Project Manager on utility issues
- Assisting with developing or processing utility agreements
- Assisting with obtaining utility authorizations as needed
- Providing estimate of inspection costs to support construction phase
- Providing escrow letter for costs sponsored by DC Water

9.4. Subsurface Utility Engineering

9.4.1. Subsurface Utility Engineering Overview

To obtain accurate utility information, Subsurface Utility Engineering (SUE) should supplement the normal processes of one-call systems and traditional engineering practices. SUE is an engineering process that accurately and comprehensively identifies, characterizes and maps underground utility facilities. It includes three major activities: designating, locating and data management. These activities, when combined with traditional records research, coordination with utility owners and site surveys, provide high-quality utility information for use during project development and design. This information can be used to improve decision-making processes, reduce utility damage during construction and minimize change orders and contractor claims.

To properly use the information obtained from this process, SUE must be used during both the preliminary and final design phases of the project development process. In accordance with the current American Society of Civil Engineers (ASCE) **Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data**, this information is expressed through four quality levels:

1. Quality Level D: Information derived from existing records or oral recollections.

2. Quality Level C: Information obtained by surveying and plotting visible aboveground utility features and by using professional judgment in correlating this information to quality level D information.
3. Quality Level B: Information obtained through the application of appropriate surface geophysical methods to determine the existence and approximate horizontal position of subsurface utilities. Quality level B data should be reproducible by surface geophysics at any point of their depiction. This information is surveyed to applicable tolerances defined by the project and reproduced onto plan documents.
4. Quality Level A: Precise horizontal and vertical location of utilities obtained by their exposure (or verification of previously exposed and surveyed utilities) and subsequent measurement of subsurface utilities, usually at a specific point. Minimally intrusive excavation equipment is typically used to minimize the potential for utility damage. A precise horizontal and vertical location, as well as other utility attributes, is shown on plan documents. Vertical accuracy is typically set to +/- 0.05 foot and to applicable horizontal survey and mapping accuracy as defined or expected by the project owner.

SUE involves managing risks associated with utility mapping at appropriate quality levels, utility coordination, and utility relocation design and coordination. These utility risks are managed by two methods: "designation" and "locating." Designation is defined as the process of using surface geophysical methods to interpret the presence of a subsurface utility and mark its ***approximate*** horizontal location (designation) on the ground surface. Utility locating is defined as the process of exposing and recording the ***precise*** vertical and horizontal location of utilities (test holes).

All projects must be designated by a prequalified consultant with SUE capabilities.

9.4.2. Policy and Standards

- **Policy:** All projects involving buried utilities, including water, gas, electric, telephone, television cables, or sanitary sewer force mains, should be designated at Quality Level B unless a waiver is requested from the Project Manager.
- **Standards:** DDOT will follow the most current version of CI/ASCE 38-02 standard entitled **Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data** with the following requirements:

  A. All submissions (designation or location) to DDOT must contain the names and contact numbers of responsible parties for any utility shown thereon. Test-hole data sheets should contain the name and contact information for the responsible party of each utility exposed.

B. All fiber optic lines must be identified with the company name.

C. Published DDOT CAD standards will be used in lieu of the information shown in the ASCE guideline legend.

D. Test holes should not be returned to DDOT as unknown. If the utility cannot be identified, DDOT should be contacted immediately while the contractor is mobilized on the project.

E. Duct banks must be dimensioned in width and depth and located. Elevations must be determined on the upper (top) corners.

F. Users of this standard must realize that this is not an all-inclusive set of rules, and if situations not covered in the standards are encountered, DDOT depends on the skill and initiative of all employees and consultants to resolve, or have these situations resolved, efficiently and practically.

9.4.3. Quality Assurance Program

The SUE Consultant must conduct quality reviews to make certain the organization is in compliance with the requirements cited in the Scope of Services. Quality reviews must be conducted to evaluate the adequacy of materials, documentation, processes, procedures, training, guidance and staffing used in the execution of the contract.

9.4.4. Utility Records Research (Quality Level D)

Utilities depicted via “records” or “records research” are meant to represent the presence and approximate horizontal location of existing utilities from information derived through existing records or oral recollections. This work must also include a visual site inspection to verify credibility of such records. Records research is typically conducted when it is necessary for the designer to make broad decisions about route selection, purchasing ROWs, or producing a higher level of data. This level of information should typically be requested during a project’s concept development. This work is considered Quality Level D.

For projects where Quality Level D information is deemed to be most appropriate, the following applies:

1. The SUE Consultant must conduct utility records research to assist in identifying utility owners that may have facilities on or be impacted by the project. Depending on the project and scope, sources of information may include:

   - DDOT or other city agencies

- One-call notification center
- Land owners
- Internet or computer database search
- Visual site inspection
- Utility owners

2. The SUE Consultant must collect applicable utility owner records. Applicable records may include:

    - Previous construction plans in area
    - Conduit maps
    - Direct-buried cable records
    - Distribution maps
    - Transmission maps
    - Service record cards
    - "As-builts" and record drawings
    - Field notes
    - District, utility owner, or other GIS databases
    - Circuit diagrams
    - Oral histories

3. The SUE Consultant must review records for:

    - Indications of additional available records
    - Duplicate information and credibility of such duplicate information
    - Need for clarifications by utility owners

4. At the DDOT Project Manager's discretion, the SUE Consultant will develop utility composite drawings or equivalent, and make professional judgments regarding validity and location of topographic features on records versus current topographic features (when available) and conflicting references of utilities. The SUE Consultant must also indicate quality levels, utility type and/or ownership, date of depiction, accuracy of depicted appurtenances (Quality Level C versus Quality Level D), end points of any utility data, active/abandoned/out-of-service status, size, condition, number of jointly buried cables, and encasement (including length of encasement if available).
5. Quality Level D information must be returned to DDOT in a digital and reproducible plan sheet format.

9.4.5. Utility Mapping (Quality Level C)

"Utility mapping" means identifying the presence and approximate horizontal locations of underground utilities by surveying visible aboveground utility features, such as manholes, valve boxes, and posts, and correlating this information with existing utility records (Quality Level D) using professional judgment. This work is considered Quality Level C. For projects where Quality Level C information is deemed most appropriate, the following applies:

- The SUE Consultant must determine and document the horizontal location of accessible surface features of utility facilities.
- The SUE Consultant must show the approximate horizontal position of the utilities between the surface features.
- The SUE Consultant must determine and document invert elevations for gravity flow systems (if not part of the survey consultant's scope of work) for all pipes within accessible structures.
- Mapping of existing Quality Level C information must be returned to DDOT in a digital and reproducible certified plan sheet format.

9.4.6. Utility Designating (Quality Level B)

For the purpose of this manual, "designate" means to indicate the presence and approximate horizontal location of underground utilities using geophysical prospecting techniques, including electromagnetic, magnetic, sonic, or other energy fields. The data obtained from these methods should be reproducible by surface geophysical methods at any point of their depiction. This work is considered Quality Level B. The SUE Consultant must:

- Designate, mark and survey the approximate horizontal location of existing underground utilities. Utility designating marks must be surveyed to the same accuracy and precision as required for the topographic data in the project's database. Utility designations must be returned to DDOT in digital and reproducible certified plan sheet format.

9.4.7. Utility Locating (Quality Level A)

As the design progresses, the SUE Consultant may be required to locate utilities that have a high potential to conflict with the proposed improvements. "Locate" means to obtain precise horizontal and vertical position of the utility line by excavating a test hole. The test holes must be dug using vacuum excavation equipment or comparable nondestructive mechanism so as not to damage the utility line. After excavating a test hole, the SUE Consultant must perform a field survey to determine the exact location and position of the utility line. This work is considered Quality Level A. The SUE Consultant must:

1. Develop a test hole Location Plan based on the guidelines set forth in the document: **Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data,** published by the ASCE, current edition, and obtain utility company records as required.
2. Neatly cut and remove existing pavement with the cut area not to exceed 144 square inches.
3. Excavate test holes in such a manner as to prevent any damage to wrappings, coatings, or other protective coverings, such as vacuum excavation or hand digging.
4. Backfill with approved material around utility structure per permit.
5. Furnish, install, and color code a permanent aboveground marker (PK nail, peg, steel pin, or hub) directly above the centerline of the structure and record the elevation of the marker.
6. Provide a permanent restoration of the pavement within the limits of the original cut at the time of backfill. If the test hole is excavated in an area other than the roadway pavement, the area disturbed must be restored to equal or better than the condition before excavation.
7. Return utility locations to DDOT in digital and reproducible certified plan sheet format. At a minimum, the SUE Consultant must provide the following test hole information to DDOT:

    - Elevation of top and/or bottom of utility tied to datum of the furnished plan
    - Elevation of existing grade over utility test hole
    - Horizontal location referenced to project coordinate datum. The SUE Consultant must perform all required survey work
    - Outside diameter of pipe or width of duct banks and configuration of non-encased multi-conduit systems
    - Utility structure material compositions and condition
    - Benchmarks used to determine elevations
    - Elevations must have an accuracy of +/- 0.05 foot and certified accurate to the benchmarks used to determine elevations
    - Horizontal data accurate must be within +/- 0.2 foot or applicable survey standards, whichever is more precise

9.4.8. Other Facilities

Other utility facilities, such as aerial utilities and gravity flow sanitary or storm sewers, can be included in the scope of work for either the survey/mapping consultant or the subsurface utility consultant at the discretion of the DDOT Project Manager.

9.4.8.1. Aerial Utilities

8. Coordinate with utility companies and the appropriate governmental jurisdictions in researching the location(s) of existing aerial utilities. Secure all "as-built" plans, plats, and other necessary data as supplied by the utility companies. While obtaining the information from the utility companies or governmental jurisdictions, the SUE Consultant should attempt to ascertain such information as the age, pole size, pole height, pole number, material type, and general condition of the utility.
9. The SUE Consultant must record the horizontal location of existing poles for aerial utility facilities. Existing poles for overhead utility facilities must be surveyed to the same horizontal accuracies and precision as is required for the topographic data in the project's database.
10. The SUE Consultant must determine the aerial utility owners and correctly show the horizontal position of the utilities between the poles, including major service drops (substations or industrial facilities).
11. Aerial utilities, along with pole locations and appurtenances, must be returned to DDOT in digital and reproducible certified plan sheet format.

9.4.8.2. Gravity Flow Sanitary Sewer Mapping

"Sanitary Sewer Mapping" means indicating the presence and approximate horizontal and vertical location of underground utilities by surveying visible aboveground and accessible subsurface utility features, such as manholes and pipe inverts and using professional judgment to correlate this information with existing utility records. If this work is part of the SUE scope, then it will be included with the Quality Level C deliverable.

1. The SUE Consultant must determine and provide the horizontal and vertical locations of accessible surface features of gravity flow sanitary facilities.
2. The SUE Consultant must determine and provide vertical locations of the flow lines of all pipes within accessible structures. When possible, the SUE Consultant must determine the material of the pipes in these structures. This data will be surveyed to the same accuracy and precision as required for the topographic data in the project's database.
3. The SUE Consultant must show the approximate horizontal position of the utilities between surface features.
4. Mapping of existing gravity flow sanitary sewers must be returned to DDOT in digital and reproducible certified plan sheet format.

9.4.9. Project Deliverables

All subsurface utility engineering tasks must be performed under the direct supervision of a Professional Engineer or Land Surveyor licensed by the District of Columbia, and project deliverables must be signed and sealed by same.

9.5. Utilities Installed in Public Space

9.5.1. General Requirements

Coordinate the design for new construction with affected utility companies in early stages of the design. Every effort should be made to avoid relocating the existing utilities unless it is deemed necessary. The cost for relocating the existing utilities will be borne by the affected utility companies, except for utilities relocated on the Interstate Highway System, where the Federal Highway Administration will contribute to the relocation cost.

9.5.1.1. Minimum Depth

All utilities must be installed at a minimum depth of 36 inches from the top of the pipe to the top of pavement, or 24 inches from the top of pipe to the top of sub-grade, whichever is greater.

9.5.1.2. Access Covers

- All manhole lids, utility access covers, and range box access covers must be depressed no more than 1/2 inch below the adjacent finished street surface. If located in concrete, all access covers must be set flush with surrounding concrete.
- Manholes or valves must not be constructed in the wheel path of a travel lane or at any location within a bike lane.

9.5.1.3. Trees and Large Shrubs Near Utilities

- Utility access must not be built in a tree box, regardless of whether there is an existing tree.
- Trees must be installed along all ROWs within the District of Columbia, regardless of location of overhead or underground utilities.
- Utility work to be performed within the root zone of a street tree must be coordinated with the District Department of Transportation's Urban Forestry Administration. The root zone is measured from the near side of the tree trunk to a distance equaling the tree diameter (measured in inches at 4.5 feet above ground) by 1.5 feet, or to the drip line of the street tree, whichever is greater. Work within this zone should be performed so as to minimize damage to

the tree and the root zone, and may require measures such as root pruning or tunneling to protect the tree and root zone during utility installation.

9.5.1.4. Conduits and Sleeves

To minimize future repairs and street cuts, utility companies must install all utilities in non-corrosive conduits or sleeves equivalent to Schedule 40 PVC meeting the requirements of the utility companies, or other conduits and sleeves encased in concrete, slurry or flow-fill material, on all public streets. Exceptions will be gas lines, which must have metal pipes meeting the requirements of the utility company.

9.5.2. Location Criteria

9.5.2.1. General

Utilities must be installed outside the curbs and gutters. They must be separated at least 2 feet from existing buried utilities. When less than 2 feet of clear space is available, the matter must be conferred with the affected utility for concurrence.

9.5.2.2. Water

- **Water Lines.** Water lines should be located on the north and east sides of streets approximately 7 feet south or west of the north or east flow line. Water lines must be separated by a minimum of 10 feet horizontally from sanitary sewer and storm sewer facilities.
- **Fire Hydrants.** Fire hydrants must be located 2 feet from faces of curbs, or 1.5 feet minimum from the back edge of a sidewalk, or 10 feet minimum from edge of pavement if no curb is present. In addition, the water line must be located such that the valves are not in the wheel path of the street lane.
- If a water line is located where reconstruction is planned, DC Water must be notified. DC Water will determine if the water line needs to be replaced.

9.5.2.3. Sanitary Sewers

Sanitary sewers should be on the centerline of the ROW unless a median is present. If a median is present, the sanitary sewer line should be located 6 feet west or south of the median. The sanitary sewer should be located such that the manholes are not located within the wheel path of the street lane.

9.5.2.4. Storm Sewers

Storm sewers should be placed so the manholes are not located within the wheel path of the street lane.

All inlet grates should be bicycle compatible. Bars should be flush with the pavement and should be perpendicular to the direction of travel.

9.5.2.5. Natural Gas

Gas mains must be located either within the ROW or in an adjacent easement on the south and west sides of the street.

9.5.2.6. Power and Street Lighting

Generally, power and street lighting lines should be located on both sides of the street, either in the ROW or in an adjacent easement.

9.5.2.7. Electric Utility Vaults

Access vaults for electrical power and similar equipment should not be located in public space unless locating them on private space is impossible. If they are located in public space, they must be located in the pedestrian clear zone and be covered with a solid lid made of sidewalk paving materials.

9.5.3. Other Utilities

Cable TV and telephone lines generally serve properties from the back. The utility companies must coordinate the locations of their installations in the ROW or easements with the District and other utility companies.

Traffic Signals and Signs:

- **Location.** Poles, signs and any other aboveground streetscape (except regulatory signs) should be located within 5 feet of the ROW line or 10 feet from the travel lane (flow line), whichever is more restrictive.
- **Clearance.** Light poles must be placed no closer to the roadway than 2 feet behind a vertical curb line and no closer than 2 feet to any sidewalk.
- The Project Manager may require breakaway poles on public ROWs where the speed limit is 40 mph or higher.
- **Other Requirements.** All signs and poles must meet the requirements of **Chapter 41** of this manual.

9.5.4. Utility Attachments on Bridges

9.5.4.1. General

The following guidance on utility installations on bridges should be followed:

- In most cases, attachment of utilities to highway structures, such as bridges, is a practical arrangement and considered to be in the public interest. However, every effort should be made when attaching utility lines to a highway structure so that they do not affect structural integrity, safe operation of traffic, efficiency of maintenance, or appearance.
- Since highway structure designs and site conditions vary, the adoption of a standard method to accommodate utility facilities is not feasible; however, the method employed should conform to logical engineering practices for preserving the highway, its safe operation, maintenance and appearance. Generally, acceptable utility installations are those that occupy a position beneath the bridge floor, between the outer girders, on beams or within a cell, and at an elevation above low superstructure steel or masonry.
- The controls for providing encasement, allied mechanical protection and shut-off valves to pipeline crossings of highways, and for restricting varied use, must be followed for pipeline attachments to bridge structures, except that sleeves are required only through the abutment backwalls. Where a pipeline attachment to a bridge is encased, the casing should be effectively opened or vented at each end to prevent possible buildup of pressure and to detect leakage of gases or fluid.
- Since an encasement is not normally provided for a pipeline attachment to a bridge, additional protective measures must be taken. Such measures must employ a higher factor of safety in the design, construction, and testing of the pipeline than would normally be required for cased construction.
- Communication and electric power line attachments must be suitably insulated, grounded, and carried in protective conduit or pipe from the point of exit from the ground to re-entry. The cable must be carried to a manhole located beyond the backwall of the structure. Carrier pipe and casing pipe should be suitably insulated from electric power line attachments.
- Guy wires supporting any utility will never be allowed to attach to a bridge structure.

To ensure that the function, aesthetics, painting and inspection of stringers of a structure are maintained, the following applies to the installation of utilities on bridges:

- Permanent installations that will be carried on and parallel to the longitudinal axis of the structure must be placed out of sight, between the fascia beams and above the bottom flanges, on the underside of the structure.
- Conglomeration of utilities in the same bay should be avoided in order to facilitate maintenance painting and future inspection of steel stringers in a practical manner.

9.5.4.2. Supports

Due consideration must be given to the weight of the pipes, ducts, etc. in the design of the beams and diaphragms. Utilities must not be supported by a system that requires inserts in the concrete deck slab. They should be supported directly on structural beams. Also, utilities must not be supported by a system that requires drilling into prestressed concrete beams. Welding onto structural steel beams or diaphragms is not permitted. The support details must be in accordance with the requirements of the individual utility companies.

- The location of a utility crossing on a structure should be selected to avoid conflict with existing utilities or future utilities for which provisions have been made. Adequate access for maintenance and inspection of the planned installation and of the structure itself must be kept in mind.
- Placing utilities on bridge decks or sidewalk areas, or attaching them to railings or parapets, is not permitted. Also prohibited are exposed installations at the outside faces of the structure.
- Existing under-clearances must be preserved. The applicant must position all elements of a crossing to clear a line defined by connecting the points where the centerline of web at the bottom of the bottom flange beams flanking the installation intersect.
- Familiarity with the structural framework is necessary to avoid conflicts with bearing seats, cross frames, intermediate and end diaphragms, and lateral bracing.
- Structural integrity of the bridge components must be preserved. The dead load of the proposed utility attachment must be accounted for in bridge design.

9.5.4.3. Plans and Installation Requirements

General plan and elevation drawings must show information about all existing and proposed utilities carried under the superstructure or in the vicinity of foundations. Complete information as to the name of owner, size, type, abandonment, proposed relocation, and material to be furnished by the utility company, etc. must be noted.

- Joints in bridge decks unusually define locations where differential movements can occur between adjacent spans resulting from temperature changes and traffic loads. Appropriate devices must be provided at these locations to accommodate similar movements in bridge attachments.

- Galvanized structural steel should be used for supports where existing structural elements cannot carry loads. Sizes of proposed structural shapes should be provided.
- Specify the type, size and location of connections. High-strength bolts must be used per specification section 815 (D) of DDOT's **Standard Specifications for Highways and Structures**, the most recent version. For new structures, welding to existing structural appurtenances is prohibited. Welding or drilling on steel structures in the field is also prohibited. The locations and details of all connections must be designated by the bridge Designer. Placement of anchor bolts or other inserts into deck slabs is also prohibited.
- Pipes installed through abutment backwalls should be placed in galvanized steel sleeves set in non-shrink grout with the opening between the pipe and sleeve packed with jute or similar material to prevent leakage through the backwall.
- Provide ducts for electrical and communication cables.
- Pipes carrying liquids under pressure in trenches should be sleeved within 10 feet of abutments, walls and piers.
- All pipelines carrying liquids or gases under pressure must extend through the supporting structure without changes in alignment. Changes in alignment must be outside the structure limits. Reactions developed at these locations should be carried by thrust blocks or other means completely independent of the bridge's structural elements.
- Provide a plan view with a north reference arrow, an elevation and a cross section of the structure and detailing; include the dimensions needed to identify and locate existing and proposed structural members associated with the bridge attachment and verify clearances. Additional sections should be shown, as required, to completely convey the extent of the work and modifications proposed.
- The outside diameters and thicknesses of pipes, weights of pipe or conduit, and materials carried should be shown on the plans. If manufactured fittings, connectors, supports etc. are used, their identity and spacing should be indicated on the plans, and catalog cuts with dimensions should be traced onto the plans.

9.5.4.4. Pipeline Expansion Joints (Water Lines)

- Allowances must be made for changes in pipe length due to thermal expansion and alternate contraction. Dresser type couplings will handle the normal amount of expansion and contraction in each length of pipe. Dresser type expansion joints or similar products are required where no flexible joints are used in the pipeline or when the amount of concentrated movement at one point is in excess of the amount that can be safely absorbed by the standard coupling.

- A Dresser type expansion joint should be used in the pipeline adjacent to every point where allowances for expansion are provided in the superstructure.
- Use Dresser type couplings or similar products to accommodate the differential movement between the structure and the line itself, and to provide flexibility to accommodate vibrations of the structure.
- Each coupling can safely accommodate up to 3/8 inch longitudinal movement. This is equivalent to the amount of movement resulting from a 150 degree F temperature variation in a 40-foot length of steel pipe.
- Proper alignment is important to ensure free and concentric movement of the slip-type expansion joint. Alignment guides should be designed to allow free movement in only one direction along the axis of the pipe and to prevent any horizontal or vertical movement of the pipe. Suitable pipe alignment guides may be obtained from reliable pipe alignment guide manufacturers. Alignment guides should be fastened to a rigid part of the installation, such as the framework of the bridge. Alignment guides should be located as close to the expansion joint as possible, up to a maximum of 4 pipe diameters. The distance from the first pipe guide to the second should not exceed 14 pipe diameters from the first guide. Where an anchor is located adjacent to an expansion joint, it too should be as close to the expansion joint as possible, to a maximum of 4 pipe diameters from the expansion joint. Pipe supports should not be substituted for alignment guides. The main pipe anchors must be designed to withstand the full thrust resulting from internal line pressure and the frictional forces from guides and supports.

10 Drafting Standards

Any DDOT design plans must be prepared with a 22" x 34" border and printed on a 24" x 36" sheet. All review sets must be printed in full-size production unless otherwise directed by DDOT. To ensure consistency, the border files provided as part of the District's computer-aided design (CAD) standards must be used. All drafting must be performed in a MicroStation (.dgn) native format and not converted from another CAD platform.

The District's **CAD Standards Manual** can be found at the following website:

- http://ddot.dc.gov/page/microstation-v8-cad-standards-manual

The construction and right-of-way plans must meet the following criteria:

- All drawings must adhere to the requirements of the latest District CAD standards as specified in the **CAD Standards Manual** and associated electronic files and tools.
- The Consultant must obtain and use the most current version of the District's **CAD Standards Manual** and electronic files and tools. The tools and files include seed files, border files, cell libraries, color tables, and programs and macros that customize the DDOT workspace.
- All hard copy submittals are to be clean, unwrinkled and undamaged. The use of paste-ups on final drawings is not acceptable.
- In addition to the reproducible and hard copies called for by the contract, the Consultant must submit all electronic files used to generate the hard copy contract documents. The file names and directory structure of the electronic files must be specified by the most current **CAD Standards Manual**.
- All drawings should be prepared to allow clear readability of plans at half-size.
- The Consultant must use the design software specified in the District's **CAD Standards Manual** to establish and generate the centerline, profile, cross sections, etc. The Consultant must provide the input files and design data files used by the design software as specified in the District's latest **CAD Standards Manual**.
- The Consultant must obtain, from the DDOT Project Manager, standard sheets for the development of construction plans. These sheets include Title Block, Summary of Quantities, General Notes, Index of Drawings and Standard Symbols and Abbreviations.

11 Control Survey and Topographic Mapping

The District of Columbia requires a complete topographic survey as part of the plan submittal for work within the right-of-way (ROW). The topographic survey must be reviewed and permitted through the Department of Transportation. All topographic surveys must meet the standards identified in this manual. Complete and accurate surveys are required to protect the City, private property, easements and ROWs, and are essential for planning, designing and constructing improvements in the ROW.

ROW limits, property lines and other legal lines must be properly established for the purposes of constructing ROW improvements. A topographic survey shows all topographic elements that can be identified using visual group survey methods, and usually includes a base map with detailed information on the location, type and size of infrastructure elements both above ground and buried.

Due to the varied nature of transportation projects in the District of Columbia, the DDOT Project Manager will have the final say on survey content based on specific project requirements.

11.1. Survey Requirements

The topographic survey must show ROW lines depicting boundaries of DDOT Public Space. At the discretion of the DDOT Project Manager, the GIS property information available from the District Office of the Chief Technology Officer can be used in place of a field boundary survey of the ROW lines

11.2. Limits of the Topographic Survey

The topographic survey information must be shown for the full width of the ROWs adjacent to the project site for at least 10 feet beyond the ROWs (if accessible) onto the adjacent private parcel(s) and for at least 50 linear feet along the ROW beyond all limits of the project site and proposed work.

For projects adjacent to an intersection, the entire intersection, including all four corners up to the far point of tangency of each curb return or roadway edge, must be included in the survey.

If the ROWs adjacent to the project site are not improved with curbs and sidewalks, the survey boundaries may, at the request of the Project Manager, need to be extended to include the entire block. If improvements will be made to an unopened or unimproved alley, the survey boundaries must extend to the intersecting streets.

11.3. Topographic Survey Requirements

11.3.1. Topographical Features

Within the pre-determined survey corridor, 3-dimensional data will be collected for all topographic breaklines, natural and cultural (man-made) features, and ground survey data. All measurements along longitudinal features or breaklines will be taken at regular intervals not to exceed 50-foot spacing between shots.

All existing underground and surface improvements that can be interpreted from a visual survey must be shown on the topographic survey. This includes ground surface contours, edges of pavements, concrete surfaces, asphalt surfaces, gravel surfaces, channelization, top and bottom of curbs, curb cuts, wheelchair ramps, gutter and flow lines, sidewalks, landscaped areas, pedestrian and bike paths, structures, rockeries, retaining walls, fences, bridges, swales, culverts, utilities, vaults and covers. The DDOT Project Manager will specify the level of detail required for any additional utility survey and investigation. Additionally, the surveyor must obtain as-built drawings of underground vaults that are not represented by surface features in order to properly accommodate their protection during construction activities.

11.3.2. Contours

If required by the DDOT Project Manager, show existing contours at 1-foot intervals.

11.3.3. Street Trees

Show all existing trees within the ROW and all trees 6 inches or more in diameter on private property where the drip line abuts or overhangs the ROW. The trunk diameter at 4-1/2 feet above grade and drip line must be shown to scale on the topographic survey.

11.3.4. Hydrologic Features

For surface water features, show the line of ordinary high water and the top of any well-defined stream or river banks. Show the 100-year floodplain as shown on FEMA maps.

11.3.5. Building Outlines

Show building outlines for buildings within 10 feet of the ROW line. Show spot elevations at all vehicle and pedestrian access points.

11.4. General Field Survey

1. The horizontal and vertical datums for field control points must be based on the most recent adjustment of the National Spatial Reference System (NSRS), as established by the National Geodetic Survey. Local datums may be used at the discretion of the DDOT Project Manager provided that conversion factors from the local datums to the NSRS are supplied.
2. Traverse points and baseline control points must be semi-permanent (using PK nails, RR spikes, iron rods, etc.) and be tied to at least three permanent objects.

11.5. Survey for Bridges

The following survey information must be depicted when a new superstructure is to be built on an existing substructure; an existing bridge is to be replaced in stages; an existing bridge is to be widened, repaired or rehabilitated; or when the underclearances are important to the project, such as for replacement bridges over water or railroads. Surveys on bridge locations are required to have a higher degree of accuracy than those on general road work. A copy of all field notes must be provided to the Design Consultant.

1. The angles of the abutments with the baseline, the location of tops and bottoms of batters, the widths of bridge seats and backwalls, the location of the angles of the wingwalls with abutments, the length of wingwalls and widths of copings must be measured, and the footings should be located if possible. The type of masonry in the substructure and its condition should be noted.
2. Detail must be provided for all main superstructure elements, including beam lines, girder lines, truss lines, floorbeam lines, curb lines, sidewalks, fascia lines, utilities, copings, ends of the bridge, etc. The stations of the bearing centerlines, and the skew angle between them and the survey baseline, must be established or verified at each abutment and at piers.
3. The bottom beam elevations must be measured on every beam at the face of each abutment, on both sides of each pier and span quarter points for spans less than 50 feet, and at span eighth points for spans over 50 feet. These elevations are needed for calculating the depth of haunches and top of form elevations.
4. Elevations must be noted for all parts of the substructure and superstructure, such as the bridge seats, tops and ends of wingwalls, gutters, top of curb at intermediate points and at the ends of curbs, tops of slab, and footings if possible.
5. Locate and establish the minimum horizontal and vertical underclearances of the existing structure.

11.6. Survey for Bridges over Railroads

Whenever a railroad is crossed, the railroad baseline should be reproduced, and the survey should show a minimum of 50 feet perpendicular to, and on both sides of, the exterior rails for a distance of about 300 feet left and right of the survey baseline.

11.7. Survey for Streams

The stream must be surveyed for at least 500 feet upstream and downstream on either side of the baseline. Elevations should be shown on a 10-foot grid. Any tributary entering the stream near the bridge site, either above or below, must be surveyed for a distance of at least 500 feet from its junction. Locations and sizes of visually accessible drain pipes should be noted. Where there is any possibility that an existing stream might be relocated, the survey must encompass the area of relocation.

In addition to the bridge, cross-sections perpendicular to the stream baseline and extending out beyond any known flood height should be shown on the survey grid every 70 feet for at least 280 feet, both upstream and downstream. Beyond 280 feet, a profile should be taken to definitely establish the grade of the stream's bed. For any downstream tributary mentioned above, cross-sections for 280 feet should also be shown.

11.8. General Requirements for Existing Conditions Plans

1. All plan drafting must conform to the requirements set forth in the Survey section of the **DDOT CAD Standards Manual**.
2. Property corners located in the field must be shown on the existing conditions plan. Owners' names and deed references must be shown along with approximate property lines pertinent to the project. Layout data are to be shown on the existing conditions plan indicating the coordinates, bearing, distances and stations between changes in geometry of the alignment.
3. All units must be in U.S. Survey feet, coordinate values must be to 4 decimal places, linear values and elevations must be to 2 decimal places, and direction bearings must be to the second.
4. Detailed information on all existing utilities that will be affected by construction must be shown on the base map. All visible infrastructure, including utilities, structures and appurtenances, must be shown on the topographic survey. The types, sizes and horizontal locations of buried utilities and aboveground infrastructure and utilities must be included within the area that will be affected by construction. At the discretion of the DDOT Project Manager, it may also be necessary to determine the elevation of buried or aboveground utilities, based on the proposed work. Utility locations must be in accordance with **Chapter 9**. In addition to providing detailed information on the base map, a list of the sources of the information must be provided. The list

must include the specific source of information, such as side sewer cards, franchise and utility maps, vault plans, etc., and plan number for all underground and aboveground utility information. Utility information obtained from an underground locator, via potholing, etc. should be noted as such.

11.9. Accuracy

All Survey topographic information must comply with National Map Standards for the scale of mapping (http://nationalmap.gov/standards/nmas.html). ROW surveying is to be performed in accordance the most recent **Manual of Practices for Real Property Surveying** published by the Government of the District of Columbia, Department of Consumer and Regulatory Affairs, Office of the Surveyor for the District of Columbia.

11.10. Drafting Requirements

11.10.1. Standard Abbreviations, Shading, Fonts and Symbols

Features must be shown and noted in accordance with standard abbreviations, shading and symbols found in the current **DDOT CAD Standards Manual** and associated **DDOT Standard Drawings** and MicroStation Workspace. The Manual and Workspace also define the required font types and sizes for labeling topographic mapping features and notes.

11.10.2. Sheet Size

Sheet size must be 24 inches by 36 inches.

11.10.3. Readability

All information provided on base maps and surveys must be readable. All text must be sized in accordance with the **DDOT CAD Standards Manual**.

11.10.4. North Arrow

The north arrow must be oriented with plan north to the left or top of the sheet.

11.10.5. Graphical Scale

The minimum scale allowed for surveys is 1 inch = 20 feet.

11.10.6. Bar Scale

All base map and survey documents must include a bar scale.

11.10.7. Street Names

Street names for all frontages must be shown on all base maps and surveys.

11.11. Survey Control Sheets

At the discretion of the DDOT Project Manager, a Survey Control Sheet may be required for inclusion in the plan set. The Survey Control Sheet will show the location, project coordinates and elevations of the permanent survey control established for the project. The detailed drawing must show the locations of the control points with dimensions in relation to three permanent features to aid in the recovery of the control points. Metadata identifying the source datum(s) of the survey control sufficient for its reestablishment must also be included on the Survey Control Sheet.

12 Project Deliverables

12.1. Project Deliverables

Throughout the life of a project, deliverables serve to convey the design intent to the community, stakeholders, reviewers, and ultimately the Contractor, to make a project reality. Deliverables include reports, collected data, calculations, plans, specifications and special provisions, cost estimates and sometimes additional items. This chapter discusses project deliverables and also describes the detailed procedure for documenting design exceptions and waivers.

12.2. Submittals

12.2.1. Preliminary Engineering Report

As directed by the DDOT Project Manager during project scoping, especially for projects of a unique or sensitive nature, a Preliminary Engineering Report must be prepared to assess design options, impacts and cost. The Preliminary Engineering Report must also document factors associated with aesthetics, design life, constructability and maintenance; additional considerations may also be required.

The Preliminary Engineering Report may include, but is not limited to, the following:

- Background and Context
- Design Criteria, Requirements and Constraints
- Roadway Design
- Pedestrian/Bike Facility Design
- Structural/Bridge Design
- Drainage and Stormwater Management Design
- Landscape
- Traffic Engineering
- Lighting
- Constructability
- Maintenance of Traffic
- Environmental Documentation
- Right-of-Way (ROW) Acquisition and Relocation Documentation
- Agency and Stakeholder Coordination
- Order of Magnitude Cost Estimate

As part of the report, conceptual engineering plans (15 percent) must include a General Plan and Typical Sections. Additional drawings and graphics should be included to illustrate design elements and the proposed project condition.

Submit one electronic copy of the Draft Preliminary Engineering Report to the DDOT Project Manager, who will distribute it for review. Upon receipt of comments, submit one electronic copy and five hard copies of a Final Preliminary Engineering Report with revisions based on comments received from the DDOT Project Manager.

12.2.2. Discipline-Specific Reports

Projects may require discipline-specific reports such as the following:

- Foundation report (see **Chapter 15**)
- Seismic and scour studies (see **Chapters 21** and **28**, respectively)
- Bridge type studies (see **Chapter 13** and **Appendix E**)
- Geotechnical engineering reports (see **Chapter 26**)
- Drainage and stormwater management (see **Chapter 28**)
- ROW analysis
- Transportation analysis technical report

12.2.3. Preliminary Plan Submittal – 30 Percent Review

Perform all tasks necessary before the 30 percent review submission for road and bridge projects, including the procedures listed below at a minimum. Also, the Consultant must arrange a field review with DDOT and Federal Highway Administration (FHWA) representatives to ensure project concurrence.

- Determine all historic structures, historic neighborhoods and other cultural resource requirements for the project and coordinate with the Historic Preservation Office.
- Determine traffic-engineering enhancements intended to improve spot safety, eliminate hazards and comply with basic design criteria and requirements within the project limits. To resolve any conflicts or issues, meet with the responsible DDOT Infrastructure Project Management Administration staff.
- Obtain and review any existing or proposed signs, markings and safety improvement designs. These designs, if still applicable, should be incorporated into the project.
- Determine if geometric changes are warranted to alleviate potential safety or operational problems and to satisfy American Association of State Highway and Transportation Officials

(AASHTO) requirements for design speed, horizontal and vertical curvature and capacity criteria. If geometric changes are proposed, prepare drawings showing the proposed changes.

- Provide horizontal and vertical curvature (profile, high and low points, maximum grade and sight distance, etc.) for conformance with AASHTO and DDOT requirements.
- Determine if the roadway warrants widening, especially if the travel lane widths are substandard. If widening is proposed, determine whether sufficient ROW is available and if trees need to be removed.
- Determine if the roadway warrants narrowing, especially if traffic calming is needed or if lane widths are well above minimum requirements and impervious surface removal will help meet stormwater management requirements (**Section 12.3.2.21**).
- Prepare ROW Plans if there is a change to the ROW lines.
- Determine the need for safety appurtenances (guiderail, impact attenuators, etc.).
- Provide design data (current and projected traffic volumes, percent trucks, directional distribution, etc.).
- Indicate the scale and format, and include a title block, legends, notes and a north arrow on drawings. The horizontal scale for the plan sheets will be 1 inch = 20 feet unless otherwise directed.
- Include all detour routes and any available staging and construction sequence requirements in the Maintenance of Traffic Plan. Forward any requirements for temporary signal design and signal timing variation for construction projects to DDOT Transportation Operations Administration (TOA) within a pre-determined timeframe to allow proper response.
- Determine if bus operations are involved and if the buses can make the necessary turns. Inform the Project Manager immediately if any bus operation will be potentially affected, and coordinate with Metrobus Operations through the Office of Mass Transit to determine a solution.
- Determine if bike lanes are proposed. Inform the Project Manager immediately if any bike lanes are involved, and coordinate with the Department's Bike Coordinator to determine a solution.
- Whenever possible, curb ramps should be perpendicular to the curb and aligned with the crosswalk line farthest from the intersection.
- For bridges, perform field reconnaissance and a hands-on inspection of the structural condition of the bridge using the latest **National Bridge Inspection Report** as a guide.
- Perform seismic and scour studies as required under AASHTO guidelines, and incorporate the findings into the design of the structures.

- Upon completion of the field inspection and seismic and scour studies for bridge-related projects, prepare a brief report describing the findings, particularly the structural deficiencies encountered and proposed recommendations for corrective action. Provide a bridge analysis and rating according to **Chapter 14**, including associated cost analysis, to achieve HL-93 AASHTO standard loading. Include inventory and operating load ratings in the computations based on the Load Factor Rating (LFR) method for the bridges in accordance with **Chapter 14** and **National Bridge Inspection Standards**. ***In-service bridges that have been designed by a method other than* AASHTO Load and Resistance Factor Design (LRFD) *must be load rated by the LFR method*.**

  Submit inspection reports and scour and seismic studies to:

  Chief Engineer
  Infrastructure Project Management Administration
  DC Department of Transportation
  55 M Street, SE, Fourth Floor
  Washington, DC 20003

- Determine the extent of bridge rehabilitation or reconstruction, and prepare drawings showing plans, elevations and the existing and proposed sections of the bridge, including all related structures and roadways affected by the proposed construction.
- Provide a hydrology and hydraulics (H&H)/drainage report showing analysis of existing capacity of hydraulic structures and establishing the need for improvement, if any. The H&H report should also assess any encroachment of project elements into floodplains as designated on FEMA Flood Insurance Rate Maps and District floodplain regulations, along with mitigation measures.
- For Stormwater Management Maximum Extent Practicable (MEP) Design, address and incorporate the steps detailed in **Chapter 28** into the submission, and provide the Stormwater Management Map, MEP Worksheet and Stormwater Management Narrative described in detail in **Chapter 28.**
- Provide pre-design report details, design issues, resolution reports, status of project and other relevant information.
- Provide a preliminary cost estimate, including contingency as coordinated with the DDOT Project Manager, to be used in determining the project budget.
- Email an electronic version and submit the required hard copy sets of half-size, rubber-stamped and dated preliminary plans and two copies of preliminary construction cost estimates for review and comment, when directed, from which two sets of plans will be forwarded to FHWA

for review and approval. Include cost of temporary construction, maintenance and protection of traffic, etc. in cost estimates for construction.

- Distribute the plans and special provisions as directed by the Project Manager. The Project Manager will furnish the addresses of the agencies. Refer to **Section 12.4** for the required number of plans to be submitted unless otherwise directed by the Project Manager.
- Submit a Quality Assurance Statement.
- A Preliminary Project Review may be scheduled 2 to 3 weeks after submittal of the plans to provide an opportunity to discuss changes.

12.2.3.1. Required Plans for 30 Percent Submission

Required plans are listed below. The preliminary plans required for this submittal include all drawings marked with (*), but DDOT may request others.

General Drawings	Title Sheet*
	General Notes*
	Standard Symbols & Abbreviation/Summary of Pay Items and Quantities
Street/Roadway Drawings	Existing Survey Plan*
	ROW Plans (if new ROW is required)
	Geometric Layout and Control Points*
	General Roadway and Bridge Plan*
	Roadway and Bridge Paving Plan
	Existing and Proposed Roadway Typical Sections*
	Existing Condition Plans Including Signage, Marking & Geometries*
	Selected Design Alternative* with Final Geometries*
	Roadway Profiles- Centerline and Top of Curbs*
	Roadway Cross Sections
	Roadway Intersection Plan and Joint Layout
	Roadway Details: Joint Details, Alley & Driveway Entrances and Sidewalks
	Roadway Miscellaneous Details: Curbs & Gutters, Islands and Curb/Bike Ramps

Bridge Drawings	Bridge Plan and Elevation*
	Bridge Deck and Approach Slabs Plan*
	Existing and Proposed Bridge Typical Sections*
	Bridge Framing Plan*
	Steel/Concrete Structural Details
	Bridge Bearing and Structural Details
	Bridge Joint Details
	Abutments Plan, Elevation, Footing/Foundation and Section
	Retaining Walls Plan, Elevation, Footing/Foundation and Section
	Piers Plan, Elevation, Footing/Foundation and Section
	Bridge Railing Plan
	Bridge Railing Details*
	Bridge Drainage Details*
	Bridge Repair Details
Utility Drawings	Existing Utilities Plan, Legend and Notes*
	Composite Utilities Plan, Legend and Notes
	Proposed Water Main Plan* (Design by Others)
	Water Main Details* (Design by Others)
	Cross Sections Showing All Existing Underground Utilities
Drainage and Stormwater Management Drawings	Proposed Storm Sewer Plans and Profiles*
	Proposed Stormwater and Hydraulic Structures
	Stormwater Management Plan*
	Storm Sewer and Stormwater Management Details
	Drainage Area Plan
	Federal Insurance & Mitigation Administration (FIMA) 100-Year Return Period Flood Elevations
Tree and Landscape Drawings	Trees and Landscape Plan and Schedule of Quantities
	Planting Plans and Details; Soil Plan and Volume Calculations

Electrical Drawings	Streetlight Photometric Analysis for Existing & Proposed Conditions*
	Streetlight Plan and Schedule of Quantities*
	Traffic Signal Plan and Schedule of Quantities
	Communication Cables Plan and Schedule of Quantities
	Streetlight, Traffic Signal and Communication Cables Details
Maintenance of Traffic Drawings	Preliminary Traffic Detour and Traffic Control Plan*
	Sequence of Construction Plan and Schedule of Quantities*
	Proposed Signs and Pavement Marking Plan*
	Proposed Sign Schedule and Quantities
	Sign Support Details
	Pavement Marking Quantities and Details
Miscellaneous Drawings	Sediment and Erosion Control Management Plan*
	Sediment and Erosion Control Details and Notes*
	Soils Boring Logs*

12.2.4. Intermediate (Pre-Final) Plan Submittal – 65 Percent Review

This review will occur while the Consultant continues project design. At this time, the Consultant will arrange a field meeting with DDOT and FHWA representatives to ensure that everyone is in agreement with all aspects of the project design. The 65 percent review submission for road and bridge projects includes the following procedures:

- Address the comments from the 30 percent plan review. Include a comment resolution matrix listing the comments that were addressed and what actions were taken.
- Submit a Quality Assurance Statement.
- Develop detailed construction plans for the project in final format, including traffic control plan, peak hour restrictions, staging and construction sequence requirements, signing and marking drawings for compliance with the **Manual on Uniform Traffic Control Devices (MUTCD)**, District policy and the restrictions established for the project. Include Pay Items and schedule of quantities.

- For Stormwater Management MEP Design, address and incorporate the steps detailed in **Chapter 28** into the submission and provide the Stormwater Management Map, MEP Worksheet, and Stormwater Management Narrative described in detail in **Chapter 28**.
- Prepare Landscape and Planting Plans per **Chapter 28**.
- Prepare the Special Provisions, including the scope of work for the project, specifications and Pay Items for the materials in draft format. These items include work that modifies the latest edition of the **DDOT Standard Specifications for Highways and Structures**.
- Prepare updated itemized cost estimates using AASHTO Estimator; the estimator will eliminate or modify the contingency percentage as directed by the DDOT Project Manager and be priced by the appropriate Pay Items listed as the quantities on the plans.
- Incorporate ROW plans, requirements, Pay Items and cost estimates provided by others, when directed.
- Incorporate design plans, specifications, Pay Items and cost estimates provided by others when directed.
- Prepare a preliminary construction schedule.
- Submit one set of full-size, 30 sets of half-size and a PDF of the 65 percent stamped and dated intermediate plans for review and comment, when directed, from which two sets of intermediate plans will be forwarded to FHWA for review and approval. Distribute the plans and Special Provisions as directed by the Project Manager. The Project Manager will furnish the addresses of the agencies and the specified number of plans and Special Provisions. Return the 30 percent review comment list with plans showing items were addressed.

12.2.4.1. Required Plans for 65 Percent Submission

The following sheets will be substantially completed and submitted in the following order:

General Drawings	Title Sheet
	General Notes
	Standard Symbols & Abbreviations/Summary of Pay Items and Quantities

Street/Roadway Drawings	Existing Survey Plan
	ROW Plan (if new ROW is required)
	Geometric Layout and Control Points
	General Roadway and Bridge Plan
	Roadway and Bridge Paving Plan
	Existing and Proposed Roadway Typical Sections
	Existing and Proposed Roadways Geometries, Including Signs and Marking
	Roadway Profiles: Centerline and Tops of Curbs
	Roadway Cross Sections
	Roadway Intersection Plan and Joint Layout
	Roadway Details: Joint Details, Alley & Driveway Entrances and Sidewalks
	Roadway Miscellaneous Details: Curbs & Gutters, islands and Curb/Bike Ramps
Bridge Drawings	Bridge Plan and Elevation
	Bridge Deck and Approach Slabs Plan
	Existing and Proposed Bridge Typical Sections Bridge Framing Plan
	Steel/Concrete Structural Details
	Bridge Bearing Shoes and Structural Details
	Bridge Joint Details
	Abutments Plan, Elevation, Footing/Foundation and Section
	Retaining Walls Plan, Elevation, Footing/Foundation and Section
	Piers Plan, Elevation, Footing/Foundation and Section
	Bridge Railing Plan
	Bridge Railing Details
	Bridge Drainage Details
	Bridge Repair Details

Utility Drawings	Existing Utilities Plan, Legend and Notes
	Composite Utilities Plan, Legend and Notes
	Proposed Water Main Plan (Design by Others)
	Water Main Details (Design by Others)
	Cross Sections Showing All Existing Underground Utilities
Drainage and Stormwater Management Drawings	Proposed Storm Sewer Plans and Profiles
	Proposed Stormwater and Hydraulic Structures
	Stormwater Management Plan
	Storm Sewer and Stormwater Management Details
	Drainage Area Plan
	FIMA 100-Year Return Period Flood Elevations
Tree and Landscape Drawings	Trees and Landscape Plan and Schedule of Quantities
	Planting Plans and Details; Soil Plan and Volume Calculations
Electrical Drawings	Streetlight Plan and Schedule of Quantities
	Traffic Signal Plan and Schedule of Quantities
	Communication Cables Plan and Schedule of Quantities
	Streetlight, Traffic Signal and Communication Cables Details
	Intelligent Transportation Systems Equipment Details & Quantities
Maintenance of Traffic Drawings	Traffic Detour and Traffic Control Plan
	Sequence of Construction Plan and Schedule of Quantities
	Existing Signs and Sign Schedule of Quantities
	Proposed Signs and Sign Schedule of Quantities
	Sign Support Details
	Pavement and Crosswalk Marking Plan and Schedule of Quantities

Miscellaneous Drawings	Sediment and Erosion Control Management Plan
	Sediment and Erosion Control Details and Notes
	Soils Boring Logs

12.2.5. Final Construction Plans, Specifications and Cost Estimates – Final Review

As directed by the DDOT Project Manager, the Consultant will conduct a final field review with DDOT and FHWA personnel to ensure agreement with all aspects of the design and provide the following:

- Incorporate comments on the intermediate plans from DDOT, FHWA and review agencies; provide an updated comment resolution matrix showing compliance or response to all comments to date; and prepare complete and detailed contract plans, specifications, Pay Item schedule and construction cost estimates for a complete job, including ROW acquisition and relocation, sequence of construction, detour layout, and maintenance of highway and pedestrian traffic.
- For Stormwater Management MEP Design, address and incorporate the steps detailed in **Chapter 28** into the submission and provide the Stormwater Management Map, MEP Worksheet and Stormwater Management Narrative described in detail in **Chapter 28**.
- Incorporate standard contract provisions and appropriate documents into the Special Provisions.
- Submit a Quality Assurance Statement.
- Use the AASHTO Estimator Pay Item numbers for the project, and assign special items numbers when standard Pay Item numbers are not applicable after consulting with the Project Manager. Use item numbers allowed by AASHTO Estimator.
- Provide detailed Special Provisions for specifications of the special items.
- **Estimates**. Prepare detailed construction cost estimates in accordance with **Section 12.5**. Incorporate cost estimate provided by the DDOT ROW Section.
- **Final Project Review.** Approximately 8 weeks prior to submitting the Plans, Specifications and Estimates (PS&E), email and submit 30 sets of half-size, rubber-stamped and dated plans, 30 double-spaced draft copies of the Special Provisions and the Pay Item Schedule, and two copies of estimates (plus soft copies [i.e., CD/DVD] of the estimates in Excel) for review and comment when directed. Two sets of plans will be forwarded to FHWA for review and approval. The plans and contract documents for final review must be complete in details and scope for construction of the project. Plans will not include the Contractor's working drawings for concrete forms or

other construction method details, nor shop drawings for structural and reinforcing steel. The Pay Item Schedule will not contain subtotal breakdown sections.

- **Construction Completion Time Analysis.** Submit an analysis demonstrating how the number of days for completion stated in the contract Special Provisions was determined. For some projects, the DDOT Project Manager may require a Critical Path Method Schedule.
- **Corrections.** Make corrections to the PS&E as directed and within the time limit assigned by DDOT. Deliver to DDOT one complete set of half-size construction contract drawings, one complete set of the Special Provisions (with appendices) single-spaced typed neatly and Pay Item Schedule typed on 8.5-inch by 11-inch white bond paper, and soft copies (i.e., CD/DVD) of the Special Provisions and Pay Item Schedule (in Microsoft Word). Format order of Special Provisions and the Pay Item Schedule will conform to the format currently in use by the District.
- The Special Provisions, Pay Item Schedule and Cost Estimates will be returned to the Consultant for any necessary modifications. Make the modifications within the time limit assigned by DDOT and return the Special Provisions, Pay Item Schedule and Cost Estimates to DDOT.

12.2.6. Plans, Specifications and Estimates Submittal

When directed, deliver two complete sets of half-size plans to FHWA for the PS&E review. This submittal must be signed and sealed by a Professional Engineer registered in the District of Columbia. DDOT will forward the Special Provisions, Pay Item Schedule and Cost Estimates to FHWA unless otherwise directed. If further comments result from this review, make the necessary modifications.

12.2.7. Final Bid Documents

After DDOT approves and appends the appropriate documents to the Special Provisions, provide eight sets of final Special Provisions, Bid Forms and appendices and eight sets of half-size final Contract Plans. The documents should be printed on bond paper and bound and covered in conformance with current DDOT practice as directed by the DDOT Project Manager. The cover sheet and back sheets of the half-size plans, Special Provisions and Pay Item Schedule will be green.

Distribute the Contract Plans, Special Provisions and appendices to agencies outside of DDOT as directed by DDOT, and deliver the remaining sets of Contract Plans, Special Provisions and appendices to DDOT at the following address: 55 M Street, SE, Washington, DC 20003, or as directed by the DDOT Project Manager.

Furnish electronic files of clear, readable design computations and diagrams for all designed portions of the project and Pay Item quantity computations. Deliver to the Project Manager two soft copies (i.e., CD/DVD) of final Contract Drawings (in latest version of Microstation), two soft copies of final Special

Provisions (in latest version of Microsoft Word) and Pay Item Schedule in AASHTO Estimator format. One soft copy set of drawings and one soft copy set of Special Provisions will be forwarded to the Contractor to prepare as-built drawings and update specifications of the construction project.

NOTE: Occasionally, the Consultant may be asked to provide full-size drawings on bond paper or vellum for field use.

12.3. Preparation of Drawings

12.3.1. Drawings

The drawings must provide all necessary information to allow reviewers to clearly understand the design intent and for contractors to understand and build the proposed design. Drawings must be clear, concise and unambiguous. Appendix F provides the Consultant Roadway Plan Checklist which has a list of the necessary elements of the project drawings. The unnecessary repetition of details and drawings is to be avoided unless absolutely necessary to clearly convey design elements. The unnecessary repeating of information will cause conflicts when any changes made on the drawings are not carried through on all affected drawings.

12.3.2. Organization of Drawings

For a project to be properly defined, a consistent and well-organized set of documents is essential. Therefore, working drawings will have the following sequence on all projects.

12.3.2.1. Title/Cover Sheet

The cover sheet for all projects must be prepared on the standard title sheet and included in the DDOT Workspace, and must contain the following Items:

- Show "District of Columbia" at the top middle of the cover sheet. In the second line, show "Department of Transportation” followed by the title of the project in the next line.
- **Project Title**. The project title must appear on the cover sheet and in the title block of all sheets. On the cover sheet, the project title will appear in large bold letters in the top middle of the sheet under "Department of Transportation."
- **Federal-Aid Project Number**. Always include this number under the title of the project.
- **Length of Project.** Indicate the length of project on the title sheet under the project title and the Federal-Aid project number. Length of project is the distance between the limits of the project and incorporates all required work for a project, including the transition area for asphalt overlay to meet existing grades.

- **Index of the Drawings.** The index must show the number and title of each sheet in the entire set of project drawings. A separate sheet should be used for the index when the list of drawings will not fit on the cover sheet. The indexing of drawings has the following requirements:
  - Drawings must be numbered consecutively starting from Sheet No. 1 to the last sheet of the project drawings
  - Numbers and titles of drawings in the index must match the numbers and titles of drawings in the title block of each sheet (cross-check the index with plan sheets)
- **Vicinity Map.** Use a base map in a suitable scale that shows the vicinity of the project area relative to the surrounding roadway network and community. It must include the following:
  - A clear, readable map highlighting the project area
  - Street names
  - North arrow and scale
- **Location Map.** Use a base map in a suitable scale that shows the entire project and access to that project from a reference point. It must include the following:
  - A clear, readable map having the necessary information and street names
  - The limits of the project including begin and end stations
  - North arrow and scale
- **Traffic Design Data.** On the cover sheet, show the design data for the year of construction and the design speed (not the posted speed) as required for the street classification.
- **Standard Title Block.** A standard title block must be used for all drawings.

12.3.2.2. Standard Symbols and Abbreviations

- Symbols and abbreviation must be consistent throughout all contract documents. For a symbol or abbreviation that is not shown in the **DDOT Standard Drawings**, applicable standard symbols or abbreviations may be used when properly denoted. A list of standard plan abbreviations is included in Appendix G. No symbol/abbreviation other than the industry standards will be used.
- Show all symbols used on drawings in a "Standard Symbols Table." Implement the standard symbols on all drawings for consistency. Whenever using a new symbol, it must be defined and added to the Standard Symbols Table. Use different symbols for new (proposed) work than for existing features to differentiate between new and existing.

- Provide a Table of Abbreviations to define all abbreviations indicated on the project drawings. Use the same abbreviations on all drawings for consistency.

12.3.2.3. General Notes

- General and/or Construction Notes are required for all projects. For roadway projects that include rehabilitation of bridges, General Notes are mandatory.
- General Notes should include at least the following items: The current Design and Construction Specifications, design loads, design method, structural members (materials and stresses), structural steel-reinforced concrete and/or pre-stressed concrete, reinforcing/pre-stressing steel, reinforcement steel cover, bolts, foundation type and load capacity, maintenance of traffic, protection shield, verification of existing dimensions and elevations, texturing, patching, bonding new concrete to old, drilling holes in concrete and anchor bolts, paint, masonry and stone masonry, utilities, sections (cross references), and horizontal and vertical control datum. (See **DDOT Standard Drawings** for a complete list of General Notes.)

12.3.2.4. Summary of Quantities Table

- The Summary of Quantities Table will incorporate all Pay Items for materials and construction activities required for certain projects. The table must include item numbers, descriptions and quantities.
- Coordinate and cross check the table with drawings and specifications to present all required Pay Items. Neglecting to provide the necessary Pay Items may create costly change orders.
- All item numbers in the table must be selected from the current **DDOT Standard Specifications** and the standard Pay Item Index. Assign a special item number when there is no appropriate number for the type of work in the index. When assigning a special item number, approval of the District's Project Manager must be obtained. Use item numbers allowed by AASHTO Estimator. A detailed Special Provision must be written, including method of measurement and payment.
- Descriptions of Pay Items must be identical (including the method of measurement and payment) to the latest version of the **DDOT Standard Specifications** and Pay Item Index. Any deviation in item descriptions from the index will not be accepted or considered the same item. In this case, the item description will be corrected or a new item number used as described above.
- All quantities must comply and agree with the drawings. Any item listed without quantities will be eliminated.

- Provide complete Special Provisions for all additional items that are not listed in the current **DDOT Standard Specifications** and Pay Item Index.
- The Summary of Quantities Table must be cross-checked with the engineer's estimate items and pay schedule items for completeness.

12.3.2.5. Geometric Layout (Including Sketches for Control Points)

- Geometric layout includes the following:
  - Base line for main roadway(s) with required data
  - Base lines for intersecting roadways
  - Traverse lines with required data
  - Control points for baseline(s) and traverse lines
  - Benchmarks
  - Tables showing the necessary geometric data to satisfy all requirements for a project including, curve data, baseline control coordinates table, traverse line control coordinates table, superelevation table and horizontal and vertical control tables
  - Scale and graphic scale on all plans
  - North arrow on all plans
- Geometric data for the Construction Baseline (CBL) must include stations, bearings, horizontal curve data, distances, control point numbers and coordinates (north and east), location of start and end of bridges if any, points of intersecting roads and alleys, and the angle of intersections. Also, the names of all streets and intersecting streets must be indicated. A table for baseline control coordinates is required to coordinate the data.
- Geometric data for traverse lines must include stations, bearings, distances, and traverse reference point numbers and coordinates (north and east). Indicate traverse lines and ties. A table for traverse line control coordinates is required to coordinate the data.
- A sketch must be provided for each control point and benchmark showing its location, elevation and full description. Show a title under each sketch indicating the point number, and also show the north arrow.
- The station numbering system for a roadway will increase in the direction of east or north. In case of more than one CBL on the same project, do not repeat station numbers.
- Provide a note stating that coordinates are based on Maryland State Plane and elevations are based on DC Datum.

12.3.2.6. Survey of Existing Conditions

- If the DDOT ROW Program Coordinator determines that it is clear and apparent that no ROW will need to be acquired for the project work, no further detailed ROW survey is necessary. However, if ROW acquisition may be necessary, the new elements of the ROW must be surveyed and shown on drawings sealed by a surveyor licensed in the District of Columbia. Drawings must be at a scale not less than 1 inch = 20 feet unless special written permission is given to accommodate site size.
- The area to be surveyed must include a minimum 50-foot-wide strip beyond the limits of the project and extend 25 to 50 feet beyond the ROW.
- The Survey of the Existing Conditions must include the following:
    - Existing roadway dimensions, orientations, bearings and curve data for construction baseline, median, curb and gutter line.
    - Existing locations and widths of roadways and ROWs for main and intersecting streets.
    - Location and widths of existing alleys, driveways, circular entrances, sidewalks, ramps, sodded areas and tree spaces. Also, provide dimensions for the same.
    - The existing contour lines at 1-foot vertical intervals. (Note: Contour lines may not always be required for normal conditions.)
    - Spot elevations on the CBL quarter points at an interval required by the specific project or every 50 feet maximum, and the top and bottom of curb every 50 feet.
    - Locations and elevations of benchmarks and all reference points.
    - The actual locations of bridges and bridge approach slabs if any. Indicate bridge numbers and/or names.
    - Locations of abutments and structural elements under bridges (if any) must be indicated in dashed lines. For deck replacements, include seat elevations.
    - Existing safety appurtenances, i.e., guiderails, impact attenuators, fences, Jersey barriers, barricades, etc. Show kind, type and number as applicable.
    - Existing walls, retaining walls, copings, steps and curbs. Provide grade elevations.
    - Existing utility lines and storm drain structures, i.e., inlets, gutters, gratings, manholes, vaults, etc. Provide rim and invert elevations.
    - Existing gas, telephone, power and light lines. Also, indicate pole locations.
    - Existing trees, tree spaces, turf grass areas, etc.
    - Scale and graphic scale on all plans.
    - North arrow on all plans.

- Provide a note stating the horizontal and vertical coordinate systems upon which the survey is based.
- Label the names of all streets. Make street names bold to stand out on the drawings.

12.3.2.7. Typical Sections

- Typical section drawings must show all typical sections required for a complete project, including all roadway sections at critical and transitional locations where road width and/or cross-slope changes. Stations must be indicated under each section to show actual location. A gap between stations shows a missing section at the gap location. Show existing and new (proposed) sections on the drawings.
- Typical section drawings must show all design items required for a complete project as follows:
    - Pavement types; all materials must be specified using the correct name and size per the current **DDOT Standard Specifications** and Pay Item Index
    - Lane widths for driving, bicycling and parking lanes
    - ROW and roadways widths
    - Normal crown section, cross slopes and superelevations
    - Curbs and gutters: types, materials and dimensions
    - Drainage channels, pipes and culverts: side slopes, invert elevations and dimensions
    - Sidewalks: widths, sections and slopes
    - Tree spaces and turf grass areas
    - Bioretention, bioswales, and other Green Infrastructure facilities
    - Medians: widths, sections, materials and slopes
    - Shoulders: widths, sections and materials stability
    - Traffic barriers: roadside barriers, median barriers, bridge railings and crash cushions
    - Frontage roads and ramps
    - Typical section actual location by station number
    - Scale and graphic scale on all sections

- Roadway cross slope must be designed in accordance with AASHTO requirements. Cross slopes for the two lanes adjacent to the crown line should be pitched at the normal minimum slope, from 1.5 percent to 2 percent maximum, and on each successive pair of lanes or portion thereof outward, the rate may be increased by about 0.5 to 1 percent. Where three or more lanes are provided in each direction, the maximum pavement cross slope should be limited to 4 percent (per current **AASHTO, A Policy on Geometric Design of Highways and Streets**).

- Drawings must show the locations of cross slope changes and the pavement cross slope at each location.
- The crown line should be at the edge of the lane. A crown line in the middle of a lane is an exception that requires approval by the DDOT Project Manager. In transition areas, for shifting the crown location, use minimum slopes on both sides of the crown.
- Typical section drawings must show the following dimensions:
    - Width and changes in width of all roadway elements at critical locations
    - Thickness of pavement materials and soil base
    - Steel reinforcement; the reinforcement size and minimum concrete rebar cover
    - All dimensions, including thickness, for sidewalks, curbs and gutters

NOTE: All typical section sheets must include the following note:

> "Proof rolling of the existing road bed soils is required prior to replacement of the soils base materials. Unstable roadbed soils detected during proof rolling must be removed and replaced with approved soils base material. The depth of the undercut will be determined in the field at the time of construction. The subgrade must be compacted to the specified percentage of the maximum dry density as determined by AASHTO T-180 method D."

12.3.2.8. Paving and Grading Plans

- Paving and grading plans must show all geometric changes and document that these changes are warranted to alleviate potential safety or operational problems. All changes must satisfy AASHTO requirements for sight distance and for vertical and horizontal alignment.
- Paving and grading plans include the following elements:
    - Limits of project and the limits of total removal. Drawings should define actual locations by stations.
    - A transition area between the limits of total removal and the beginning and end of project for asphalt overlay where mill and resurfacing works will take place to meet existing grades.
    - Roadway areas that receive new pavement and the required types of pavement.
    - Start and end of new curb and gutter, specifying types and materials for curb and gutter and pattern for brick gutters. Provide curb return radii.
    - Final roadway geometry including cul-de-sac radii, dimensions, bearings and curve data for construction baseline, median, ROW and curb and gutter line.
    - The widths of ROWs and roadways for main and intersecting streets.

- The geometry and width of medians; specify types and materials and indicate new works.
- Final geometry and width of alleys, driveways, circular entrances, sidewalks, ramps, sodded areas and tree spaces. Also, provide required dimensions and curb return radii.
- The angle between the centerline of the main roadway and intersecting streets, alleys and driveways.
- The existing and final contour lines at 1-foot vertical intervals.
- Spot elevations on the CBL and at the top and bottom of curb every 50 feet maximum, and at critical locations such as slope changes and joint locations.
- Locations and data for vertical curves.
- Locations of cross slope transitions; at each location show pavement cross slopes.
- Locations and elevations of benchmarks, all reference points and traverse control points.
- Locations and geometries of curb ramps.
- The actual locations of bridges and bridge approach slabs, if any. Indicate bridge numbers and/or names.
- Locations of abutments and structural elements under bridges (if any) using dashed lines.
- Safety appurtenances, i.e., guiderails, impact attenuators, fences, Jersey barriers, barricades, etc. Show details, kind, type and number as applicable.
- New and existing walls, retaining walls, copings, steps and curbs. (Provide grades and elevations.)
- Final locations of drains and catch basins.
- Final locations of trees, tree spaces, turf grass areas, etc.
- Final locations of bioretention, bioswales and other Green Infrastructure facilities.
- Scale and graphic scale on all plans.
- North arrow on all plans.
- Locations of cross slope changes and transitions. At each location provide designated slopes.
- Plans must show the names of all streets in bold lettering, to stand out on the drawings.

12.3.2.9. Roadway Profiles

For the roadways and for the top of curbs, roadway profiles will include the following elements:

- Existing and final roadway profiles
- Existing and final roadway grades
- A transition area between the limits of total removal and the beginning and end of project, so that asphalt overlay can meet the existing grades where mill and resurfacing work will take place
- Vertical curve data (provide table)

- Profile slopes
- Location of bridges
- Existing and final top of curb profiles for right and left curbs
- Scale and graphic scale (horizontal and vertical)
- Grades on profiles must be coordinated to match all indicated spot elevations on existing conditions plans and pavement plans
- Profiles must be coordinated with cross section drawings to resolve problems created from changing the roadway elevations
- Show the drainage path (maximum or as required by the project)

12.3.2.10. Cross Sections

- Provide cross sections at 50-foot intervals of roadway project length. Stations must be indicated under each section to show its actual location. Drawings must indicate existing and new (proposed) sections together on the same drawing for comparing changes in geometry and grades.
- Provide cross sections at 50-foot intervals 100 feet upstream and downstream of the inlet and outlet of a culvert.
- Cross section elements are as follows:
    - Existing and final roadway cross sections and crown location
    - Existing and final roadway grades and slopes
    - ROW and roadway widths
    - Curbs and gutters showing the above-curb grade
    - Median width and grades
    - Sidewalks
    - Shoulders and retaining walls
    - Traffic barriers, roadside barriers, median barriers and bridge railings
    - Existing and final sub-surface utilities, as required by project
    - Frontage roads and ramps
    - Stations to show the actual locations of sections
    - Scale and graphic scale

12.3.2.11. Roadway Intersection Details

- Roadway intersection details are required for Portland cement concrete (PCC) pavement only. Drawings must include a detailed roadway intersection plan indicating the design for different types of joints on PCC base and/or reinforced PCC pavement with welded wire fabric.
- Details will include the following elements:
  - Roadway intersection showing stations and dimensions
  - Layout of different types of joints
  - ROW location and roadway widths
  - Dimensions of each slab including lengths, widths and lengths of skewed sides
  - Slope of slab sides in two directions
  - Final spot elevation at each corner of the slab
  - Curbs and gutters showing the above-curb grade
  - Final locations of catch basins
  - Scale and graphic scale on all plans
  - North arrow on all plans
  - Delineate different types of joints, including transverse expansion joints, transverse contraction joints, longitudinal contraction joints and longitudinal construction joints
  - Indicate lane width and location of crown line where longitudinal joints will be located
  - The scale of the Roadway Intersection Detail must be 1 inch = 10 feet or larger

12.3.2.12. Paving Details

Paving details must be shown on the full-scale drawing plans in accordance with **DDOT Standard Drawings**, including the following elements:

- Typical joint details and layout
- Detail for alleys, driveway and sidewalk entrances
- Proposed pavement section based on the project's pavement design

12.3.2.13. Miscellaneous Details

Miscellaneous detail drawings will show all details required for a complete project meeting the Department's current design criteria and standards. Details must include at least the following:

- Curbs
- Directional islands
- Medians

- Wheelchair/bicycle ramps (curb ramps)
- Walls and retaining walls
- Steps and leads
- Copings
- Handrails
- Guide rails
- Fencing
- Bench marks
- Traffic poles
- Breakaway sign posts
- Metal sign posts and attenuators must be shown on the full-scale drawing plans

12.3.2.14. Utility Plans

The utility plans should show all surface and subsurface utility information. This information will include:

- ROW
- Sidewalks
- Curbs, curb ramps
- Trees, hydrants
- Signals, signs
- Electrical conduits
- Communication lines
- Sewer and waterlines
- Inlets, manholes and valves
- Scale
- North arrow

12.3.2.15. Landscape and Planting Plans

The landscape and planting plan must show:

- ROW
- Sidewalks, curbs, ramps, tree spaces
- Trees, plantings (existing)
- Trees, plantings (proposed)
- Soil volume and calculations

- North arrow
- Scale

12.3.2.16. Pavement Marking Plans

The pavement marking plans should include existing and proposed markings and the following information:

- Widths of all cross section elements on the main and adjacent streets, including widths of travel lanes, parking lanes, bicycle lanes and crosswalks, and any raised or marked medians and raised islands
- All existing pavement markings on the project street and at least 100 feet in each direction of intersecting streets
- All existing corner radii, the locations of Americans with Disabilities Act (ADA)-compliant ramps, and locations where ramps need to be added
- ADA ramps, which are required for each pedestrian travel direction; verify that the ramps are within the crosswalks
- All markings including cross walks, stop bars, lane lines and centerline striping
- For each intersection, the locations of all 2-foot-long traffic guidelines
- The radii of all left and right turning lane swing lines
- Direction of each street and all existing signs
- Traffic controls at each intersection in the project location including signals, signs, signal controllers and other similar devices
- All driveway and alley widths along contracted streets
- Location and size of arrows or word markings
- North arrow
- Scale

12.3.2.17. Signage Plans

Provide a legend for signage to include the following:

- Small solid square = Proposed sign to be installed
- Small circle with cross-hatching = Existing sign, FADED, DAMAGED and/or MISSING in field
- Large X = Existing sign to be removed
- Small triangles = Existing sign to be relocated

Note: A small white triangle represents an existing sign and a small solid black triangle represents a relocated sign location. Indicate movement from the existing location to the new location using small arrows and the words “from” and “to” beside the respective triangle.

Intersection signage sheets to show the following:

- North arrow and scale
- All intersecting street names and location of city section, such as NW, NE, SW or SE; indicate unit or block numbers
- All regulatory signs for a motorist should be shown facing in the direction a motorist would read them in the field; some of these signs may be upside-down on the plan sheet
- The mounting order of each sign location, especially for one or more signs
- The material requirements for all signposts
- Locate all signs mounted on streetlights, traffic signals, wood utility poles and U-posts on all corners, medians and channeling islands at each intersection adjacent to or within the project boundaries
- Indicate ROW, curb lines, sidewalk and roadway lines

Block signage sheets to include the following:

- North arrow and scale
- Note direction of streets
- Note the street names at the beginning and end of each block
- Make a block map for each side of the street
- Indicate location, width and length of street for each block
- Locate all signs mounted on streetlights, traffic signals, wood utility poles and U-posts on all corners, medians and channeling islands within the block
- All regulatory signs for a motorist should be facing in the direction a motorist would read them in the field; some of these signs may be upside-down on the plan sheet
- The mounting order of each sign location, especially for one or more signs
- The material requirements for all signposts
- ROW, curb lines, sidewalk and roadway lines

12.3.2.18.Street Light Plans

Show the following features on street light plans:

- ROW, curb line, sidewalks and roadway
- Street light locations, elevations and sections of pole
- Pole and luminary types and attachment details
- Conduit locations
- Locations of all existing and proposed utilities
- Pull box locations
- PEPCO connection locations
- Manholes
- Dimensions for plans, elevations and sections of details
- North arrow and scale

12.3.2.19.Traffic Signal Plans

Show the following features on traffic signal plans:

- ROW, curb line, sidewalks and roadway
- Signal locations, elevations and sections of pole
- Controller locations
- Manhole and pull box locations
- PEPCO connection locations
- Pole and mast arm types and attachment details
- Conduit locations
- Locations of all existing and proposed utilities
- Location, type and number of traffic signal heads and pedestal signal heads
- Dimensions
- North arrow and scale

12.3.2.20.Storm Sewer Plans

Show the following features on storm sewer plans:

- ROW, curb line, sidewalks and roadway
- Inlet locations
- Manhole locations

- Existing mainline
- Proposed pipeline
- North arrow
- Graphic scale
- Locations of all existing and proposed utilities
- Crossings of other utilities on storm drain profiles
- Existing and proposed grades
- Type of pipe, inlets and other features
- Invert of all pipes (inlet and outlet)
- Stationing of inlet, pipe slope changes (horizontal/vertical)
- Pipe slopes
- Hydraulic grade line

12.3.2.21.Stormwater Management Plans

Show the following features on stormwater management plans:

- Full topographic survey
- Existing contour lines
- Drainage area boundaries
- Limits of disturbance
- ROW lines
- Adjacent public lands
- Soil boundary lines based on Natural Resources Conservation Service Hydrologic Soil Groups
- Existing tree locations and proposed tree locations
- Stormwater management facilities and land conversion locations
- Stormwater structure locations
- Soil boring locations
- Underdrain locations and connections to storm sewer lines or structures
- North arrow
- Graphic scale

12.3.2.22.Stormwater Management Details

Show the following features on stormwater management detail plans:

- Stormwater management facility elevations

- Top of ponding elevation (if applicable)
- Typical sections of stormwater management facilities
- Profiles of stormwater management facilities
- Maintenance schedule

12.3.2.23. Structural Plans

Show the following features on structural plans:

- Bridge plan
- North arrow and scale
- ROW lines
- Baseline and centerlines
- Locations of bridge structure from baseline
- Location and stationing of waterway or roadway crossing from baseline
- Abutment locations and stationing from baseline
- Pier locations and stationing from baseline
- Retaining wall locations
- Pavement joint locations from baseline
- Profile with water elevation (if appropriate)
- Expansion and fixed joint locations from baseline
- Minimum vertical clearance
- Bridge deck and approach slab location and stationing from baseline
- Parapet/railing location from baseline
- Curb-line location from baseline
- Bridge fascia from baseline
- Conduit locations
- Locations of borings and log identification number
- Foundation pile design loadings
- Profiles of roadway on the bridge and lower roadway
- Locations of bridge-mounted signs
- Locations of subsurface utilities and proposed utilities on the superstructure
- Hydraulic and hydrologic data for waterway structures
- For existing railroad crossing tracks, profile of tracks, proposed horizontal and vertical clearances and topography along the railroad

- Where water crossings are involved, horizontal and vertical clearances should be shown. Any special inlet-outlet treatment should be shown.
- Approach roadway showing median, roadway and shoulder dimensions, and location of guiderail, if any.

12.3.2.24. Bridge Elevations

Show the following features for bridge elevations:

- Elevation grades of the structure and immediate approaches
- Span lengths
- Skew
- Controlling minimum horizontal and vertical clearances (also show the actual vertical clearance)
- Type of superstructure
- Location of expansion and fixed bearings
- Proposed elevations of bottom of footings together with the original ground line, finished ground line and assumed rock line (if any)

12.3.2.25. Typical Bridge Sections

Show the following features for typical bridge sections:

- Type, spacing and arrangement of beams
- Widths of median
- Traveled roadway
- Shoulder (or curb offset) and curb or sidewalk
- Type of railing/fence
- Type of parapet
- Cross slopes or superelevations

12.3.2.26. Superstructure Plans

Show the following features on superstructure plans:

- North arrow and scale
- Dimensions of framing and beam locations from baseline
- Pier and abutment locations from baseline
- Beam dimensions, elevations and sections
- Beam camber diagrams and tables

- Structural member details and dimensions
- Structural connections and diaphragm details and dimensions

12.3.2.27. Bridge Deck Plans

Show the following features on bridge deck plans:

- North arrow and scale
- Pavement joints
- Dimensions of bridge deck from baseline
- Expansion joint locations from baseline
- Parapet/railing locations from baseline
- Deck elevations
- Pier and abutment locations from baseline
- Conduit locations
- Approach slab locations and stationing from baseline approach slabs plans, elevations and sections
- Staging

12.3.2.28. Bridge Joint Plans

Show the following features on bridge joint plans:

- North arrow and scale
- Bridge expansion joint elevations and sections
- Bridge fixed joint elevations and sections
- Details and dimensions of joints
- Bridge joint details at median, parapet/railing

12.3.2.29. Bridge Abutment Plans

Show the following features on bridge abutment plans:

- North arrow and scale
- Abutment cap and footing dimensions and location from baseline
- Abutment elevations and sections including rebars
- Bottom of footing elevation
- Abutment pile foundation plan and dimensions from baseline
- Details of replacements

- Plans of existing abutments
- Removal extents
- Load capacity data for abutment foundation
- Beam pedestals will not be allowed on abutment caps. Provide steps in the cap to accommodate change in elevations for the beam shoe pads.

12.3.2.30. Bridge Pier Plans

Show the following features on bridge pier plans:

- North arrow and scale
- Pier cap and footing dimensions and location from baseline
- Pier elevations and sections including rebars
- Bottom of footing elevation
- Pier pile foundation plan and dimensions from baseline
- Details of replacements
- Plans of existing piers
- Removal extents
- Load capacity data for pier foundation
- Beam pedestals will not be allowed on pier caps. Provide steps to accommodate change in elevations for the beam shoe pads.

12.3.2.31. Retaining Wall Plans

Show the following features on retaining wall plans:

- North arrow and scale
- Retaining wall and footing plan and dimensions from baseline
- Bottom of footing elevation
- Retaining wall elevations and sections including rebar
- Details of replacements
- Retaining wall pile foundation plan and dimensions from baseline
- Load capacity data for retaining wall foundation
- Plans of existing retaining walls
- Retaining wall layout line

12.3.2.32. Bridge Parapet/Railing/Pedestrian Plans

Show the following features on bridge parapet/railing/pedestrian plans:

- North arrow and scale
- Typical railing height and location
- Connection details including bolts and welds
- Dimensions
- Architectural treatment details
- Post spacing
- Post, joint and connection details

12.3.2.33. Bridge Drainage

Show the following features for bridge drainage:

- Bridge drainage and scupper/inlet locations
- North arrow and scale
- Typical scupper/inlet details
- Drainpipe connection details
- Dimensions of scupper/inlet and size of pipes

12.3.2.34. Maintenance of Traffic and Construction Phasing Plans

The maintenance of traffic and construction phasing plan should include all phases of construction. For each phase, show the following information:

- Location of ROW, streets, sidewalks and driveways
- North arrow and scale
- All existing signage, pavement marking and signals
- All signage and striping to be removed or covered during construction
- All proposed temporary barrels, signs, etc. required by **MUTCD** and the District of Columbia **Work Zone Manual**
- All dimensions of tapers, type of equipment
- Work area

12.3.2.35. Traffic Control Plans

Typical traffic control plans will include the following information:

- Schedule of construction traffic control devices/tabulation of traffic engineering items
- Construction signing plan
- Tabulation of signs
- Permanent/existing signing plan
- Cross-sections at Class III and overhead sign locations (if applicable)
- Tabulation of pavement markings
- Signal plan
- List of standard special provisions
- List of project special provisions
- Detailed sign layouts

12.3.2.36. Sediment and Erosion Control Plans

Sediment and erosion control plans are required for each roadway for traffic and structural design projects. They should be completed in accordance with the District of Columbia Department of Energy and the Environment. Typical sediment and erosion control plans will include the following information:

- Sediment/erosion control plan (use Roadway base plan)
- Limits of disturbance
- Tabulation of erosion control devices
- List of Special Provisions
- Standard details:
    - North arrow
    - Scale
    - Show all dimensions

12.3.2.37. Soil Boring Logs

The soil boring logs should be incorporated into the plans. The horizontal locations should be delineated on the roadway design plan sheets. Typical soil boring log control plans will include the following information:

- Locations of borings
- Soils types and depths for each boring

12.4. Required Number of Plans

Table 12-1 lists the number of copies that will be required for each submittal.

Table 12-1 | Required Number of Plans

Stage of Design Process	Number of Copies
Pre-Design Report (When Requested)	5 Copies
30% Preliminary Design	30 sets of half-size plans 2 copies of Preliminary Construction Costs 2 sets of full-size stormwater management (SWM) plans
65% Review Design	30 sets of half-size plans 30 sets of Special Provisions 2 copies of Preliminary Construction Costs
Final Review Design	30 sets of half-size plans 30 sets of Special Provisions (double spaced) 2 copies of Construction Costs and Pay Item Schedule (hard copy and on disk)
PS&E Submittal	2 sets of stamped half-size plans 2 sets of Special Provisions 2 sets of Pay Item Schedule and Cost Estimates 4 sets of full-size SWM plans 1 set of full-size SWM plan on Mylar
Final Bid Documents	8 sets of half-size final Contract Plans 8 sets of Special Provisions, Bid Forms and Appendices One set of full-size reproducible final contract drawings on tracing linen or tracing plastic and five full-size prints Two computer disks of final contract drawings (in latest version of Microstation) and two disks of final Special Provisions and Pay Item Schedule

NOTE: The number of Final Contract Plans, Special Provisions, Pay Item Schedules and Appendices may be modified by DDOT by written notice to the Consultant.

12.5. Cost Estimate Preparation

The Designer will prepare a project cost estimate for DDOT's use in obligating funds for project construction. An updated estimate will be submitted concurrently with each milestone submission (30%, 65%, Final and PS&E). The Engineer of Record must prepare supporting documentation for the quantities and cost estimate for DDOT's review. This supporting information must detail how the quantities and rates were determined for each item.

12.5.1. Bid History

The DDOT Project Manager will provide bid histories of recent and comparable projects to help determine current unit prices.

12.5.2. Pay Items

The DDOT Project Manager will provide the latest standard Pay Item information for use on the project. In general, Pay Items should be subdivided as follows:

- Itemized costs and subtotals for right of way acquisition and relocation as prepared by DDOT ROW section.
- Itemized costs and subtotals for street/highway work, including sidewalks, concrete/steel barriers, street lighting, traffic signals and maintenance of highway traffic and all work associated with the street/roadway, including force account work as directed by the Project Manager.
- Itemized cost and subtotal for bridge work, including sidewalks, concrete/steel barriers, street lighting and maintenance of highway traffic and all work associated with the bridge and related structures.
- The cost of maintenance of traffic will be divided into costs of individual items that make up the total work.
- Include itemized costs and subtotal of work 100 percent back-chargeable to private utility companies such as DC Water and Sewer Authority (DC Water), Washington Gas, telephone company, PEPCO, etc. Include Pay Items and cost for DDOT internal use.

12.5.3. AASHTO Estimator

12.5.3.1. Software

AASHTOWare Project Estimator is a software program that generates estimates using cost-based and bid-based techniques. It supports the use of multiple bid histories from which the user can choose the most appropriate for the current project.

12.5.3.1.1. Info Tech Estimator

Info Tech is an official AASHTO contractor for the AASHTOWare Project suite (formerly AASHTO Trns•port). The software enables transportation agencies to manage information throughout the entire contract and construction lifecycle, from cost estimation to proposal preparation, letting and bids, construction and material management, and data collection.

12.5.3.1.2. DDOT Catalog Files

The most up-to-date version of the DDOT Standard Items catalog should be used when creating an estimate in Estimator.

12.5.3.2. Procedure for Numbering and Naming Non-Standard Items

All items being used in the estimate should be chosen from the DDOT Standard Items catalog. If no item listed in the catalog corresponds exactly to a given item, then a special item with the appropriate units within the most applicable item category should be chosen. (Do not input a new item number manually into Estimator.) Provide a brief description for each special item to denote what the item is and how it may be different from other special items in the same category. The description is input manually by the user.

12.5.3.3. Bid Histories

DDOT bid histories are incorporated into the costs of many of the standard items in the catalog. These costs are dependent on quantities of items and, when the bid histories are available, will self-propagate in the cost column after quantities are noted. For several items, newer items in particular, no bid histories are available in the catalog, and the costs will need to be entered manually by the user. Even when bid histories are available in the catalog, the user must check all costs to ensure that the estimates are reasonable and up-to-date.

12.5.3.4. Project Information

All relevant project information must be entered into Estimator including project name, project number, project year, description of work and contingency.

12.5.3.5. Item Grouping

Items should be grouped based on funding sources:

- **Participating Roadway Construction.** This group includes all items for which federal funding will be provided. The group title must specify the level (percentage) of federal funding.
- **Non-Participating Roadway Construction.** This group (or groups) includes all items for which no federal funding will be provided.

Separate groups must be noted for each unique funding scenario, and items funded by third parties (such as DC Water or utilities) must be listed separately from items funded by the District.

Shared items across groups:

- For lump-sum items split across multiple groups in Estimator, the quantity used in each group should be equal to the percentage of that item attributable to that group.

- For identical items included in more than one group, ensure that the text in each description is identical across all groups so that the final cost estimate will lump identical item quantities together.

12.5.3.6. Check for Errors

Ensure that there are no errors in the Estimator file by clicking the Verify button.

12.5.4. Contingency

The contingency percentage used on a project will decrease as the design advances toward construction. The contingency is used to account for such elements as unknowns, accelerated construction and unique design elements. The Consultant will coordinate with the DDOT Project Manager on the percentage to be used. Following are suggested values:

- At preliminary design phase, the cost estimate should include a 30 percent contingency.
- At the final design phase, the cost estimate should maintain a 10 percent contingency to cover potential change orders during the construction phase.

12.6. Special Provisions

Special Provisions must be prepared for items within the scope of the project and necessary for its execution, as well as for any item that is non-standard or that modifies the latest edition of the **DDOT Standard Specifications for Highways and Structures**.

12.6.1. Organization

12.6.1.1. Project Information

DDOT Special Provisions contain general project information as directed by the DDOT Project Manager. DDOT will provide an example to the Consultant, which may contain at least the following topics:

- Information to be provided by DDOT:
  - Contract type
  - Pre-award approval
  - ROW certification
  - Notice to proceed
  - Contractor identification
  - Pre-bid conference (date, time and location)
  - Consideration of proposals

   - Contract administration data
   - Award of contract
   - Coordination with others
   - Construction completion time

- Topics to be addressed by the Designer:

   - **Scope of Work.** Scope must include a concise description of the project that covers all work items in the contract
   - List of applicable documents such as specifications and drawings
   - Supplemental specifications and modifications to the Standard Specifications, including but not limited to, Maintenance of Highway Traffic, Erosion and Sediment Control, Bridge Construction, and Streetlight Installation

- **DC Water Specifications.** DC Water specifications can be requested by emailing: DCWater_Specification_Request@dcwater.com.

12.6.1.2. Non-Standard Items

Special Provisions must be prepared for non-standard items or to modify the latest edition of the **DDOT Standard Specifications for Highways and Structures**. Include the item number selected in Estimator and the name of each non-standard item.

12.6.2. Writing and Formatting

Special Provisions must be well written and consistently formatted to allow the reader to easily understand the intent of the specification and/or modification. As outlined in the **Specification Writers' Guide for Federal Lands Highway**, Publication No. FHWA-CFL/TD-08-001, May 2008 (http://flh.fhwa.dot.gov/resources/manuals/swg/). Special Provisions must be clear, concise, complete, correct and consistent.

12.7. Reports

In addition to project reports being informative and technically accurate, reports prepared on behalf of DDOT need to be consistently branded and presented.

12.7.1. Report Guidelines

12.7.1.1. DDOT Branding Guidelines

Please refer to the latest **DDOT Branding Guidelines** for guidance on:

- DDOT branding
- Color use and typography
- Photographic content
- Formatting
- Text style
- Word use
- Brochures, website layout and PowerPoint presentations

12.7.2. Preliminary Engineering Reports

See **Section 12.2.1** for Preliminary Engineering Report requirements.

12.7.3. Other Reports

See **Section 12.2.2** for requirements for other reports.

12.8. Design Exceptions and Waivers

NOTE: Design exceptions apply to the National Highway System (NHS) only. For off-system and local projects, any deviation from design standards and standard details requires a design waiver.

12.8.1. DDOT's Design Waiver Process

For off-system (non-NHS) and local projects, a design exception through FHWA is not required when minimum AASHTO criteria have been met. However, if the design does not meet DDOT standards, which may exceed AASHTO requirements, a DDOT design waiver is required. Design waivers will be granted by the Chief Engineer. Complete documentation of the authorized design waiver should be retained permanently in DDOT project files.

All requirements set forth for design exception in the following sections, including timing of request, types of supporting documents and the process of documenting the design deviation, are also applicable to design waivers, except that submittals will be made only for the Chief Engineer's approval, not FHWA's.

12.8.2. Design Exception Overview

The geometric design standards approved for use are contained in AASHTO's **Policy on Geometric Design of Highways and Streets**, commonly referred to as the "Green Book." In addition, AASHTO's **Policy on Design Standards—Interstate System** is applicable to the Interstate System. For the interstate system, the current editions of AASHTO's **A Policy on Geometric Design of Highways and Streets** and the **AASHTO LRFD Bridge Design Specifications** should be used as design standards where they do not conflict with AASHTO's **Policy on Design Standards—Interstate System**.

DDOT recognizes the FHWA publication **Mitigation Strategies for Design Exceptions** as a guideline to follow when processing design exceptions and developing strategies. This publication is available at: http://safety.fhwa.dot.gov/geometric/pubs/mitigationstrategies/fhwa_sa_07011.pdf.

DDOT also recognizes the FHWA publication **Flexibility in Highway Design** as a source of inspiration for developing creative solutions to geometric challenges, as well as appropriately documenting exceptions. This publication is available at: http://www.fhwa.dot.gov/environment/publications/flexibility/.

Changes to posted speed limits on highways need to be evaluated by considering applicable design standards. Design exceptions are required whenever the change causes the design features of the roadway to not conform to the minimum criteria for the new speed limit. Do not make isolated changes in design speeds to eliminate a possible design exception. Instead, when possible, provide a consistent design speed for the facility. Design exceptions caused by proposed changes in the posted speed that adversely affect the design features of the roadway will not be considered.

In a number of instances, ranges of specific minimum, maximum and desirable speeds are contained in AASHTO policies and guides. The Designer should strive to meet the highest standard. Any design feature that does not meet AASHTO minimum criteria requires a design exception. Note that the interstate system and NHS have no resurfacing, restoration and rehabilitation standards. Design exceptions granted as part of a previous project must be resubmitted to FHWA for approval when new work is proposed in the area, regardless of funding source.

A design exception should be approved only after thoroughly reviewing project elements, such as maximum service and safety benefits for dollar invested, compatibility with adjacent section of the roadway, and probable time before reconstruction would take place due to increased traffic demand or changed conditions, at which time the appropriate standard would be met.

12.8.3. FHWA's 13 Controlling Criteria

Although all exceptions from accepted standards and policies need to be justified and documented, the FHWA's current policy has established 13 controlling criteria requiring formal approval. Currently, a design exception request letter must be submitted with appropriate documentation addressing the design exception and any related criteria.

Existing access points are not subject to the "Access Control for Interstate Interchanges Agreement" between FHWA and DDOT. However, design criteria for new or totally reconstructed interchanges will be developed from an operational analysis, but will not be less than 100 feet for urban areas.

Project boundaries for design exception determinations will be at logical points, such as at ramp termini. An exception to this would be any transitional work that results from mainline improvements.

12.8.4. Non-Standard Design Features

The Project Manager will identify non-standard design features along with the rationale for the exception (purpose and need for design exception, accident data, effect of design exception on safety, mitigation measures of the substandard design element, and cost analysis for any non-standard feature must be explained) on the Project Design Exceptions Form (refer to FHWA Federal-Aid Policy Guide NS, Code of Federal Regulations Title 23 Part 625).

12.8.5. DDOT's Project Design Exceptions Processes

Design exceptions must be submitted via letter to the FHWA, DC Division Office, when non-standard features or design exceptions are proposed on the project. The design exception letter must discuss the standards in **AASHTO A Policy on Geometric Design of Highways and Streets**, **AASHTO LRFD Bridge Design Specifications**, or **National Association of City Transportation Officials Urban Street Design Guide** that apply, what it would cost to attain the full standard, and the effect that the non-standard design is anticipated to have on safety in the future. When possible, the Program Manager should avoid design exceptions. The Program Manager/Project Manager will discuss the need for design exceptions with the Chief Engineer before a letter is sent to FHWA. All design exceptions should be identified as a part of the preliminary design review and approved prior to the final design review. The Program Manager should discuss the design exception requests with FHWA to determine necessary approvals and the possibility of project delays.

The FHWA should receive an invitation to the preliminary design review meeting when a design exception is anticipated on a Federal-Aid project.

12.8.6. FHWA Approval

12.8.6.1. Timing of Design Exception Request

The FHWA's participation in communications and plan reviews is vital throughout the design process. Design exceptions should be identified at the Preliminary Field Inspection and requested shortly thereafter. Plans at the Preliminary Design Stage and the Bridge Type Study Stage should reflect approved design exceptions for those key design elements or features.

For Federal-Aid projects, a formal exception to design standards request must be submitted to FHWA for approval prior to the 65 percent design review. The submittal must include justification for design exceptions and mitigation measures where field conditions, lack of ROW, etc., require the construction of facilities that do not meet minimum standards.

12.8.6.2. Design Exception Supporting Documentation

Supporting documentation for all design exceptions is to be submitted to the Chief Engineer for filing, with a copy kept by the Project Manager in the project file. Any documentation regarding why AASHTO minimums were used when higher standards were recommended is to be made available to FHWA upon request.

12.8.6.3. Documenting Design Exceptions on the Project Plans

All design exceptions and design waivers must be shown on the Design Exceptions and Waivers sheet of the project plans.

Whenever project design elements do not meet AASHTO minimum design criteria, the locations and reason for any differences are to be noted on the Design Exceptions and Waivers sheet of the project plans to alert everyone concerned. Potential locations where a design exception may be required should be identified from the earliest stages of plan development. If it is determined that a design exception will be required the location of the design exception must be documented on the project plans. If changes are made during plan development that would alter the situation, then the title sheet must be corrected to reflect the new design.

Part III – Engineering and Design

Chapters 13 through 45

13 Bridge Design, Rehabilitation and Replacement

13.1. Design Specifications

All bridges and transportation structures must be designed in accordance with the American Association of State Highway and Transportation Officials **(AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications**, latest edition including all interims except as modified herein. All evaluation and rating of the existing bridges must be in accordance with the **AASHTO Manual for Bridge Evaluation**, latest edition including interims for rating and evaluation procedures.

13.2. Materials

13.2.1. Structural Steel

Structural steel must be in accordance with Section 706 of **DDOT Standard Specifications for Highways and Structures** (latest edition). In addition, see **Chapter 17** of this manual.

13.2.2. Concrete Structures

Concrete. Concrete compressive strengths must be in accordance with Sections 700 and 817 of **DDOT Standard Specifications for Highway and Structures** (latest edition) and must be documented on the plans in the General Notes.

Stay-in-Place bridge deck forms will not be permitted.

Reinforcing Steel. Structures must be designed to use deformed bars meeting the requirements for AASHTO M31, Grade 60. When detailing lengths of reinforcing bars, transportation and handling must be considered, and where extremely long lengths are contemplated, availability and special orders must be taken into account. The reinforcing bars must not be longer than 60 feet. Specify long bars, insofar as possible, to minimize splicing. The minimum size of main reinforcing bar is #5.

All sizes of bars are readily available in lengths up to 60 feet. However, #3 and #4 bars more than 40 feet long tend to bend in handling; therefore, longer lengths should be avoided. Sizes #5 through #18 in lengths exceeding 60 feet can be rolled at mills by special order.

Corrosion-Resistant Reinforcing Steel. DDOT may require the following corrosion-resistant reinforcing steel on a project-specific basis:

1. Low-carbon, chromium steel bars: American Society for Testing and Materials (ASTM) A1035/A1035M (MMFX-2)
2. Stainless steel-clad steel bars: AASHTO Designation MP 13M/MP 13-04

3. Solid stainless steel bars: ASTM A955/A955M, Unified Numbering System designation: S32101

All reinforcing steel that is not corrosion-resistant must be epoxy-coated. Galvanized reinforcement is not allowed.

When specifying reinforcement, the availability, cost and lead time for the method chosen must be included in the investigation.

Minimum Concrete Cover. The minimum cover shown in Table 13-1 must be provided for reinforcement.

Table 13-1 | Minimum Concrete Cover

Bar Location	Minimum cover (inches)
Pier caps, bridge seats and backwalls:	
Principal reinforcement	2-3/4
Stirrups and ties	2-1/4
Footings and pier columns:	
Principal reinforcement	3
Stirrups and ties	2-1/2
Concrete deck slab:	
Top reinforcement	2-1/2*
Bottom reinforcement	1-1/4
Concrete piles	2
Drilled shafts:	
Principal reinforcement	4
Ties and spirals	3-1/2
All other components not indicated above:	
Principal reinforcement	2-1/2
Stirrups and ties	2

*** Includes 1/2-inch monolithic (integral) wearing surface.**

13.3. Design Guideline

13.3.1. Bridge Geometrics

The design criteria for bridge geometrics include levels of service, roadway classification, design speed, traffic volumes, traffic composition and traffic projections. The designer should consider the need for future widening.

Typical Deck Transverse Section. The typical deck transverse section is determined by DDOT. Generally, the bridge width should not be less than that of the approach roadway section. Pedestrian/bicycle access must be considered. Barriers are provided in accordance with the **AASHTO LRFD Bridge Design Specifications**, and **Chapter 20** of this manual.

Line and Grade. Designers will determine the line and grade, pending approval from the District.

Horizontal Clearance. Fixed objects must be placed as far from the edge of the roadway as economically feasible. **Chapter 8** of this manual outlines clear zone and recovery area requirements for horizontal clearances without guiderail or barrier being required. Actual horizontal clearances must be shown in the plan view of the Preliminary Plan. Bridge piers and abutments should ideally be placed such that the minimum clearances can be satisfied. However, if the best span arrangement requires a pier to be within a clear zone or recovery area for structural or economic reasons, a pier protection barrier or guiderail may be used to mitigate the hazard. Required horizontal clearance at railroads should be coordinated with the pertinent railroad agency.

Vertical Clearance. The required vertical clearances are established by the functional classification of the highway. Actual vertical clearances must be shown in the Elevation view of the Preliminary Plan, and the location given in the Plan view as well. The Designer should consider the effects of future widening, and the final grade must provide the minimum vertical clearance. The minimum clearances in the District are as follows:

- Overhead structures over roadways: 14.5 feet
- Overhead structures over the interstate system and National Highway System (NHS): 16.5 feet
- Overhead structures over highways connecting to the interstate system and NHS: 16.5 feet
- Pedestrian structures over roadways: 17.5 feet
- Overhead structures over railroads: as directed by the railroad company

Overhead structures that do not meet the minimum requirements must be approved by the Chief Engineer. Signage stating under-clearances must be in accordance with the Federal Highway Administration's (FHWA's) **Manual of Uniform Traffic Control Devices (MUTCD)**.

Bridge Length. The length of the bridge is determined by the attributes it crosses, such as streams, highways, railroads, and cultural and natural resources.

Highway Crossings. Bridge layouts for highway crossings are usually controlled by the cross section of the roadway below. Minimum vertical under-clearances, horizontal safety clearances and adequate sight distances will frequently control not only the overall length of the bridge, but the span arrangement as well.

Relatively extreme gradients at either roadway grade require careful consideration of the vertical clearances. The point of minimum under-clearance can be beneath any of the superstructure members at any point in the traveled way below. The superelevation rates for both alignments must be evaluated throughout the layout process.

Stream Crossings. Stream and floodplain crossings must be designed to not exacerbate flooding or stream instability. The Designer should refer to **Chapter 28** for further guidance. Freeboard, the clear distance above the design discharge elevation and the lowest portion of the superstructure, is ideally 2 feet to ensure that the bridge bearings are above the design discharge elevation.

The toe of the embankment must not encroach into the stream channel. The Designer should avoid a span arrangement that places a pier in or near the center of the stream. It is preferable for pier columns to be located outside the normal flow.

Railroad Crossings. Amtrak, VRE, MARC, Norfolk Southern Corporation, CSX Transportation and WMATA are the principal railroads currently operating in the District. Bridge abutments and piers located in the railroad right-of-way must be approved by the railroad. The proposed bridge length must be coordinated with the railroad and is determined from the embankment slopes and berm requirements, similar to those for highway crossings.

Cultural and Natural Resources Crossings. The Designer should avoid any cultural and natural District resources. When these areas cannot be avoided, prior to the advancement of the bridge layout, the Designer must consult with the District of Columbia State Historic Preservation Office (SHPO) for potential impacts on cultural resources and the District of Columbia Department of Energy & Environment for potential impacts on natural resources.

Geometric Guidelines. The following are guidelines for the geometric layout of new or replacement structures:

1. The desirable berm width in front of an abutment is as follows: A minimum berm width of 3 feet should be used under dry conditions. For wet conditions, a berm width of 5 feet is preferred. The berm should be at an elevation below the bridge seat that will allow access to the bridge seat for future maintenance. A minimum 1.5-foot clearance between the berm and superstructure is required.
2. The maximum desirable skew is 30 degrees.

3. Substructure units that are either parallel to one another or radial to the roadway curvature are desirable. The number of substructure units is determined by cost comparisons of various span arrangements and the topography of the site.
4. All horizontal and vertical clearances for roadways, railroads, navigable waterways or any adjacent features that require a clear zone must be maintained. If they cannot be maintained, appropriate measures must be taken to protect the public and the structure.
5. The maximum side slope of embankments is generally 2:1. Flatter slopes may be warranted by the existing topography, aesthetics, or slope stability concerns. However, steeper slopes up to 1.5:1 may be used if a geotechnical analysis is performed and concludes that soil/rock conditions are suitable.

13.3.2. Bridge Type

In planning new bridges, several typical structure materials and types of construction should be considered. At any given location, the ultimate selection should be based on suitability and aesthetics for the particular bridge and its site as an entity, and also as part of the surrounding environment.

The character and coloration of the terrain and the form of nearby structures should all be influences on the aesthetics proposed for the structure. Engineering, architectural (when warranted) and cost studies must be prepared for each structure or group of structures. When a structure proposed for construction or modification is near other structures, a study must be prepared to show possible interactions with the other structures.

These initial studies should be developed based on a careful appraisal of the site, foundation, drainage conditions, highway limitations, and environmental impact, both present and future. Economy, aesthetics and maximum safety are not incompatible in the design of structures.

For grade separation structures, the absence of shoulder piers allows possible future widening of the lower roadway while removing sightline restrictions and minimizing safety hazards. The resultant "open" structure is usually more visually pleasing.

Designers should strive for superstructures of shallow proportion; however, stiffness requirements and other design considerations must be balanced against those of aesthetic appeal. Complicated details, which present abrupt discontinuities in the bridge profile, should be avoided.

When establishing span proportions, substructure elements should be positioned clear of traveled roadways. Concrete piers that are built near roadways should generally be of open-type construction (e.g., column bent piers). When supporting many closely spaced stringers, a common and simple frame consisting of a uniform depth cap beam on circular columns may be suitable. Often times, frame proportions are enhanced by allowing the cap beam to cantilever over the exterior columns with a variable depth that tapers to a minimum beyond the fascia stringer bearing. The slender tee-pier should not be overlooked for the support of high crossings or narrow structures.

New designs for high-level or complex structures should include permanent provisions for inspection, such as catwalks, to make bridge members accessible. The Designer should avoid using fatigue-prone elements. All new bridges must be designed as redundant structures.

When assessing the cost and practicality of a movable bridge versus a fixed bridge, the long-term investment associated with machinery maintenance, liabilities associated with navigation hazards, and staffing the structure with operators, as well as the impact of traffic congestion due to openings, should be considered.

The Designer should consider possible future addition, widening or otherwise improving the pedestrian/bicycle facility as part of the project.

13.3.3. Bridge Type, Size and Location (TS&L) Report

Bridge TS&L report must be submitted to the Chief Engineer and FHWA for review and approval before moving the bridge project beyond preliminary design (30 percent). The Bridge TS&L report must be submitted for all new bridge construction projects.

The report must contain the alternatives considered, including evaluation criteria with recommendations and conclusions.

13.4. Bridge Rehabilitation

The purpose of bridge rehabilitation is to eliminate conditions causing costly frequent maintenance. Rehabilitation involves major work to restore the structural integrity of a bridge and correct any serious safety defects. Rehabilitation may be justified by a life-cycle cost analysis. Functional improvements such as adding a travel lane or raising the vertical under-clearance may be made. Bridge rehabilitation projects completely or nearly completely restore bridge elements or components.

13.4.1. Typical Rehabilitation

Typical rehabilitation items include:

- Bridge deck repair or replacement
- Superstructure repair or replacement

- Substructure repair

Additional work may include removal and replacement of all deteriorated components, including overlays, structural members, curbs, sidewalks, parapets, bridge rails, bearings, deck joints and other similar incidental items. All recommended repairs noted on biennial inspection reports must be completed, and wherever possible, functionally obsolete elements must be replaced.

When rehabilitating historic bridge structures, every effort should be made to preserve the original shape and to use original texture and type of materials. The construction plans must be coordinated with the National Capital Planning Commission, the SHPO, the U.S. Commission of Fine Arts and DDOT's Environmental Program Branch.

13.4.1.1. Deck Repair and Overlay

The main cause of deterioration of concrete bridge decks is the exposure to de-icing salt. Salt penetrates the concrete and causes corrosion of the reinforcing steel. The steel corrosion exerts pressure and causes internal cracking, delamination and spalling of the concrete. Concrete bridge deck repair includes: 1) removing the deteriorated concrete, 2) cleaning the reinforcing steel from corrosion, and 3) patching and repairing the concrete. The depth of the deteriorated concrete may be such that the full depth of the deck needs repair, requiring form placement under the deck. Deck repair may also involve addition of new reinforcing steel to compensate for the section loss of the severely corroded reinforcing steel.

Bridge deck repair may involve applying a concrete overlay protective system. The purpose of the overlay is twofold: 1) to provide a solid and uniform rideable surface, and 2) to protect the deck and mitigate the ongoing corrosion of the reinforcing steel in the areas with sound, but salt-contaminated, concrete. This is done by reducing moisture, salt and oxygen, the three elements necessary for steel corrosion, from seeping into the deck.

Overlays currently include specialized, low permeable concrete overlays, e.g., latex-modified concrete, silica fume concrete, or others when approved by DDOT. The **DDOT Standard Specifications** require the contractor to use a finishing machine for placing overlays. However, the Specifications also say that hand-operated vibrators and screeds may be used to place and finish small areas of work.

13.4.1.2. Deck Replacement and Superstructure Repair

If rehabilitation necessitates deck replacement, the condition of the superstructure must be evaluated to determine the repair needs and remaining service life. A life-cycle cost analysis should then be performed to determine whether the superstructure needs replacement or repair.

The Designer must verify that the existing bridge components will not be adversely affected during the deck replacement or by the new conditions created by the deck replacement. During staged replacement, the effective flange width of existing girders may be reduced by removing a portion of the width of the deck. The dead loads from a new deck may introduce additional stresses in the existing stringers and/or beams. If calculations indicate that the existing beams will be overstressed during or after deck replacement, it should be brought to the attention of the Chief Engineer along with recommendations for correction.

The Designer should evaluate other repairs that will be made during the deck replacement to take advantage of access to repair locations while the deck is removed. Repairs to be considered may include:

- Eliminating joints at abutments by modifying the abutments to semi-integral abutments.
- Eliminating joints over the piers, if feasible, considering the overall movements of the superstructure and configuration of the bearings.
- Employing special measures to improve strength or reduce deflection, such as retrofitting stringers with shear connectors.
- Repairing damaged members such as traffic-impacted girders or other deterioration of main structural elements, including heavy section loss.
- Repairing steel girders with extensive section loss due to corrosion.
- Retrofitting fatigue cracks and fatigue-prone details in steel girders. Fatigue retrofits must be given high priority in the retrofit or repair recommendations. The components remaining fatigue life should be considered when deciding whether to repair or replace.
- Cleaning and re-painting steel beams.
- Repairing or replacing failed or frozen bearings to return them to their intended structural and mechanical function.

13.4.2. Additional Considerations

Where possible, bridge rehabilitation should eliminate functional and structural deficiencies and bring the structure up to current standards. Additional rehabilitation items to be considered include:

- Widening the bridge to increase shoulder width, add traffic lanes or provide pedestrian access
- Replacing old traffic barriers with crashworthy ones
- Installing or replacing pedestrian fences to provide protection from the roadway below or railroad underneath
- Replacing existing overhead sign structures

- Retrofitting or replacing the superstructure for strengthening
- Raising the superstructure to increase vertical clearance

13.4.2.1. Widening

Widening is typically confined to deck bridges supported on steel or concrete beams or girders. The following requirements apply to all components in a widening project:

- Materials used in the construction of the widening should be the same as the existing materials in terms of thermal and elastic properties. The use of beams that are the same type as the existing beams is preferred.
- The structure should be widened such that the new construction blends with the existing structure.
- The main load-carrying members should be proportioned to provide a uniform stiffness over the entire cross section.
- The construction sequence and degree of interaction between the existing structure and the widened portion after completion must be fully considered when determining the distribution of the dead load during design of the widening and stress checks for the existing structure.
- The widened deck section must be structurally attached to the existing deck, and the transfer of moment and shear must be provided using dowels with sufficient splice laps. Reinforcement splicing must be accomplished by either exposing existing reinforcement or by means of mechanical couplers.
- A concrete shear key is not necessary, but a roughened construction joint should be used. A closure pour should generally be used when construction staging does not prohibit its use. The closure pour must be given the proper cure time before reestablishing traffic on it.
- Deck drainage must be investigated for both temporary and permanent conditions.

13.4.3. Field Condition Survey

Where an existing bridge or structure is to be rehabilitated, review all as-built drawings and existing condition and inspection reports, and conduct a supplemental Field Condition Survey to update the original inspection reports. The bridge inspection reports must meet the FHWA's **National Bridge Inspection Standards** and are not intended as templates for rehabilitation. A more in-depth inspection may be required to assess the condition of the bridge. The report from the Field Condition Survey must include recommendations for rehabilitation work and a preliminary cost estimate.

Safety improvements must be considered in the Field Condition Survey. The minimum vertical under-clearance and its location must be measured and noted in the Field Condition Survey. If the under-clearance is substandard, a discussion about the extent of work needed to improve the situation, together with a preliminary cost estimate, must be included. DDOT will determine if a detailed study is warranted.

When directed by the Chief Engineer, an updated load rating may be required.

13.4.3.1. Deck Evaluation for Deck Rehabilitation or Replacement

If the Field Condition Survey indicates that rehabilitation of the bridge deck may be warranted, a detailed Bridge Deck Evaluation Survey should be performed to further define the extent of the deterioration or other deficiencies in the existing deck. This evaluation should, to the extent appropriate, consider the following as recommended test procedures:

- Detect any delamination with appropriate equipment to determine the extent of internal fractures of the concrete
- Determine the extent of reinforcing steel corrosion using a half-cell corrosion detection device
- Determine areas with inadequate concrete cover over the reinforcing steel using appropriate equipment
- Conduct chemical analysis to determine extent of chloride contamination in the concrete

For further information on the Deck Evaluation Survey and testing of concrete bridge decks, refer to Appendix E.

13.4.4 Construction Staging

If the rehabilitation or replacement of an existing bridge will require alteration of the traffic flow, a construction staging plan should be generated during concept development to reduce the impact of construction activities on the existing traffic. A traffic management plan may also be required. The construction staging must be coordinated with, and match the maintenance of, traffic phasing. When preparing the construction staging plans, consideration must be given to traffic both on the bridge and under it. A construction sequence detail, including maintenance of traffic details, must be shown on the preliminary bridge plan submittal for all projects utilizing staged construction. In addition, the final plans must include a complete outline of the order of construction.

Potential items to be considered in construction staging include:

- Reduced load capacity of the portions of the structure being rehabilitated or replaced in each stage of construction
- Need for temporary shoring
- Reduced vertical clearance caused by temporary falsework, etc.
- Erection of steel or concrete beams above traffic flow
- Reduced site distance resulting from use of temporary barriers, etc.

13.4.5 Bridge Rehabilitation Report

For all bridge rehabilitation projects, a bridge report must be submitted to the Chief Engineer for review and approval before moving the bridge project beyond the preliminary design (30%). The report must contain the alternatives considered, including evaluation criteria, with recommendations and conclusions. Life-cycle cost analyses may be performed, if applicable, to justify the recommended alternative. For projects that require alterations to the existing traffic flow during construction, user costs must be determined and considered in addition to the construction cost. User cost generally represents the traffic delays during construction.

13.5. Bridge Replacement

Bridge replacement projects entail the total replacement of a structurally deficient or functionally obsolete bridge with a new facility constructed in the same general traffic corridor. A nominal amount of approach work sufficient to connect to the new facility to the existing roadway or to return the gradeline to an attainable touchdown point in accordance with good design practice is also eligible. The replacement structure must meet the current geometric, construction and structural standards required for the types and volume of projected traffic on the facility over its design life. Life-cycle cost and other economic factors are usually considered when weighing rehabilitation versus replacement costs. The preliminary design must include a bridge type, size and location (TS&L) report in accordance with **Section 13.3.3**.

14 Bridge Load Rating Analysis and Reporting

The primary purpose of a bridge load rating is to determine the live load that the structure can safely carry to preserve public safety. In addition, a load rating is required by the **National Bridge Inspection Standards (NBIS), Title 23 of the Code of Federal Regulations, Section 650**, and may be required if heavier traffic is anticipated in future. The following guidelines are to be used to rate bridge loads within the jurisdictional boundary of the District of Columbia. All new and rehabilitated bridges, including widened structures, must be load rated as part of the design phase, and the load rating must be based on the as-built plans and the bridge's present condition. The Inventory and Operating ratings must appear on the plan cover sheet. A load rating must also be performed when findings from routine inspections warrant or when changes in bridge features warrant. Such features include new bridge barriers or wearing surface.

14.1. Methodology

- Bridge evaluation must follow The American Association of State Highway and Transportation Officials (AASHTO) Manual for Bridge Evaluation, current edition with Federal Highway Administration memorandums
- All bridges designed using **AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications** must be load rated using Load and Resistance Factor Rating (LRFR).
- In-service bridges that have been designed by a method other than LRFD must be load rated by the Load Factor Rating (LFR) method. In some special cases, where DDOT would like to know more about the behavior of a structure under live loads, DDOT may request the Consultant to rate the loads of a specific bridge using the LRFR method, in which case the bridge must be load rated for the HL-93 loading.
- For structure where load rating results in a lower rating capacity, LRFR, LFR, Allowable Stress, or engineering judgment may be used.

14.2. Loads to Be Evaluated

- For routes where permitted or overweight trucks are likely, bridges must be load rated for the following loads:

    a. AASHTO Design Loads, HS-20-44, HS-25-44 or HL-93, based on design loads.

AASHTO Legal Loads, Type 3S2, Type 3-3.

AASHTO Notional Rating Load (NRL) for screening all AASHTO Specialized Hauling Vehicles (SHVs). Bridges that do not pass the NRL loading must be investigated for Type 3 and SHVs to determine posting requirements.

The FAST Act's Emergency Vehicles; Type EV2 and Type EV3

DDOT Permit Truck, 90,000 lbs. (See Figure 14-1).

DDOT Permit Truck, 147,000 lbs. (See Figure 14-1).

- For routes where Permit Trucks are unlikely, bridges must be load rated for the following loads:

  a. AASHTO Design Loads, HS-20-44, HS-25-44 or HL-93, based on design loads.
  b. AASHTO Legal Loads, Type 3S2, Type 3-3.
  c. AASHTO NRL for screening all AASHTO SHVs. Bridges that do not pass the NRL loading should be investigated for Type 3 and SHVs to determine posting requirements.
  d. The FAST Act's Emergency Vehicles; Type EV2 and Type EV3

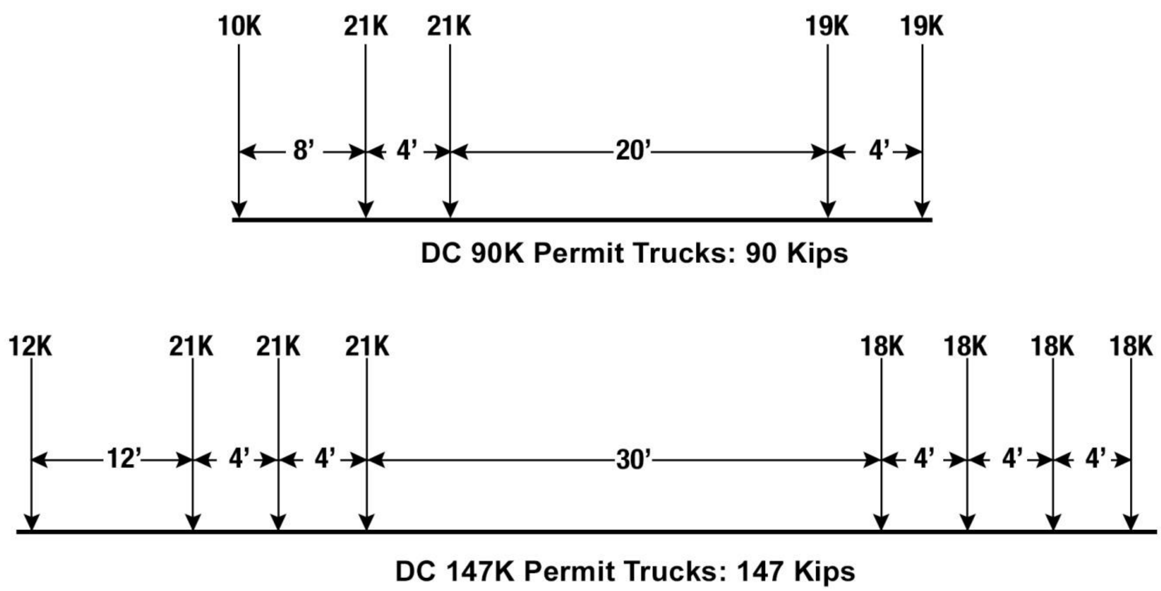

Figure 14-1 | DDOT Permit Truck Loadings

14.3. Selection of Bridge Elements

Prior to rating an existing bridge, the most recent detailed inspection report must be thoroughly reviewed and used as the basis for assessing the present condition of the bridge. In addition, as-built plans and any modifications since the bridge was built must be completely reviewed. When load rating the bridge, the section loss in primary load-carrying members and current bridge features must be considered. In special circumstances, DDOT may request field measurements.

Select only the primary load-carrying members in a bridge such as concrete deck, steel stringers, floor beams, structural plate girders, steel box girders, concrete T-beams, truss gusset plate connections, and in some cases, steel bracket overhangs, and other configurations. For each span, one exterior and one interior beam or girder is to be load rated, for each geometric condition, for the worst-case scenario. In reinforced concrete arch bridges, the reinforced arch ribs need not be load rated; however, if the reinforced arch deck rests on fill, then the reinforced arch ribs will be load rated. In special circumstances, some elements of the substructure such as integral steel straddle bent may be load rated.

For horizontally curved and highly skewed bridge, diaphragms and cross frames must be analyzed. Other items such as pin and hanger assemblies, splices of fracture critical girders, and integral pier caps must also be analyzed.

Substructure elements must be evaluated where the condition or geometry of the substructure are suspected to govern the load rating. Such conditions may include scour, extensive section loss, foundation undermining, settlement, collision damage, etc.

For culverts with a fill height greater than or equal to 20 feet, live load effects are negligible and load rating need not be performed. For culverts with a fill height less than 20 feet, a load rating analysis must be performed following the procedures herein.

14.4. Software

DDOT does not have specific software requirements for bridge load ratings. However, AASHTOWare **Bridge Rating (BrR)** is preferred. The Consultant may use software such as BAR 7, Merlin Dash, MDX, DESCUS, BRASS, STAAD PRO, CSiBridge and other programs deemed appropriate for the complexity and type of bridge.

14.5. Load Rating Reports

A bridge load rating report is required for each bridge and must be submitted to the Asset Management Division. The load rating report must include the following elements:

1. **Data Input Calculation.** Submit an executive summary letter stating the methodology and outcome of the load ratings for all bridge elements, with the load rating output clearly

describing the controlling elements of the structure. The executive summary letter must include a summary table of the load rating results, and a description of the bridge, material properties, loading assumptions, bridge history, etc. A sample summary of load ratings may be found on pages 14-6 and 14-7 of this chapter. Data developed by hand or electronic calculations (e.g., MATHCAD) must be documented and submitted. Provide electronic data files in both native file and PDF format files, and printed copies of the data file after the data calculations.

2. **Framing Plan and Others.** Provide the Plan and Elevation, Framing Plan, Girder Elevations and Typical Sections of the bridge. Indicate the elements in the Framing Plan that are being load rated. For simplicity, photocopies from existing bridge plans may be used if they clearly show span lengths, girder spacing and other pertinent appurtenances. Provide half-size plans and make sure relevant information from the bridge plans is legible (written by hand if necessary). Only relevant sheets or sketches should be included in the rating report.
3. **Load Rating Output.** Submit printed and PDF copies of the full bridge load rating output if the software used is specifically for load rating tasks, such as BAR 7. Submit selected output sheets if the software used is general analysis purpose software such as STAAD PRO, and output hand calculations.
4. **CD Submission.** Submit the above report elements for each bridge on CDs, in text (native or working format) and PDF format. For simplicity, submit the load rating report corresponding to each bridge on one CD. Provide a listing of load-rated bridges on a printed label for easy identification along with the date when the rating was performed.
5. **Reports.** Submit two copies of each bridge load rating report containing the above elements 1 through 4. Reports are to be provided in 8 ½" x 11" format. All reports must be signed and sealed by a Professional Engineer licensed in the District of Columbia.

14.6. Posting

All bridges with a calculated Rating Factor greater than or equal to 1.0 for the NRL need not be posted.

A bridge with a calculated Rating Factor less than 1.0 for the NRL must be posted with the Safe Posting Load as calculated below:

$$\text{Safe Posting Load} = W \times (RF-0.3) / 0.7 \text{ [Tons]}$$

Where W = Total axle load of a legal truck.

Bridges must be posted using the lowest Safe Posting Load as calculated using AASHTO Type 3 and AASHTO Specialized Hauling Vehicles.

14.7. Quality Control and Quality Assurance Process

Load ratings must be performed and checked by qualified individuals, one of whom must be a Professional Engineer licensed in the District of Columbia.

The quality control (QC) review verifies that appropriate assumptions were made to develop the load rating, calculations were performed correctly and any discrepancies were satisfactorily addressed.

The quality assurance (QA) review verifies that the load rating analysis, including the load rating output and calculations, has been performed, checked and reviewed by a Professional Engineer licensed in the District of Columbia and ensures that the results and assumptions are reasonable.

District Department of Transportation

DEPARTMENT OF TRANSPORTATION d. **Bridge #**

Transportation Operations Administration **Bridge Name:**

Asset Management Division

LOAD RATING SUMMARY

Load Type	GVW (tons)	Controlling Rating	Software Used	Critical Members	Controlling Location	Controlling Force
Design Trucks		**Factor**				
HL-93 (INV)	N/A					
HL-93 (OP)	N/A					
		Tons				
HS-20 (INV)	36					
HS-20 (OP)	36					
Legal Trucks		**Tons**				
Type 3	25					
Type 3S2	36					
Type 3-3	40					
NRL	40					
SU4	27					
SU5	31					
SU6	34.75					
SU7	38.75					
Permit Trucks		**Tons**				
DC-90	45					
DC-147	73.5					
Emergency Vehicles		**Tons**				
EV2	28.75					
EV3	43					

Recommended Load Rating:

NBI Code	Inventory Rating, (Item 66) Tons	Operating Rating (Item 64) Tons

Recommended New Posting: **Yes** ☐ **No** ☐

Seal:

Calculated By:

Checked By:

Signature:

Date:

DEPARTMENT OF TRANSPORTATION d.

Transportation Operations Administration

Asset Management Division

Bridge #

Bridge Name:

LOAD RATING COMMENTS / ASSUMPTIONS

15 Foundation Design

This chapter is intended to guide the Designer in the selection of the appropriate foundation type and provide general guidelines for the structural and geotechnical design of foundation systems. Foundation design should be performed in accordance with the most recent **American Association of State Highway** and **Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications**. The use of Federal Highway Administration (FHWA) design manuals is acceptable where specific foundation design details are not adequately provided in AASHTO specifications.

Alternate design methods not described herein should conform to industry-accepted standards and design procedures and be approved by the DDOT Chief Engineer. Design methods, reference values and technical information should be properly cited. In addition to the considerations provided herein, sound engineering judgment and specific project conditions should be accounted for in any foundation design process.

15.1. References

Listed below are references used in the development of this chapter, and that are to be used in foundation design:

- American Association of State Highway and Transportation Officials, AASHTO LRFD Bridge Design Specifications (Current Edition)
- American Society for Testing Materials. Annual Book of ASTM Standards (Current Edition)
- American Association of State Highway and Transportation Officials (AASHTO) - Standard Specifications for Transportation Materials and Methods of Sampling and Testing (Current Edition)
- District of Columbia Department of Transportation Standard Specifications for Highways and Structures (Current Edition)
- Federal Highway Administration, Publication No. FHWA-NHI-10-016: Drilled Shafts: Construction Procedures and LRFD Design Methods (May 2010)
- Federal Highway Administration, Publication No. FHWA NHI-05-042: Design and Construction of Driven Pile Foundations (April 2006)

15.2. Geotechnical Investigations and Reporting

Geotechnical investigations and reporting should consist of subsurface investigation (borings, on-site testing, and sampling), laboratory testing, geotechnical analysis of all data, and design recommendations according to **Chapter 26** of this manual.

15.3. Foundation Design Approach

Foundation design should satisfy service limit, strength limit and extreme event limit states, as specified in the most recent **AASHTO LRFD Bridge Design Specifications**. Soil properties used in foundation design should be selected to reflect the findings of the geotechnical investigation. Foundation design will be presented as part of the Geotechnical Engineering Report. Refer to **Chapter 26** for specific design requirements for each design phase.

15.4. Foundation Loading Considerations

Applied loads and load combinations with their respective load factors for use in foundation design should be determined in accordance with the most recent **AASHTO LRFD Bridge Design Specifications**.

15.5. Engineering Evaluations

Information and engineering evaluations needed for foundation design are presented in Table 15-1. The Designer should perform all necessary evaluations as required.

Table 15-1 | Information and Engineering Evaluations Needed for Foundation Design

Foundation Type	Information from Geotechnical Investigations	Engineering Evaluations
Shallow Foundations	• Subsurface profile (soil, groundwater, rock) • Shear strength parameters • Compressibility parameters (including consolidation, shrink/swell potential and elastic modulus) • Frost depth • Stress history (present and past vertical effective stress) • Depth of seasonal moisture change • Geologic mapping including orientation and characteristics of rock discontinuities	• Structural resistance • Nominal and factored bearing resistance per AASHTO LRFD manual • Overturning or excessive loss of contact • Sliding at the base of footing • Settlement (magnitude and rate) • Shrink/swell of foundation soils (natural soils or embankment fill) • Frost heave • Scour depth at water crossings • Extreme loading • Constructability

Foundation Type	Information from Geotechnical Investigations	Engineering Evaluations
Pile Foundations	• Subsurface profile (soil, groundwater, rock) • Shear strength parameters • Interface friction parameters (soil and pile) • Compressibility parameters • Unit weights • Presence of shrink/swell soils (limits skin friction) • Geologic mapping including orientation and characteristics of rock discontinuities	• Structural resistance • Axial compression resistance for single piles (end-bearing and skin friction) • Pile group compression resistance • Uplift resistance for single piles • Uplift resistance for pile groups • Settlement • Downdrag • Punching failure into a weaker stratum below the bearing stratum • Single pile and pile group lateral resistance • Lateral earth pressures • Long-term durability of the pile in service (i.e., corrosion and deterioration) • Drivability • Presence of boulders/very hard layers • Scour at water crossings • Vibration/heave damage to nearby structures • Extreme loading • Constructability
Drilled Shaft Foundations	• Subsurface profile (soil, groundwater, rock) • Shear strength parameters • Interface shear strength friction parameters (between soil and shaft) • Compressibility parameters • Horizontal earth pressure coefficients • Unit weights • Permeability of water-bearing soils • Presence of artesian conditions • Presence of shrink/swell soils (limits skin friction) • Geologic mapping including orientation and characteristics of rock discontinuities • Degradation of soft rock in contact with water or air (e.g., rock sockets in shales)	• Structural resistance • Axial compression resistance for single drilled shaft (shaft end bearing and shaft skin friction) • Shaft group compression resistance • Uplift resistance for single shafts • Uplift resistance for shaft groups • Punching failure into a weaker stratum below the bearing stratum • Downdrag • Depth of rock socket • Single shaft and shaft group lateral resistance • Lateral earth pressures • Settlement (magnitude and rate) • Groundwater seepage/dewatering • Presence of boulders/very hard layers • Scour at water crossings • Extreme loading • Constructability

Foundation Type	Information from Geotechnical Investigations	Engineering Evaluations
Micropiles	• Subsurface profile (soil, groundwater, rock) • Shear strength parameters • Horizontal earth pressure coefficients • Interface friction parameters (soil and pile) • Compressibility parameters • Unit weights • Presence of shrink/swell soils (limits skin friction) • Geologic mapping including orientation and characteristics of rock discontinuities	• Structural resistance • Axial compression resistance for single micropile • Micropile group compression resistance • Uplift resistance for single micropile • Uplift resistance for micropile groups • Micropile group punching failure into a weaker stratum below the bearing stratum • Single micropile punching failure where tip resistance is considered • Single micropile and micropile group lateral resistance • Constructability, including method(s) of micropile construction

When a shallow foundation is recommended, the geotechnical engineering report should include the following:

- Plan, layout and dimensions of footings
- Structural loads
- Bearing resistance of soil at footing subgrade elevations, supported by engineering calculations
- Settlement calculations
- Any geotechnical instrumentation installation and monitoring requirements
- Construction considerations including the presence of unsuitable soils, subgrade evaluation criteria, undercut requirements, dewatering, etc.

If deep foundations are recommended, the geotechnical engineering report should specify the following:

- Type of piles
- Size of pile/drilled shaft
- Proposed pile/drilled shaft lengths and minimum tip elevations
- Ultimate design pile/drilled shaft structural resistance (tensile and compression) for drivability
- Any geotechnical instrumentation installation and monitoring requirements
- Construction considerations including the evaluation of bearing materials, the need for temporary casing ad drilling fluids, plumbness, video/camera observation requirements, criteria

for removal of sediments at the bottoms of the shafts, etc.   for drilled shafts, Shallow Foundation

A shallow foundation is recommended where hard or dense materials are encountered at proposed footing or mat subgrade elevations. The use of a shallow foundation is not recommended in the following cases:

- Erosion, scour, or undermining may cause loss of bearing over time. Footing/mat subgrade should be below scour elevation.
- Test results indicate that the proposed footing/mat would compromise stability of existing adjacent slopes or other structures
- Considerable excavation is necessary to reach suitable soils
- Significant shoring would be needed to protect adjacent structures during footing/mat construction
- Significant seismic loads are expected, and liquefaction could occur at or below the footing/mat level
- Expansive or collapsible soils are present near bearing elevations

Allowable superstructure movement is often a determining factor that adversely affects the use of shallow foundations. Allowable superstructure movements should be checked against the predicted total settlement of the foundation system, as well as differential settlement. Total foundation settlement calculations should include elastic settlement, primary consolidation settlement and secondary consolidation settlement. Where applicable, alternatives to control settlement should be provided by the Designer.

Exterior footing subgrades should be located at least 2.0 feet below final exterior grades for frost considerations. Where expansive fat clay or elastic silt soils are present at footing subgrades, footings should be lowered to suitable material, should be lowered to below the zone of seasonal moisture variation or the unsuitable material should be undercut and replaced as recommended by the engineer.

In general, uplift loads on foundations due to expansive soils should be avoided by removing such soils where possible or foundations may be lowered below the zone of seasonal moisture variation. If removal of soil and lower of foundation is not possible, deep foundations should be used. The potential for soil swell that may result in heave of shallow foundations should be evaluated based on **AASHTO LRFD Bridge Design Specifications**. The most common test procedures to obtain physical properties for expansive soils are the Constant Volume Swell test and the Free Swell test performed in accordance with **ASTM D4546**.

15.5.1. Shallow Foundation Design Requirements

The geotechnical and structural design of footings should conform to the most recent **AASHTO LRFD Bridge Design Specifications**.

Footing bearing resistance values should be calculated at the Service Limit State for settlements corresponding to 1/2 inch of differential and 1 inch total settlement unless stricter settlement limits are established by the structural designer. If differential settlement exceeds 1/2 inch, or total settlement exceeds 1 inch, soil improvement techniques or a deep foundation is required. The use of soil improvement techniques (e.g., surcharging, wick drains, dynamic compaction, jet grouting, soil mixing, lightweight fill, stone columns and aggregate piers) should be considered prior to the design of deep foundations.

Shallow foundations should be designed in consideration of the highest anticipated groundwater table, including seepage forces, if present. The use of combined footings is preferable to increasing footing sizes to keep footing eccentricity within limits per **AASHTO LRFD** standards. Adjacent footings should be properly spaced to prevent overlapping of the zones of stress created by individual footings.

The width of individual column footings and continuous wall footings should be at least 30 inches and 18 inches, respectively, for local and punching shear considerations. Any footing that exceeds 3 feet in depth should have vertical reinforcement to prevent cracking. Where shear controls the size of footing depth, it is preferable to increase depth in lieu of using shear reinforcement.

15.5.2. Shallow Foundation on Shallow Rock

Where a rock material is at or near the ground surface, the most economical foundation system to support structures will usually be a shallow foundation bearing in or on the rock. The Designer has three options to install the foundation:

- Excavate to the top of rock, then specify concrete from the rock surface to the proposed bottom of footing
- Lower the bottom of the footing (creating a thicker footing) to bear directly on the top of rock
- Construct a taller pier or abutment

The geotechnical design of shallow foundations near the crest of a slope should include detailed consideration of global stability, including planar, wedge, sliding and toppling failure mechanisms of the supporting slope. The potential for slope instability in rock may be a function of the intact mass strength properties, orientation and condition of unfavorable structure or discontinuities (e.g., bedding, joints, foliations, etc.) or both.

When supporting structures with large horizontal or uplift loads, shallow foundations may need to be tied into the rock to provide sufficient resistance to uplift and lateral forces and overturning moments. When considering design of a shallow foundation in rock conditions that will be required to resist large uplift or lateral loads, consideration should be given to the use, economics and constructability of a deep foundation socketed into the foundation material.

15.5.3. Shallow Foundations Materials and Methods

Footing subgrade preparation and protection are subject to the recommendations described in the Geotechnical Engineering Report and **DDOT Standard Specifications for Highways and Structures**. Footing materials and construction methods are subject to the specifications of the **DDOT Standard Specifications for Highways and Structures**.

15.6. Deep Foundations

Deep foundations should be used only where shallow foundations and soil improvement techniques would be impractical or uneconomical. Unless approved by the DDOT Engineer, the use of multiple foundation types to support an individual structure is not permitted due to differential settlement concerns and constructability issues.

Deep foundation systems should be designed according to **AASHTO LRFD Bridge Design Specifications.** Deep foundation types are categorized as *driven piles* and *other deep foundation systems*. These other deep foundation systems are primarily drilled shafts, but also include micropiles, auger cast piles and other drilled deep foundation systems. FHWA publication **FHWA NHI-05-042** provides the comprehensive design and construction methods of driven piles and FHWA publication **FHWA-NHI-10-016** provides the comprehensive design and construction methods of drilled shafts.

Materials and construction methods for driven pile and drilled shafts are subject to the requirements of the **DDOT Standard Specifications for Highways and Structures**. Deep foundations should extend at least 10 feet below the existing ground surface to achieve adequate lateral stability. Pile penetration of less than 10 feet is allowed if piles are pre-bored at least 3 feet into solid rock with RQD > 50%.

The following should be considered in the design of deep foundations:

- Driven pile and drilled shaft lateral resistance should be assessed assuming that the soils subject to scour are completely removed, resulting in no overburden stress at the bottom of the scourable zone or resistance above scourable layers.
- Downdrag loads should be considered if a pile penetrates through compressible soil layers. Downdrag estimation and mitigation methods should be provided per **AASHTO LRFD Bridge Design Specifications**. Battered piles should not be used where downdrag loads are expected.
- Pullout resistance and structural resistance of deep foundations subjected to uplift should be assessed.
- Damage of concrete by direct chemical attack (e.g., from organic soil or industrial wastes), electrolytic action (chemical or stray direct currents), or oxidation should be assessed. The use of special cements or special coatings is required to protect piles from chemical attacks, if applicable.
- Driven piles should be designed to resist driving and handling forces. For transportation and handling, a precast pile should be designed for not less than 1.5 times its self-weight per **AASHTO LRFD** recommendations.
- Protection is needed for steel piles where they are exposed to potential corrosive soils. Protection should extend at least 5 feet below the stream bottom or ground surface. Solutions to protect the steel from corrosion include the application of coatings (e.g., coal tar epoxy) before driving, cathodic protection, specification of copper content in the steel, and encasement by cast-in-place concrete jackets. Alternatively, a sacrificial thickness and increased steel cross-sectional area can be used based on predicted corrosion rates throughout the given design life.
- Piles may need to be socketed into bedrock to achieve the required pile resistance and fixity at the pile tip. In designing rock-socketed sections, a minimum rock socket of 3 feet below the top of the rock is required to guarantee plastic stress redistribution and inelastic rotation in the pile.
- Soil/pile interaction should be considered if lateral forces or overturning moments have to be resisted by the pile/drilled shaft. The “p-y” curve method using appropriate soil parameters is required for analysis of piles subjected to lateral loads. The top of pile deflection is restricted to 1/2 inch unless stricter requirements apply. The P-multiplier method is recommended to account for group effects on lateral load response. For closely spaced piles in a group, the values of soil resistance for a given p-y relationship are multiplied by a P-multiplier less than 1.0. Refer to **AASHTO LRFD** for the appropriate P-multiplier values.

- When required, piles should be tested in accordance with **DDOT's Standard Specifications for Highways and Structures** and/or most recent **AASHTO LRFD**.

15.7. Overall (Global) Stability Considerations

Overall (global) stability of earth slopes with or without a foundation unit should be investigated according to requirements of the **AASHTO LRFD Bridge Design Specifications**. Specifically, overall stability is of concern under the following circumstances:

- Foundation is placed on an embankment
- Footing is located near or within a slope
- Highly plastic, over-consolidated or soft soils are present

The overall (global) stability of retaining walls, retained slopes, permanent slopes, and temporary slopes should be evaluated using limiting equilibrium methods such as Modified Bishop, simplified Janbu, or Spencer methods. The analysis should utilize load combinations as detailed in **AASHTO LRFD Bridge Design Specifications** and resistance factors (ϕ) as listed in Table 15-2.

Table 15-2 | Resistance Factors for Soil Slopes

Application	Resistance Factor (ϕ)
Where geotechnical parameters are well defined, and the slope does not support or contain a structural element	0.75
Where geotechnical parameters are based on limited information, or the slope contains or supports a structural element	0.65

Adapted from AASHTO LRFD Bridge Design Specifications, 7th Edition, Section 11.6.2.3

16 Walls, Abutments and Piers

The design of retaining walls, abutments and piers shall be in accordance with American Association of State Highway and Transportation Officials (AASHTO) **Load and Resistance Factor Design (LRFD) Bridge Design Specifications**, latest edition, including all interims except as modified herein.

16.1. Architectural Treatments

Architectural treatments will be considered on a case-by-case basis when approved by the Chief Engineer, District of Columbia State Historic Preservation Office (SHPO) or other project stakeholders. Some of the treatments may include:

- Brick facing
- Stone facing
- Exposed aggregate
- Form liners

16.2. Substructure Protection

The District requires pier and abutment areas under expansion joints, as well as exposed ends of concrete piers and abutments, to be coated. Use water-based epoxy, silane or approved method to protect substructure concrete. The bridge substructure must be reviewed to determine its potential as a target for graffiti vandalism, and an anti-graffiti coating will be specified as warranted. Substructure coating protection will be evaluated on a case-by-case basis and when approved by the Chief Engineer.

16.3. Substructure Drainage

Any water that accumulates behind abutment backwalls and retaining walls must be drained to prevent settlement of the embankment or failure of the wall. This may be accomplished through footing drains, weep holes, and geosynthetic drains. The Designer must provide pervious backfill behind the walls and direct the water to footing drains and weep holes.

A drainage system is preferred instead of weep holes to drain fill behind walls that are visible to the public. A drainage system with a perforated drainpipe installed behind the footing and outlets located to minimize aesthetic impacts is preferred. Weep holes may be used in walls that are not generally visible to the public, such as in backwalls for stream crossings. Water must not be drained onto sidewalks and roadways.

16.4. Retaining Wall Design

Retaining walls are designed to withstand lateral earth and water pressures, including live and dead load surcharges, the weight of the wall, loads created by temperature and shrinkage effects, and earthquake loads in accordance with the latest **AASHTO LRFD Bridge Design Specifications.**

Creating passive pressure resistance by using the fill in front of the wall is not allowed.

16.4.1. Retaining Wall Types

There are three general types of retaining wall structures commonly used in the District. The three types are:

- Reinforced concrete cantilever walls are constructed using cast-in-place or precast concrete elements. They may be constructed on spread footings or deep foundations. They derive their capacity through combinations of dead weight and structural resistance.
- Gravity walls generally use interlocking, soil-filled reinforced concrete bins to resist earth and water pressures. They depend on dead weight for their capacity. Mechanically stabilized walls use metallic or polymeric tensile reinforcement in the soil mass and modular precast concrete panels to retain the soil. Gravity walls are often constructed for property walls on neighborhood streets where the construction of footings or any portion of the wall is constrained by a right-of-way (ROW).
- Tie-back walls consist of piles driven at designated spacing and then tied back using drilled or grouted type anchors. The spaces between the piles are spanned with structural elements, such as wood, reinforced concrete lagging, precast or cast-in-place concrete panels or steel members, to retain the soil. Timber lagging must not be used for permanent wall facings unless approved by the Chief Engineer.

Other wall system types that can be considered are:

- Sheet-pile wall
- Slurry wall
- Secant wall

16.4.2. Proprietary Retaining Walls

Economics, location, construction requirements and aesthetics should be considered in the evaluation of proprietary wall systems. All abutments constructed behind proprietary retaining walls must be founded on piles. Spread footings are not permitted. Proprietary retaining walls are used to retain earth and do not carry vertical structure loads.

Each wall site must be evaluated based on the advantages and disadvantages of the specific type of wall. Long-term stability and storm flows should be considered in the selection of the wall system. Use of positive erosion control in addition to geotechnical fabric is required. Do not use these walls in locations where water might reach the wall.

When proprietary retaining walls are included in a project, special provisions must be included in the contract documents to guide the contractors and wall suppliers. The special provisions must be developed in generic form without specifying any one supplier exclusively. The specifications must outline the criteria to which the proprietary design must conform while also promoting competitive bidding. The wall suppliers will provide all required engineered designs of the structural wall, signed and sealed by a Professional Engineer licensed in the District of Columbia. The Contractor selects a supplier's design and submits a bid accordingly.

Per the **AASHTO LRFD Bridge Design Specifications** and District requirements, the Designer must be aware of the limitations of Mechanically Stabilized Earth (MSE) walls and prefabricated modular walls.

MSE walls should not be used under the following conditions:

1. When utilities other than highway drainage must be constructed in the reinforced zone
2. With galvanized metallic reinforcements exposed to surface water or groundwater contaminated by acid mine drainage or other industrial pollutants as indicated by low pH and high chlorides and sulfates
3. When floodplain erosion may undermine the reinforced fill zone, or where the depth of scour cannot be reliably determined

Prefabricated modular systems are not allowed under the following conditions:

1. On curves with a radius of less than 800 feet unless the curve can be substituted by a series of chords
2. When calculated longitudinal differential settlements along the face of the wall are greater than 1/200

NOTE: Steel modular systems are not permitted where the groundwater or surface runoff is acid contaminated or where deicing spray is anticipated.

16.4.3. Proprietary Wall Design

For projects in which proprietary retaining wall structures are deemed feasible, the Designer must analyze site conditions during preliminary engineering and make recommendations on which wall system may be used.

Conceptual wall plans, hereafter referred to as Control Plans, must be provided in the final contract documents and include project-specific details. Complete detailed proprietary wall drawings will not be included in the contract documents. After the award of the contract, complete proprietary wall plans for the selected wall will be prepared by the proprietor and submitted by the Contractor as shop drawings in accordance with DDOT standards. A set of original drawings will be added to the record set of the contract documents after approval of the shop drawings.

If site conditions warrant that only one proprietary manufacturer can be used, the Designer must request and obtain approval to prepare complete plans for the suitable wall type. For such an occurrence, sole source justification is required. In accordance with the requirements of **Title 23 of the Code of Federal Regulations (CFR) Section 635.411**, a waiver must be obtained from the Federal Highway Administration once the Chief Engineer agrees to it. Special site conditions include, but are not limited to:

1. Excessive height of wall (more than 30 feet)
2. Poor foundation conditions (low allowable bearing pressure)
3. Constructability
4. Noise barriers mounted on the wall
5. Longitudinal drainage in the retained soil
6. Obstructions such as sign structures, utilities and/or limited ROW

The Control Plans must include at least the following information:

1. Plan and elevation views of the walls: The elevation view of walls should show existing and proposed ground lines, elevations at 25 feet intervals at the top of wall and proposed ground line (used to compute quantities), wall embedment (maximum elevation at top of leveling pad) and beginning and end of wall station
2. Control data for horizontal and vertical alignment
3. Specific/nominal limits of the walls
4. Locations of existing and proposed utilities
5. Boring locations

6. General notes:

    a. ROW limits / construction easements

    b. If warranted, construction sequence requirements, traffic control, access, and staged construction sequence

    c. Work Item Quantities table (including excavation and backfill)

    d. Estimate of Quantities table (including excavation and backfill)

    e. Limits of retained soil

    f. Limits and requirements for drainage features within the retained soil, and limits and requirements that will affect the construction or stability of the wall beneath, on top of, and behind the retaining wall

    g. At stream location, high water and normal water levels and scour protection

    h. Design parameters (safety factors), which must include at least the following:

        i. Allowable bearing capacity

        ii. Soil unit weight including backfill unit weight

        iii. Angle of internal friction

        iv. Anticipated settlement

        v. If required, foundation subgrade treatment

        vi. Magnitude, location and direction of external loads due to bridges, sign structures, traffic surcharge, etc.

        vii. Seismic criteria

        viii. Sections through wall showing offset control point, pay area, ditches, sidewalks, superelevations and any unusual features

7. General details showing:

    a. Ends of wall interfaces

    b. Wall, coping, and barriers or barrier interfaces

    c. Drainage pipe and inlet details, slip joint details

    d. Compatibility with roadway plans

    e. Excavation and cofferdam requirements

    f. Architectural details (such as dimensional requirements or special wall features such as facing finish, texture, color or planting)

g. Location and size of any existing or proposed structures

h. Location of overhead signs or roadway lighting

i. Location and height of noise barrier, if applicable

j. Geotechnical Report and recommendations to include the following:

   i. When alternate type retaining walls are to be used in a project, the Geotechnical Report must provide complete detailed information as to why the alternate type of retaining wall system is recommended. The Designer must evaluate global external stability, sliding, overturning, slope stability, bearing pressure and settlement.

   ii. The Report should indicate the maximum elevation at the top of leveling pads or footings and the design foundation pressures at those elevations.

   iii. If soil subgrade treatment, soil enhancement, or unsuitable material removal is required, the Report must clarify such recommendations along with potential effects that the recommendations may have on the various alternatives.

   iv. To expedite the availability of the Report to the Contractor, the Designer should ensure that the most current Report is provided to the Project Manager.

8. When alternate type proprietary walls are permitted, the Contractor must be responsible for:

   a. Providing the design calculations and construction plans for the proprietary wall systems. The calculations must include internal and external stability verification of the wall system.

   b. Submitting drawings and design calculations for review in accordance with **DDOT Standard Specifications**. Once the submission is found to be acceptable, the Contractor will submit final signed and sealed design calculations, one set of mylars, the required number of signed and sealed prints, and electronic copy of the submittals in (pdf and dgn formats).

   c. The Designer will sign and seal these mylars, noting that the walls were checked for external stability and for conformance with the design concept of the project. Also, the Designer will modify the Index of Drawings on the contract set of plans.

   d. An additional set must be furnished if railroad structures are involved.

   e. A note on the Control Plan must specify which type of proprietary wall is to be constructed at each wall location.

The Contractor must submit detailed shop and working drawings and design calculations. Complete information as to the proposed method of fabrication and erection of precast units and related components must be provided. Shop drawings must be prepared and submitted in accordance with the **DDOT Standard Specifications**. DDOT reserves the right to reject any alternate wall system or details that do not conform to the Control Plans, pre-approved details, **DDOT Standard Specifications** with construction documents and/or **AASHTO LRFD Bridge Design Specifications.**

16.4.4. Steel Sheet Pile Walls

When steel sheet pile walls will be used as a temporary structure, the Contractor is responsible for their design, with approval by the Engineer that the design meets the requirements of the contract documents and current codes and standards. Sheet pile walls may be designed as either cantilever or anchored. Exposed cantilever walls must be no more than 15 feet in height. In anchored designs, deadmen or other anchorages are constructed and the sheeting wall is anchored to them using tie rods. Driven sheet piles must not be used as an abutment to resist the bridge structural loads. ASTM A690 sheet piles should be used in marine environments. ASTM A709 Grade 36 and A709 Grade 50 sheet piles should be used in non-marine environments. Both types must be coated with a bituminous type coating.

Where steel sheeting is used in the construction of coffer dams, the steel sheeting below the top of the seal concrete will generally be left in place, with the approval of the responsible government agency having jurisdiction. If sheeting is left in place it must be anchored to the top of the seal concrete.

16.5. Abutments

16.5.1. Conventional Abutments

The components of a conventional abutment are as follows:

1. Bridge seat
2. Backwall
3. Stem
4. Wingwalls
5. Wall drainage
6. Slope protection
7. Foundation

Bridge Seat. The bridge seat must be wide enough to accommodate the bearings and future jacking operations, and meet the seismic requirements of **AASHTO LRFD**. Sufficient room between the beams and backwall must be provided to allow for expansion joint inspection, where applicable. For seats that are stepped 4 inches or more, additional reinforcement is required in the seat directly under the bearings to prevent cracks or possible spalling due to localized stresses.

Backwall. A backwall retains the embankment behind the bridge and supports the approach slab. The minimum thickness for a backwall is 1 foot. A roughened horizontal construction joint must be provided between the bridge seat and the backwall extending the entire width of the abutment, although this joint is optional for small abutments. Concrete must not be placed above this joint until the deck slab is in place.

Stem. The stem retains the embankment behind the abutment and transmits the loads from the superstructure to the foundation. The stem thickness must be designed to support the required loading and have sufficient space for the bridge seat. The top of stem may be level, stepped or sloped depending on bridge geometry.

Wingwalls. Wingwalls must be long enough to retain the roadway embankment based on the embankment slopes. Generally, an embankment slope of 2:1 is used. When this is not possible, 1.5:1 may be acceptable with approval of the Engineer. Wingwalls may be placed parallel to the roadway ("U shape"), at some angle ("flared" or "elephant ear"), or on the same alignment as the centerline of abutment bearings ("straight"), depending on the bridge geometry and site factors.

Wall Drainage. Drainage behind abutment walls must pass through geocomposite drain sheets installed behind the wall that collect the water and drain it through an underdrain system. Porous select backfill may be used in place of geocomposite drain sheets behind the wall with DDOT's approval. The underdrain system should include weep holes in the wall formed with 6-inch-diameter, non-rigid tubing and placed at proper elevations above the embankment. Alternatively, a 6-inch-diameter pipe underdrain may be used at the bottom of the geocomposite sheet, or select backfill, along the wall. The underdrain must flow or connect into an existing drainage system.

Slope Protection. Suitable slope protection must be provided in the form of a concrete slab in the area under the bridge. The concrete slab must be 6 inches thick and reinforced with welded wire fabric. For water crossings, to protect against scour, see **Chapter 28**.

Foundation. The Designer must assess feasible foundation alternatives based on a geotechnical exploration program. Abutments on spread footings are permitted unless the magnitude of the excavation or the size of the footing makes the spread footing uneconomical. In that case, deep foundations will be assessed (e.g., steel H-piles and drilled shafts).

Soil Downdrag. If steel H-piles are used, the Designer should consider alternative construction sequences to ensure that all loads applied to piles are accounted for in the design. It is possible to develop negative skin friction in some soils, and the Designer should consider augering through these soils to reduce the downdrag forces. Downdrag may be reduced by specifying that coating be applied on that portion of the pile subject to downdrag. Refer to **AASHTO LRFD** for additional information concerning downdrag. Battered piles should be avoided in negative skin friction situations because of the additional bending forces imposed on the piles, unless analysis indicates their suitability.

Scour. Designers should consider the consequences of changes in foundation conditions resulting from scour, regardless of the countermeasures used. The scour depth must be determined for both the Design Flood (100-year event) and Check Flood (500-year event). The latter must be considered at the Extreme Event Limit State, per **AASHTO LRFD**. Deep foundations (e.g., piles and drilled shafts) must be designed so that the penetration/embedment into the ground satisfies the requirements for fixity after the scour has taken place. The axial and lateral load analysis must take into consideration the unsupported pile/shaft length due to scour and its resistance against buckling.

16.5.2. Abutment Design Loads

There are various combinations of loads and forces that act on the abutment. The abutments must be designed to adequately resist all applicable load combinations in accordance with **AASHTO *LRFD Bridge Design Specifications.***

Designers must consider construction sequence when designing abutments. Abutments must have adequate capacity to resist the backfill pressure and construction loading surcharge without the superstructure in place. This is especially important when checking the pile batter. Abutments must be designed to resist all soil lateral loads during construction phases and not rely on superstructure dead loads for stability.

16.5.3. Types of Abutments

The types of abutments include:

- Cantilever
- Stub
- Jointless

16.5.3.1. Cantilever Abutments

Cantilever abutments consist of a vertical wall (stem and backwall) rigidly fixed to the footing. The wall resists the reactions from the superstructure and also the thrust from the earth backfill. It is designed to resist this thrust as a retaining wall cantilevered from the footing. The footing may be a spread footing foundation or the cap of a deep foundation, such as steel piles or drilled shaft.

16.5.3.2. Stub Abutments

These abutments are set near the top of an embankment or slope and have a relatively short vertical height. The beam seats are supported either directly on the cap of a pile foundation or on a short stem which is, in turn, supported on a spread footing underneath. Typically, pile foundations with caps are used due to the height of the embankment.

Because of their sloped front, stub abutments are rarely used where space under the bridge has to be fully utilized to accommodate transportation facilities. In this case, an MSE wall may be placed in front of the stub abutment to retain the slope and provide more space under the bridge.

Installing an MSE wall in front of the piles will require driving the piles into the existing ground before beginning the wall construction to prevent a conflict when a pile is in the path of the MSE wall reinforcement. To install the MSE wall close to the abutment, battered piles may be replaced with plumb piles to prevent conflict with the wall, considering the magnitude of the lateral loads.. Pile sleeves may also be used to reduce negative skin friction due to settlement of the embankment.

16.5.4. Jointless Abutments

Jointless abutments should be used whenever possible to eliminate deck expansion joints. The types of jointless abutments include:

- Full integral
- Semi-integral

Selection of the type of a jointless abutment depends on: 1) total continuous bridge length (without joints) from abutment to abutment, 2) skew angle and 3) movement at abutments, as summarized in Table 16-1.

Table 16-1 | Integral Criteria for Jointless Abutments

Bridge Type	Full Integral Criteria	Semi-Integral Criteria
Steel	Up to 300’ for 0° skew Up to 150’ for 30° skew	Up to 450’ 30° max. skew
Concrete	Up to 500’ for 0° skew Up to 250’ for 30° skew	Up to 750’ 30° max. skew
Steel or Concrete	Movement at abutment: 1-1/2”	Movement at abutment: 2-1/4”

The movement at the abutment is the maximum total movement under both temperature rise and fall, and must be calculated using moderate temperature ranges according to **AASHTO LRFD**.

16.5.4.1. Full Integral Abutments

The full integral abutment is the preferred type of jointless abutment. It accommodates superstructure movements through flexing of the abutment piles. With the superstructure positively connected to the substructure, and with flexible substructure piling, the superstructure is permitted to expand and contract. To provide pile flexibility, a single row of piles is used.

The pile is connected with the beams by encasing the beams in a reinforced concrete integral backwall (end diaphragm). The integral backwall is in turn connected to the reinforced concrete pile cap (footing) via a rotationally flexible hinge. The hinge serves as a moment-relief device, thereby resulting in the transfer of only the lateral load from the beams to foundation piles, eliminating moment-related stresses at the beams and piles that would have developed otherwise.

The hinge consists of: 1) a line of dowels between the integral backwall and the pile cap placed along the centerline of the integral abutment, and 2) strips of neoprene (3/4-inch expanded rubber joint filler) between the integral backwall and the pile cap placed on both sides of the dowel line. The dowels transmit shear forces, and the strips transmit vertical loads. The hinge must be waterproofed on the backfill side, with a strip of waterproofing fabric (12 inches wide) centered at the hinge and along the abutment.

On steel superstructures, conventional diaphragms and cross frames at abutments are not required with the integral backwall. Bearing stiffeners are required.

Designers must address the temporary support of beams on the pile cap prior to the construction of the integral backwall and document it in the contract plans. Steel beams may be temporarily supported by anchor bolts set into the pile cap along the centerline, with leveling nuts and plates supporting the bottom flange. Slotted bolt holes in the bottom flanges will aid in girder placement. These anchor bolts, one on each side of the beam, perform similar to hinge dowels.

Concrete beams are too heavy to be temporarily supported by anchor bolts, as described above. The Contractor has the flexibility to choose the method of temporarily supporting concrete beams.

The connection of the approach slab to the integral backwall must allow flexible rotation of the backwall to prevent cracking. This can be achieved by providing an inclined bar that passes through the point of rotation at the front edge of the approach slab seat. The edge of the approach slab seat must be chamfered to prevent spalling of concrete.

The approach slab, connected to the abutment, moves with the superstructure. A plastic sheet under the slab (10 mils thick) will reduce friction. At its junction with the approach pavement, the approach slab may be supported by a sleeper slab to allow movement via an expansion joint in the sleeper slab. If a sleeper slab is not used, the superstructure movement must be accommodated using a detailed joint in the flexible pavement as approved by the Chief Engineer.

Wingwalls must be cantilevered off the integral backwall and isolated from the pile cap through a flexible joint (3/4-inch expanded rubber joint filler). The joint will allow the rotation of the integral backwall.

U-shaped wingwalls (placed along the roadway) are the preferred arrangement for integral abutment construction. Wingwalls more than 12 feet long must be supported on their own foundations independent of the integral abutment system. In this case, a flexible joint must be provided between the wingwall and the integral abutment to allow the movement of the integral backwall.

Straight wingwalls (placed along the abutment), or angled wingwalls (flared) more than 7 feet and 10 feet, respectively, must not be used because of high passive backfill pressure, unless approved by the Chief Engineer. Alternatively, such wingwalls may be supported on a foundation independent of the integral abutment and separated by a flexible joint.

To reduce the passive soil pressure behind the integral abutment, loose (non-compacted) select material for backfilling should be used. Alternatively, a layer of Expanded Polystyrene (EPS) geofoam with sufficient thickness (minimum 10 inches) can be placed between the abutment and the roadway fill to act as a cushion. In case of a single-span bridge, the EPS must be placed only on the abutment at the higher elevation.

EPS material should also be used behind “straight” or flared wingwalls to reduce the passive soil pressure.

Because of their flexibility steel H-piles should be used to support full integral abutments. Lighter steel pile sections are preferred. Steel H-piles must be oriented in their weak axis-bending configuration.

Piles must be at least 25 feet in length and penetrate at least 5 feet into undisturbed soil with 10 feet of fill or loose material under the pile cap to facilitate movement.

Depending on the soil characteristics and the magnitude of thermal movement, pre-boring for each pile and filling with sand may be used with the Chief Engineer's approval to facilitate movements. Pre-bored holes must be specified when the piles are placed in a roadway embankment.

When piles are subject to scour, the calculated scour depth must be within the limits of the piles, regardless of whether countermeasures are installed. Pile penetration beyond the scour depth will satisfy the pile fixity requirements.

When an MSE wall is installed in front of the abutment, piles must be driven into the existing ground before the wall is constructed to prevent a conflict with the MSE wall reinforcement. Also, pile sleeves may be used to reduce negative skin friction and eliminate potential pile interaction with the adjacent wall due to lateral movements.

Drainage behind integral abutment must be through either porous select material or geocomposite drain sheets, the same as conventional abutments (Refer to **Section 16.5.1**). When EPS is used, the geocomposite drain sheets must be installed between the EPS and backfill, at the interface.

16.5.4.1.1. Full Integral Abutment Design Guidelines

Full integral abutments are not allowed to be used in conjunction with curved beams/girders, or bridges with variable width.

The beam/girder deeper than 6 feet and grade between abutments greater than 4 percent are not allowed unless approved by the Chief Engineer.

The integral backwall is designed for the passive earth pressures and is treated as a continuous beam on its side with the main bridge beams acting as supports. The pile cap is designed for vertical loads from the superstructure and passive pressures that develop during thermal expansion. The dowels connecting the end diaphragm to the pile cap must be designed for longitudinal forces from the superstructure, including thermal and seismic forces.

A minimum concrete thickness of 9 inches must be provided between the bottom of the beam flange and top of the pile cap. Concrete thickness between the bottom of the beam flange and top of the pile cap must not exceed 2 feet. The pile cap must be designed with a minimum height of 3 feet and a maximum height of 4 feet.

The axial loads on the pile cap will be based on the reactions from the superstructure and tributary area of the approach slab. This includes the dead load, including the weight of the end diaphragm, and live loads. Dynamic load allowance must also be included in the design of the integral abutment piles. The rationale for this requirement is that the piles and cap are not fully below the soil; therefore, the top portions of the piles do no benefit from the damping effect of the soil.

For determining the lateral seismic forces from the superstructure, Designers should note that the District is in Seismic Zone 1 with PGA (Peak Ground Acceleration Coefficient on rock) less than 0.05. Refer to **AASHTO LRFD** to determine the lateral seismic forces.

Piles must be analyzed for the combination of vertical loads and lateral loads, per **AASHTO LRFD**, transmitted from the pile cap. Dynamic load allowance must also be included. The analysis must be based on pile-soil interaction. Piles must be designed for the resulting moments, shears and axial loads.

For lateral load analysis of piles, the depth and geotechnical design parameter values for each soil layer must be determined. All applicable geotechnical notes and charts required by the Geotechnical Engineer in the Foundation Report must be noted on the plans.

Use of integral abutments for water crossings must be approved by DDOT. If the use of an integral abutment is approved, Designers must consider the changes in foundation conditions resulting from scour and accordingly determine the unsupported pile length, regardless of scour countermeasures specified. The scour depth must be determined for both the Design Flood (100-year event) and the Check Flood (500-year event). The latter must be considered at the Extreme Event Limit State per **AASHTO LRFD**.

Piles must be sufficiently embedded below the scour depth to develop fixity. Buckling of partially embedded piles subjected to scour must be considered in the analysis.

Designers must address the lateral seismic forces from the superstructure through the integral abutment into the piles in accordance with **AASHTO LRFD**. The seismic forces transmitted to the piles must be determined based on the seismic connection forces between the end diaphragm and the pile cap, as noted elsewhere in this section.

16.5.4.1.2. Full Integral Abutment Construction Procedures

The following sequence is recommended when constructing full integral abutments with a flexible hinge between pile cap and integral backwall. Suitable notes must be placed on the plan sheets.

1. Drive piles and place and cured concrete for the pile cap with the dowels installed for rotationally flexible hinges.
2. Set the beams above the pile cap at the right elevation and temporarily secure. When steel beams are used, anchor bolts may be set into the pile cap along the centerline, with leveling

nuts and plates, to support the bottom flange and adjust the elevation of the beam. Slotted bolt holes in the bottom flanges will aid girder placement.

3. Place the integral backwall above the hinge and cure to minimum 3000 pounds per square inch (psi) compressive strength before placing the deck concrete. The wingwalls, cantilevering off the integral backwall, may also be cast concurrently with the bridge deck.
4. The integral backwall end diaphragm must be cast when the least thermal movement of the superstructure can be expected during the period of initial set of the concrete, such as at dusk or during a cloudy day.
5. Cast the bridge deck. Be aware that with the rotationally flexible hinge at the abutment, there will be no moments in the backwall or the pile cap as a result of beam deflection caused by deck placement.
6. Do not start backfilling behind the pile cap until concrete in the upper portion of the abutment (i.e., integral backwall) has attained a minimum of 3000 psi compressive strength. The remainder of the backfill (i.e., backfill behind the integral backwall) must be placed such that the difference in fill height between both abutments does not exceed 6 inches after compaction.
7. For approach slabs and sleeper pads, the excavation should be dug carefully after compacted abutment backfill material is in place. The slabs will be founded on undisturbed compacted material. No loose backfill is allowed.

16.5.4.1.3. Full Integral Abutment Construction Staging Considerations

Staged construction requires special considerations at integral abutments to mitigate undesirable torsional forces on the integral backwall when constructing a succeeding stage. For example, when casting the second stage of an integral bridge, beam deflections caused by the non-composite dead loads cause rotation of the hinged integral backwall in the second stage, which is connected to the static integral back wall in the first stage. This results in torsional forces in the backwall. To accommodate this rotation and prevent torsional forces, a closure pour between Stage 1 and Stage 2 integral backwalls may be cast. Designers should determine the necessity for the closure pour based on the significance of the rotation and the torsional capacity of the integral backwall.

16.5.4.2. Semi-Integral Abutments

Semi-integral abutments are preferred secondarily to jointless abutments after integral abutments, primarily due to the cost involved. Semi-integral design is usually considered when the bridge length, skew or the thermal movement at the abutment does not allow the use of a full integral abutment. Also, when a minimum pile length of 25 feet cannot be achieved for the full integral option, a semi-integral abutment is an option.

Semi-integral abutments have some of the features of a full integral abutment, and some of the features of a conventional stub, or cantilevered, type abutment. Similar to a conventional abutment, in a semi-integral abutment, the superstructure is not rigidly connected to the abutment stem or wingwalls; thus, conventional seats and bearings are used on the abutment stem. The difference between semi-integral and conventional abutments is that the backwall and expansion joint are eliminated, and the beams are encased in an end-reinforced concrete diaphragm (integral backwall), which is allowed to move freely in the longitudinal direction.

The expansion and contraction movements of the superstructure are accommodated at the roadway side of the approach slab. The approach slab is supported on the integral backwall on one end, and a sleeper slab is placed on the other end, similar to the full integral abutment. An expansion joint in the sleeper slab accommodates superstructure movements.

To reduce the passive soil pressure behind the integral backwall, loose (non-compacted) select material for backfilling should be used. Alternatively, a layer of EPS with sufficient thickness (minimum 10 inches) should be placed between the integral backwall and the roadway fill to act as a cushion.

To allow free longitudinal movements of the superstructure, the integral backwall should overlap the abutment stem and overhang it slightly with a small gap in between (3/4 inch), which is filled with expanded rubber joint filler. Flexible joints are also provided to allow movement between the integral backwall and wingwalls, and between the approach slab and wingwalls when applicable (i.e., full with approach slabs). The wingwalls are rigidly connected to the abutment stem below the integral backwall.

The joints between the approach slab and wingwalls, when applicable, are oriented along the two components and must accommodate superstructure movements in the direction of the joint (parallel). Typically, 1-inch, pre-formed joint filler is used to the full depth of the approach slab to allow movement.

The best type of the joint between the integral backwall and wingwalls depends on the configuration of the wingwall. For straight wingwalls (placed along the abutment) and flared wingwalls (angled to the abutment), the joints should be oriented along the direction of superstructure movement. Typically, 1 inch of preformed joint filler is used to the full depth of the integral backwall.

For U-shaped wingwalls (placed along the roadway), the joints between the backwall and wingwalls are oriented normal to the wingwalls and must accommodate the superstructure movements perpendicular to the joint. Typically, EPS is used in the joint to the full depth of the backwall. The thickness of the EPS should be sufficient to accommodate the design movement. Additionally, a neoprene water stop should be placed in the joint and embedded in the concrete on the both sides of the joint.

Straight or flared wingwalls are the preferred practice on semi-integral abutment layout to minimize interference between the integral backwall and wingwalls. When U-shaped wingwalls have to be used because of layout restrictions, the wingwalls may be offset about 3 feet to the outside edge of the superstructure to allow the joint between the wingwalls and integral backwall to be oriented along the direction of the superstructure movement, similar to straight and flared wingwalls.

16.5.4.2.1. Semi-Integral Abutment Construction Procedures

The following sequence is recommended when constructing semi-integral bridges. Suitable notes may be placed on the plan sheets.

1. Integral backwall concrete must be placed and cured to a minimum 3000 psi compressive strength prior to placement of deck concrete.
2. Backfill above the abutment seat level should not be started until the deck has been placed and cured to 3000 psi. Backfill must be placed such that the difference in fill height between both abutments does not exceed 6 inches after compaction.
3. The integral backwalls must be cast when the least thermal movement of the superstructure can be expected during the period of initial set of the backwall concrete, such as at dusk or during a cloudy day.
4. Concrete formwork for the integral backwall must be attached to the beams/girders only so they are free to move relative to the stem.

16.5.4.2.2. Semi-Integral Abutment Construction Staging Considerations

Similar to full integral abutments, when casting a succeeding stage of an integral backwall in a semi-integral abutment, a closure pour between the two stages of the backwall may be cast to eliminate rotation and the resulting torsional forces. Refer to **Section 16.5.4.1.3** for more information.

16.6. Piers

16.6.1. Pier Selection

There are many criteria and considerations when selecting an economical and structurally appropriate type of pier. These include:

- Separate or continuous footings

- Footing size
- Type of pier, column, solid shaft or hammerhead
- Number, spacing and size of columns
- Shaft dimensions
- Cap size

16.6.1.1. Frame and Multi-Column Piers

Generally, one- and two-column piers should not be considered because of the lack of redundancy, though in certain situations (i.e., very tall or very large columns), they may be viable. Minimum pier column dimensions are 30 inches by 36 inches. Loading conditions may dictate a larger column size. Multiple-column piers are more economical in normal highway-over-highway construction. Depending on the pier length, three or more columns are usually used. All pier columns must be protected and connected with at least 36-inch-high crash walls at the base of columns for bridges over roadway and bridges over railroads.

The Designer should consider the location of piers with respect to roadway clear zone and railroad crash zone to determine needs for crash barriers and walls.

16.6.1.2. Reinforcement

Care should be used when spacing vertical column bars to avoid excessive interference with the pier cap reinforcement. Double rows and/or bundling of column bars for large-diameter columns should be considered to alleviate this problem. The spiral reinforcing should be the full height of the column, extend into the pier cap and the footing by a minimum of 18 inches, and end with 1.5 turns at each end.

16.6.1.3. Construction Joints

If pier columns are over 30 feet high, a construction joint should be placed at approximately mid-height.

16.6.1.4. Column Spacing

Columns should be spaced far enough apart to be appealing to the eye. The minimum center-to-center spacing is 15 feet.

16.6.1.5. Pier Caps

Pier caps should be proportionally sized to the columns while also accommodating the bearing and bearing pedestal geometry; caps must conform to **AASHTO LRFD** seismic requirements. The minimum width of a cap is 33 inches or the width of the column plus 4 inches, whichever is greater.

16.6.1.6. Solid or Hollow Shaft Columns

In cases where space for large footings and multiple column piers is limited or columns are very tall, piers with solid or hollow shaft columns can be considered. Aesthetic treatment is preferred for massive concrete elements.

16.6.1.7. Anchor Bolts

DDOT standards do not permit drilling holes for anchor bolts in rigid frame and T-type piers. Proper construction clearances must be provided for anchor bolts and shown on the design drawings. Design drawings must show, in a detail plan and a cross-section view, the relationships between the anchor bolts and the layers of reinforcement steel immediately under each bearing pad. Detail dimensions must be given specifying the locations of the centers of the anchor bolts and reinforcement bars. Reinforcement bars adjacent to anchor bolts must be spaced to allow the free installation of 3-inch-diameter sleeves for setting the anchor bolts.

16.6.2. Waterways

When a pier is located in a marine environment, reinforcement steel (including footing bars and dowels) must be corrosion-protected. The Designer will designate the use of epoxy-coated reinforcement steel, or employ another corrosion protection method such as stainless steel or corrosion-resistant alloy steel with the approval of the Chief Engineer. Galvanized reinforcement will not be used in the District. When specifying alternate corrosion protection methods (e.g., metalizing), the Designer should consider the effects of dissimilar metals (i.e., galvanic action) in the design and detailing.

16.7. Railroads

The design of structures over or adjacent to railroad facilities must meet the minimum requirements of the **American Railway Engineering and Maintenance-of-Way Association (AREMA),** as well as the additional DDOT minimum requirements described below.

The Designer will coordinate the design requirements with the applicable railroad companies. Piers and abutments must be placed outside the railroad ROW when possible. All new construction must meet the railroad company's horizontal and vertical requirements. Placement of the piers and abutments must not interfere with railroad drainage ditches or facilities. Additionally, the Designer should consult with the railroad company involved to confirm the current and future use of the ROW, such as track removals, installations and access road needs, when considering foundation placement.

Railroad companies usually require steel sheet piling for excavations adjacent to railroad tracks. The railroad company's engineering department should be contacted for specific information about these requirements. This information should be obtained before Preliminary Plan submittal.

When AREMA requires a reinforced concrete crash wall, it must extend not less than 7 feet above the top of rail. This will allow for future ballasting of the railroad tracks and potential encroachment during construction or maintenance operations. The crash wall must be at least 3.5 feet thick and connect with all the columns. The crash wall must be anchored to the columns and footings with adequate steel reinforcement.

Footing designs within the theoretical railroad embankment line must be a minimum of 8.25 feet from any point on the rail to the side of the steel sheet piling used to support the tracks during construction.

16.8. Pile Bents

Pile bents are not recommended for use as permanent structures in the District; they may be considered for temporary structures. If pile bents are proposed as a permanent structure, the Designer must obtain the approval of the Chief Engineer. This type of pier is generally most suited for structures crossing rivers, structures with low- to mid-level clearance and multi-span structures.

In cases where piles are subject to wet and dry cyclic exposure, only concrete piles with pile protection may be used. A protective coating must be applied to the surface of precast, prestressed concrete piles after the pile is cast.

NOTE: The minimum pile size is 18 inches either in diameter or square.

16.9. Rock Riprap

Refer to **Chapter 28** for information regarding riprap.

17 Structural Steel

17.1. Analysis and Design

The analysis and design of structural steel must be in accordance with the latest edition of the American Association of State Highway and Transportation Officials (AASHTO) **Load and Resistance Factor Design (LRFD) Bridge Design Specifications**, including latest interims, with modifications specified herein. The analysis and design of welds and weldments must be in accordance with the latest **AASHTO/American Welding Society (AWS) D1.5M/1.5 Bridge Welding Code**, including latest interims, with modifications specified herein.

For all steel structures, the load modifier for ductility must be 1.00.

There are three basic approaches to analyzing structural steel designs: 1-D line girder, 2-D grid, or 3-D finite element analysis. The method used in the design of steel I-beam bridges, is dependent on several factors, including skew and curvature of the structure, span length, bridge width, steel framing and structure stiffness. Two-dimensional grid analysis is considered a higher level of analysis than line-girder analysis; and 3-D finite element analysis is considered a higher level of analysis than 2-D grid analysis. The appropriate method of analysis required for design should be chosen by the Designer following the procedures outlined in the National Cooperative Highway Research Program (NCHRP) Report 725, **Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges**. For bridges where 1-D line-girder analysis is deemed appropriate, NCHRP Report 725 should be used in conjunction with the Distribution Factor Method for Moment and Shear and the Distribution Factor Method for Shear found in **ASHTO LRFD Bridge Design Specifications.** The V-load 1-D analysis method is not permitted for final design of curved girder structures.

For the analysis of multi-span, multi-beam or girder superstructures, the Designer must not redistribute negative moments in continuous beam or girder bridges.

For staged construction, the Designer must consider the number of beams and girders that are erected in each stage, along with the applicable loads applied during that stage. The Designer must recognize that until cross frames are connected in subsequent stages, the applied loads will not be distributed.

For heavy loads applied to more rigorous models, such as 2-D and 3-D, **AASHTO LRFD** recommends the loads be placed in the model as they are located on the typical bridge section.

An analysis must be performed to determine an acceptable slab placement sequence. The analysis must consider the following conditions at a minimum:

1. Change in the stiffness of the girders as different segments of the slab are placed and cured; this will affect both temporary stresses and deflections (the latter will affect haunch thickness)
2. Bracing (or lack thereof) of the compression flange of girders and its effect on the stability and strength of the girder or girder systems
3. Stability and strength of the girder or girder system during the slab placement sequence
4. Bracing of overhang deck forms
5. Uplift at bearings
6. Temperature changes

17.1.1. Structural Steel Material

For steel bridges, **AASHTO M270**, Grade 50 structural steel must be used unless otherwise approved by the Engineer. This steel type must be painted. For painting requirements, refer to **DDOT Standard Specifications for Highways and Structures**.

AASHTO M270 grade 50W, weathering steel may be considered for structures over roadways with high traffic volumes or railroads, where access for painting or repainting is limited or dangerous. The use of weathering steel is subject to approval by the Engineer.

- The material for all main load-carrying members of steel bridges subject to tensile stresses must conform to the applicable Charpy V-Notch (CVN) Impact Test requirements of **AASHTO M270** for temperature Zone 2. The Designer must indicate on the plans or specifications that the CVN testing must be for temperature Zone 2 (CVN-2).
- All structural steel plans must display the following note:

STRUCTURAL STEEL: AASHTO M270, GRADE ___ with Supplementary Requirements for Notch Toughness (CVN-2) for all member components marked (T).

- Designate the main load-carrying member components that are subject to tensile stress. The designation (T) must be noted on the contract plans.
- The components to be designated (T) must include at least flanges, webs and splice plates of the welded girders or rolled beams. The above note and designations must be verified on the shop drawings.

17.1.2. Protective Coatings

The Designer must specify the federal standard paint color in the general notes for painting of all structural steel, except weathering steel. Normally, light gray paint, Standard Color Chip No. 26408, Federal Standard No. 595, is used on bridges, but other colors may be used with the approval of the Chief Engineer, except for bridges over waterways. All painting (protective coatings) must be done per **DDOT Standard Specifications for Highways and Structures**.

The use of weathering steel is prohibited for bridges over waterways. Weathering steel must not be used in corrosive environments where there is high humidity or high concentrations of chloride. Weathering steel may be considered for structures over roadways carrying high traffic volume and at railroads, where access for painting and repainting is limited. Weathering steel should not be used in corrosive environments where there is high humidity or high concentrations of chloride. Refer to Federal Highway Administration Technical Advisory T5140.22, **Uncoated Weathering Steel in Structures** (1989), for further information. Avoid the use of weathering steel on structures with open-grid decks.

Paint the ends of weathering steel girders near bearing areas under joints; normally, the length of the painted area is equal to 1-1/2 times the depth of the beam, but must not be less than 5 feet from the end of the beam/girder. Where weathering steel is painted, brown Standard Color No. 10076, Federal Standard No. 595, is used.

If primary members are weathering steel, secondary members must also be weathering steel. Bridges with weathering steel beams/girders must have the fascia beams/girders painted.

When pipe support straps are attached to weathering steel, a neoprene or vinyl washer must be placed between the contact surfaces of the support strap and the hex nut with the weathering steel to isolate the contact between the two surfaces.

17.1.3. Span Type Selection

Simple and continuous beams/girders are within the range of span types that should be considered for the majority of bridges in the District. The choice should be made on the basis of judgment, economy, appearance and serviceability. Non-redundant systems and fracture-critical members should be avoided, and their use must be approved by the Engineer prior to submitting the Bridge Type, Size and Location report and preliminary plan to DDOT. To achieve redundancy, all new steel superstructures must have a minimum of four longitudinal girders/beams as part of a multi-beam or multi-girder system.

Structures containing pin and hanger connections for suspended/cantilever spans should be avoided.

The depth of the beam/girder must be in accordance with the optional criteria for span-to-depth ratios in **AASHTO LRFD** Chapter 2. Exceptions to these criteria are for haunched girders or where vertical clearance is unobtainable.

The maximum preferred spacing for beam/girder bridges is 12 feet unless a design waiver is approved.

17.1.4. Beam and Girder Design

Straight (tangent) beams and girders are preferred to facilitate fabrication and erection. The following types of steel beams and girders should be considered:

1. Rolled beams
2. Welded-plate girders
3. Welded-plate haunched girders

The use of steel box girders in the District is discouraged because of the difficulty they present in construction and maintenance.

Beam/girder-type selections must consider cost for fabrication, delivery, erection, simplification and repetition of details, and material quantities.

17.1.4.1. Rolled Beams

Assess the applicability of rolled beams for spans up to 100 feet. Refer to **AASHTO/ National Steel Bridge Alliance (NSBA) Short Span Steel Bridge Alliance Standards**.

Cover plates are not permitted on rolled beams for new bridges.

17.1.4.2. Welded Plate Girders

Typically, welded plate girders are assessed for spans longer than 100 feet; however, they may be used on shorter spans based on other geometric constraints such as vertical clearance. Refer to **AASHTO/NSBA Short Span Steel Bridge Alliance Standards**.

Use a minimum flange plate thickness of 3/4 inch and width of 12 inches to reduce warping during fabrication, improve transportation stability, provide adequate surface to install shear connections, and reduce construction problems. Consider increasing the minimum thickness to 1 inch for curved girder bridges.

Cover plates must not be added to plate girder flanges.

17.1.4.3. Welded Plate Haunched Girders

Welded plate haunched girders are used for bridges where:

- Vertical clearance cannot be attained
- Aesthetics is a consideration

Haunched girders require special attention to details such as cross frames in the variable depth region of the beams, and the potential need for web stiffeners at the locations where the depth of the web changes because component forces derive from flange forces. These and other details require careful consideration in the design and fabrication process.

17.1.4.4. Design Considerations and Requirements

Composite design with shear connectors is required.

In the design of welded plate girders, transverse intermediate stiffeners must be minimized. Consider the fabrication costs of the stiffeners against the material cost of increasing the web thickness.

Minimize the number of butt-welded flange plate transitions. It is preferred that plate size transitions be located at the field splice so that butt-welding requirements are either reduced or eliminated.

17.1.5. Fracture Control Plan

The **AASHTO/AWS Fracture Control Plan for Non-Redundant Members** is stipulated in Chapter 12 of the **AASHTO/AWS D1.5** (AWS D1.5), which states that all steel bridge members and member components designated on the plans or elsewhere in the contract documents as fracture critical are subject to the additional provisions of that chapter.

As defined in **AWS D1.5**, fracture critical members or member components (FCM) are "tension members or tension components of bending members (including those subject to reversal of stress), the failure of which would be expected to result in collapse of the bridge."

In accordance with **AASHTO LRFD**, the Designer is responsible for determining which member or component member is an FCM. The location of all FCMs must be delineated on the contract plans. Additionally, the contract documents must include a requirement that all FCMs be fabricated in accordance with **AWS D1.5**.

It should be noted that FCMs are subject to more stringent CVN impact energy requirements than non-fracture-critical members or components. For CVN impact requirements to be shown on the structural steel plans, see **Section 17.1.1** above.

If members or component members are deemed FCM, then they must be documented on the contract plans, including the temperature zone designation (Zone 2), as required by **AASHTO LRFD**, and the following note must be shown on the plan:

> **Fracture Critical Members: Members or member components designated as FCM must meet the requirements of AWS D1.5, Bridge Welding Code (with current interims) and DDOT Amendments. FCMs must comply with CVN-2 requirements.**

17.1.6. Composite Design

Composite girders are designed such that both the deck and beam or girder respond to live loads and superimposed dead loads as a unit. Superimposed dead loads include all dead loads placed on the deck after it is cured. For steel beams and girders, the deck-to-beam or girder connection is accomplished using stud-type shear connectors attached to the top flange of the beam or girder. Channel-type shear connectors are prohibited. Refer to **DDOT Standard Drawings** and **DDOT Standard Specifications for Highways and Structures** for details on shear connectors.

Steel beams and girders with a concrete deck slab must be designed as a composite structure assuming no temporary supports will be provided for the beams or girders during placement of the permanent dead load.

Shear connectors must be **AASHTO M169** end-welded studs with a 7/8-inch diameter. The height of studs depends on the concrete haunch dimensions. Shear connectors must penetrate at least 2 inches above the bottom bar of the bottom mat of the deck slab reinforcement, but the top of the stud head must be 3 inches minimum below the top of the deck slab. Using studs of uniform height on a bridge is preferred. Stud-type shear connectors must be used for both positive and negative moment areas. The maximum stud spacing is 24 inches, including the negative-moment regions. Shear studs must be placed in a minimum of two rows.

For more complex bridges or situations, the contract plans may need to show an erection/construction sequence for the bridge.

17.1.7. Camber and Deflections

A camber diagram for fabrication of the beams/girders and the cross frames must be included in the bridge plans. Camber and deflections must be computed for each beam/girder at the 1/10th points of each span or at 10-foot maximum intervals, whichever is less; the finished deck elevations must be at the same interval as the camber and deflections (see **DDOT Standard Drawings for additional information**). The Designer must furnish the camber ordinates on the structural steel plans for the following loadings:

1. Dead load due to weight of structural steel
2. Dead load due to concrete deck
3. Dead load due to superimposed dead loads such as sidewalks, parapets, and utilities
4. Camber for vertical curve ordinate to meet proposed roadway profile
5. Total of dead load deflections and camber

In developing camber diagrams, the Designer should consider the differences in loadings, such as the effects of sidewalks, parapets and barriers, on individual beams and girders. The deflections caused by the dead load from the structural steel, stay-in-place deck forms, and reinforced concrete deck are resisted by the steel superstructure. Deflections caused by superimposed dead loads are resisted by the composite section comprising the reinforced concrete deck and the beams/girders. The fascia beams likely will not deflect the same as the interior beams. Consequently, a camber diagram must be provided for fascia beams as well as for interior beams. For special situations such as curved girders or splayed girders with unequal splay, camber diagrams for all girders are required.

Because the screed rail for the deck-finishing machine is typically set from the fascia beams/girders, camber of the fascia beams/girders is critical to achieve the correct deck elevations, the specified deck thickness and proper drainage. Because of the potential hazard from ponding and freezing of water on the deck, the Designer must evaluate beam deflections, deck cross slope, roadway geometry and scupper locations to ensure that water drains properly.

The Designer must also consider the staged sequence of construction when determining the tributary loads and the section of beams/girder where each load is applied (composite or non-composite section) for predicted deflections. The Designer will need to consider distribution of load when beams/girders are erected and connected by cross frames at the time the loading is applied. Additionally, careful consideration for the relative position of beams/girders adjacent to a staged construction joint is required to ensure alignment of the cross frames in the staging bay. The Designer may consider adding a longitudinal deck closure pour within the staging bay to obtain near-final relative position of the beams/girders to allow the cross frames to align in the staging bay. The Designer must detail the width of the longitudinal deck closure pour to accommodate the deck reinforcement lap lengths. If the width of the closure pour cannot geometrically accommodate the reinforcement lap lengths, then mechanical couplers should be considered. However, the use of mechanical couplers must be minimized for economic purposes. Refer to **NCHRP Report 725** for a description of the above load conditions, cross-frame fit/alignment, design considerations and recommendations on which load condition to specify for various structural configurations and structural behavior.

17.1.7.1. Simple Spans

The conditions of dead load deflection and camber for each simple span beam/girder must be tabulated on the structural steel plans as shown on the **DDOT Standard Drawings**.

The column heading "Vertical Curve Ordinate" must be used exclusively for simple span beams/girders located within the limits of a crest vertical curve. Where such beams/girders are located within the limits of a sag vertical curve, their ordinates must be designed to be within the concrete haunch. Consequently, the tabulation of their ordinates is unnecessary.

Total dead load camber is equal to the sum of the dead load deflections. A camber diagram must be provided for all beams/girders unless the roadway vertical curve ordinate is parabolic with a vertical ordinate of L/1200 in the middle of the span, where L is the length of the span, in which case the camber diagram may be omitted. When establishing the thickness of the concrete slab and haunch in composite design, the following items must be considered:

1. Total camber required
2. Girder dimensional tolerances per **AWS D1.5**
3. Cross slope of the deck
4. A minimum cover of 3 inches over the shear connectors

When total camber is less than the minimum that can be maintained in a beam (W Section), no camber is required, but a note stating "Beams must be placed with any mill camber up" must be shown on the drawings.

Multi-span bridges composed of simple spans are not allowed without a design waiver by the Chief Engineer.

17.1.7.2. Continuous and Cantilevered Spans

The conditions of dead load deflections and cambers for each beam/girder must be tabulated at the 1/10th point of each span or at 10-foot maximum intervals, whichever is less, and at the bolted field splice points. The camber and deflection at the bolted field splices will be used to determine the elevation to be maintained at the splices during erection of the girder field sections.

17.1.7.3. Camber Table Notes

1. See **DDOT Standard Drawings** for a sample typical tabulation and camber diagram. The total camber as tabulated is assumed to be measured vertically to the top of the fully cambered web, from a straight line drawn from the intersection of top of web and centerline of bearing at one end of the girder, to the intersection of top of web and centerline of bearing at the other end of the girder.
2. The camber labeled “Steel” in the table is the camber required in the beam/girder to offset the deflection due to the dead load of the structural steel (beams/girders, cross frames, splice plates, connection plates, etc.) in the girder.
3. The camber labeled “Concrete D.L.” in the table is the camber required in the girder to offset the deflection due to the dead load of the concrete deck.
4. The camber labeled “Superimposed D.L.” in the table is the camber required in the girder to offset the deflection due to the superimposed dead load, that is, the curb, sidewalk, railing, etc., and future wearing surface.
5. The camber labeled “Forms and Added Concrete Thickness” is the camber required in the girder to offset the deflection due to the weight of the deck forms and concrete added to meet the deck grades (deck haunch).
6. The camber labeled “H” in the table is the camber required in the girder to follow the vertical curve. The vertical curve value is to be used only for beams/girders within a crest vertical curve. Where such beams/girders are within a sag vertical curve, a provision for their value must be designed to be within the concrete haunch. Consequently, the tabulation of their values is unnecessary.
7. The camber labeled “H” in the table is the geometric camber required based on the vertical curve and deck cross slope to obtain the finished deck elevations.
8. The camber labeled “Architectural Camber” is calculated as a parabola with a vertical middle ordinate of L/1200, where “L” is the span length. If the vertical curve value provides this camber, the architectural camber may be omitted.
9. Cambers listed in the table as positive are upward cambers.
10. Cambers listed in the tables as negative are downward cambers.
11. The cambers are tabulated in inches.

17.1.7.4. Sag Cambers

Because of the objectionable appearance of a sag camber in a beam/girder, sag or negative cambers must be avoided to the extent practical. The following are a few guidelines on possible means of avoiding a negative camber in a beam/girder:

1. Avoid sag vertical curves on bridges.
2. Do not begin or end a superelevation transition or runoff in the middle of a span. Begin or end transitions off of the bridge or, if this is not possible, at a centerline of a bearing or pier.
3. Do not place a sag camber in a straight beam/girder on a curved roadway in order to accommodate variation in the theoretical bottom of slab elevation. The variation should be taken up in the haunch.
4. Upward dead load deflection may occur in some areas of continuous girders when the ratio of maximum to minimum span lengths becomes significant. There is a possibility that computed camber built into the girder is not completely removed with the application of dead load. Additional camber may remain due to differences between design assumptions and actual girder performance.

17.1.7.5. Live Load Deflections

Live load deflections must be calculated at the Service Limit State and must use the composite section properties as the moment of inertia. The Designer must confirm that live load deflections are being controlled in accordance with the Optional Criteria for live load deflections in **AASHTO LRFD.**

17.1.8. Multiple Span Structures

Beams/girders must generally be of uniform depth for the full length of the structure, except where changes in depth are absolutely necessary to meet underclearance requirements or where a change in depth is desirable to enhance the appearance of the structure. Beam/girder depths within a span must be the same. Changes in depth must be approved by the Engineer.

17.1.9. Diaphragms, Cross Frames and Stiffeners

17.1.9.1. Diaphragms and Cross Frames

Diaphragms, cross frames and lateral bracing are used to provide lateral support and stability for beams/girders. Diaphragms are used to connect rolled beams with depths of 36 inches or less. Channel diaphragms for rolled beams must be at least 1/2 the beam depth. Cross frames are used for rolled beams with depths greater than 36 inches and for plate girders. Cross frames must be at least 3/4 of the girder depth. Cross frames must have top chords to provide adequate lateral stiffness prior to the concrete deck hardening. Refer to **DDOT Standard Drawings** for cross frame details.

End diaphragms, the top chord of end cross frames and their connections must be designed for the effect of wheel loads they may be required to support and for the effect of lateral superstructure forces. The effect of transverse movement of the bearing shoes due to differences in temperature effects on the superstructure and substructure must be considered when deemed necessary. The diaphragms, cross frames and their connections must be designed for the transverse force necessary to move the bearing shoes in appropriate combinations with the other applied forces.

Gusset plates used as connection plates for cross frames and diaphragms must be checked for adequate capacity against controlling loads.

For severely skewed (30 degrees or greater) structures, the structural steel layout should be examined to determine if the location of relatively stiff intermediate cross frames placed normal to the beams/girders introduce detrimental twisting stresses in the cross frames and beams/girders due to differential deflections in adjacent beams/girders. If the condition exists, consider staggering the spacing of the cross frames.

For curved steel bridges, the intermediate cross frames/diaphragms must be radial, and cross frames/diaphragms located at supports must be parallel to the supports.

17.1.9.2. Stiffeners

Transverse stiffeners should be bearing stiffeners, jacking stiffeners, intermediate stiffeners, connection plates for diaphragm or cross-frame connections, or a combination thereof. For girders with webs of 54 inches or shallower, it is preferable not to use intermediate stiffeners. For girders with webs deeper than 54 inches, the web thickness may be increased so that only one or two transverse stiffener locations are needed per span beyond those provided for diaphragm or cross-frame connections. Transverse stiffeners must be a minimum of 3/8 inch in thickness. Stiffeners must be welded to the web with a continuous fillet weld. Intermediate stiffeners will be welded to the compression flange and tight-fit to the tension flange. Bearing stiffeners must be provided at all bearing locations. Bearing stiffeners must be welded to the web, welded to the top flange at end supports, tight-fit to the top flange at interior supports, and milled to bear to the bottom flange at all supports. Transverse stiffeners and bearing stiffeners used as connection plates for diaphragms must be welded to both flanges, and the flange stress must be assessed for fatigue. Transverse stiffeners must be clipped as shown in the **DDOT**

Standard Drawings. Welded plates are preferred for bearing stiffeners and transverse stiffeners. However, bolted angles may be used with the approval of the Engineer.

Longitudinal stiffeners are used to improve the bending resistance of welded plate girders. Because fabrication is more complex and there is more likelihood of weld or weld-intersection flaws, longitudinal stiffeners may be used only with the approval of the Engineer. The longitudinal stiffeners should always be placed on the opposite side of the web from the transverse intermediate stiffeners to minimize the number of intersections between longitudinal and transverse stiffeners. Transverse intermediate stiffeners used for cross-frame connection plates must be placed on both sides of interior beams. Longitudinal stiffeners must be continuous and must not be terminated at their intersections with transverse stiffeners. Close attention is needed when tending to details at the intersection of longitudinal and transverse stiffeners. Avoid intersecting welds, if possible, by stopping the welds short of the intersection. Where intersecting welds cannot be avoided, nondestructive testing (NDT) must be specified to detect weld flaws that may cause cracking.

17.1.10. Stability between Transportation and Erection

The stability of the beams/girders during transportation and erection is typically the responsibility of the Contractor; however, the Designer should consider geometry and details that facilitate transportation.

Review of shop drawings must verify that the Contractor has met the contractual responsibilities in this respect.

17.1.11. Welded Details

Field welding on rolled beams, plate girders or any primary structural components is not permitted.

When field welding is deemed necessary or prudent for minor bridge elements, it must conform to **AASHTO/AWS Bridge Welding Code D1.5**.

Where welding is absolutely necessary on temporary components, the weld must be ground smooth after removal of the temporary component.

DDOT follows **AASHTO/AWS D1.5-Bridge Welding Code** with current interims for welding design. Electro-slag welding is one exception to the Code; its use is not permitted for bridges in the District. Fillet welds are preferred over other types of welds because they are easier to make with automated welding equipment.

Provisions in the **AASHTO/AWS Bridge Welding Code D1.5** require that contract documents identify both main members and groove welds in these members as to category of stress (tension, compression or reversals of stress). Both of these identifications are needed to define the extent of NDT required by the Contractor as a minimum level under Quality Control inspection specifications. The NDT required for all welds must be identified in the plans using symbols and notes.

For main member components in structure types such as trusses, bents, towers, box girders, etc., it is the Designer's responsibility to identify such members and welds as part of the details on the contract drawings with the appropriate welding and NDT symbols.

Certain miscellaneous details (supports for screed rails, steel deck forms, miscellaneous connection plates, etc.) should not be welded to permanent members or components subject to tensile stress if possible. At locations where welding cannot be avoided, the maximum stress at the point of attachment must be checked for fatigue.

The contract plans and shop drawings must clearly show the beam/girder flange areas where welding is not permitted and the areas on continuous girders where the stiffeners are to be connected to the top or bottom flanges.

17.1.12. Bolted Field Splices

To facilitate the fabrication, shipping and the erection of steel girders, one optional bolted field splice is permitted in spans between 115 and 150 feet in length. This field splice must be between the outer 1/3 and 1/4 points of the span length. When the span exceeds 150 feet, optional bolted field splices may be located between each of the outer 1/3 and 1/4 points. In continuous spans, the bolted field splice is preferably made at or near the points of dead load contraflexure. Locations and details of the optional field splice must be shown on the plans. The Contractor may request modifications subject to approval by the Engineer. Welded field splices are not permitted.

Bolted field splices must be designed and detailed using **AASHTO M164 (ASTM A325)** high-strength bolts, unless otherwise approved by the Engineer. All field splices of beams or girders and connections must be bolted. Construction considerations include site conditions and weight of the beam/girder.

The use of 7/8-inch-diameter **ASTM A325** high-strength bolts are preferred for bolted field connections. In some circumstances, the use of **ASTM A490** high-strength bolts may be considered to avoid an excessive number of bolts in splices or connections, when approved by the Engineer. All bolts in a bridge should be the same type and diameter. The Designer should avoid bolts over 1 inch in diameter. The Designer must design splices with bolts that have threads excluded from the shear plane and must provide a note on the drawings stating that the threads are excluded from the shear plane.

DDOT typically uses two types of high-strength bolts: Type 1 and Type 3. Type 1 bolts are made from medium carbon steel. Type 3 bolts have atmospheric corrosion- and weathering-resistant characteristics comparable to weathering steel. Type 1 M164 bolts are painted after installation. Hot-dip galvanizing is not permitted.

Splices must be designed as slip-critical connections. Class A faying surfaces must be used unless a Class B faying surface is approved by the Engineer. The Designer must specify the faying surface used on the plans and verify the correct faying surface is called out during review of the shop drawings.

Thicker webs can be used to eliminate the need for longitudinal stiffeners, unless approved by the Engineer. The Designer must proportion the size of the flange plates such that the outer flange splice plate closely matches the sum of the two inner splice plate areas.

Splice locations are generally selected near transitions in flange thickness or width in order to minimize the number of welded butt splices. For additional information, refer to **Chapter 19.**

18 Prestressed Concrete Beams

Design must be in accordance with the American Association of State Highway and Transportation Officials **(AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications**, current edition including latest interims. All concrete beams for bridges must be precast and prestressed by pre-tensioning. Post-tensioning may be warranted for prestressing on a case-by-case basis. Refer to Precast/Prestressed Concrete Institute (PCI) and Post-Tensioning Institute (PTI) standards for design aids and details.

Precast/prestressed concrete beams must have a minimum 28-day compressive strength of 5000 pounds per square inch (psi). Concrete strengths up to 10,000 psi may be used when deemed economical or necessary to meet the design requirements of the project. Concrete strengths exceeding 8000 psi may be used with the approval of the Engineer. Reinforcing steel must meet the requirements for **AASHTO M31M**, Grade 60. Prestressing strand must be high-strength, 7-wire, low-relaxation strand and conform to **AASHTO M203**, 270,000 psi grade. Draped strand must have a diameter of 0.5 inch to achieve the hold-down force required to produce the drape. Post-tensioned concrete and straight strand design must use 0.6-inch diameter strand. When draped and straight strands are used together, all strands must have the same 0.5-inch diameter. Debonded strands should be used sparingly due to potential corrosion from the sleeve opening at the ends of the beam. Minimum strand spacing (center-to-center of strand) must be four times the nominal strand diameter.

Epoxy coating is not typically specified for prestressing strands, but may be justified in areas where flooding may inundate the bottom of the superstructure. On post-tensioned structures, the Designer must specify that all strands will be uncoated and all strand conduits will be pressure-grouted. AASHTO, in conjunction with the PCI, has several standards for voided slabs, I-beams and box sections, commonly referred to as the AASHTO Girders or the PCI/AASHTO Standard Sections.

The following spacing for concrete beams should be considered:

- Minimum: 7 feet 6 inches
- Desirable: 8 feet 6 inches
- Maximum: 10 feet 0 inches

18.1. Composite Design

Composite flexural members consist of cast-in-place concrete elements constructed in separate placements but so interconnected that all elements respond to superimposed loads and live loads as a unit. The entire composite member may be used to resist shear and moment.

18.1.1. Cast-in-Place Deck Slabs

Cast-in-place deck slabs are designed as composite with concrete box or I-girders. The use of composite designs must be noted under General Notes on the plans for future reference.

18.1.2. Continuity for Live Load

Prestressed concrete beams must be designed as simply supported for dead load and continuous for live load and impact. Continuity is attained by additional reinforcing steel in the deck over beam joints and cast-in-place reinforced diaphragms at the beam joints. Diaphragms and beams must be designed to accommodate loading at the interface.

Continuity must be established for multi-span girders after 90 days curing time to minimize the time-dependent effects and associated moments over the piers. This requirement must be shown on the plans or in the project specifications.

18.1.3. Diaphragms

On skewed bridges, the end diaphragms for each span must also be skewed. Intermediate diaphragms must be perpendicular to the beams. Diaphragms must be placed and cured prior to placing the deck. The minimum number of diaphragms is three per span, one at each end and one at mid-span. Longer spans may require additional intermediate diaphragms. Intermediate diaphragms may be cast-in-place concrete, precast concrete or weathering steel.

18.2. Strands

Standard AASHTO drawings for prestressed concrete I-beams and box beams must be used. Complete details, including the prestressed strand pattern and bearing details, must be shown on the contract plans for each bridge. Drilling for inserts into prestressed concrete beams is not permitted. For any pre-tensioning application, 0.5-inch diameter strands must be used. Also, the use of 0.6-inch-diameter strands is permitted for non-draped strand patterns. Strands must be spaced at 2 inches unless stipulated otherwise by the precast supplier.

Shipping and handling stresses must be considered when designing prestressed concrete beams. This is especially important for long span members (over 130 feet) with slender webs and small flanges.

18.3. Adjacent Voided Slab and Box Beam Design

DDOT recommends that adjacent slab and box beams not be used for bridges with skew angles greater than 30 degrees. Typical box widths are 36 inches and 48 inches. Prestressed concrete box beam bridges must use 48-inch-wide box beams whenever possible. All efforts must be made to avoid a mixture of 48-

inch and 36-inch-wide box beams in satisfying geometrical constraints. Adjacent prestressed concrete slab and box beams must be analyzed as non-composite, but must have a minimum 4-inch-thick concrete deck slab designed for composite action. Reinforcement steel must be #5 with 12-inch centers in both directions, with 2-1/2 inches of cover. All reinforcement must be corrosion resistant, such as epoxy-coated or corrosion-resistant alloy steel. Galvanized reinforcement is not permitted within the District.

The **DDOT Standard Specifications for Highways and Structures** allows a tolerance of ± 1/4 inch in the width of box beams. Abutment seats must be detailed to accommodate the aggregate tolerance of the group of beams. Abutment seats may be sloped in the transverse direction to conform to the deck cross slope; however, bearing seats must be set level in the longitudinal direction parallel to the direction of the beams. A tapered sole plate or tapered grout pad may be required for bearing surfaces to be set level to avoid imposing excessive rotation and resulting stresses in the bearing.

18.3.1. Transverse Ties

Transverse ties must be high-tensile steel bars conforming to **AASHTO M275M** (**ASTM A722**). Transverse bars should be a minimum of 1 inch in diameter and a maximum of 1-3/8 inch; 1/2-inch-diameter 270 kips per square inch (ksi) strands may also be used.

18.4. Camber

Beams must be cambered to compensate for the predicted dead load deflections. A camber diagram must be included in the bridge plans. Camber should be computed for each beam at the midpoint of each span. The Designer should furnish camber deflections for the following:

- The deflection due to prestress
- The estimated prestress camber loss due to the dead load of the beam at the time of installation multiplied by a creep factor
- The deflection due to dead load of the slab and parapet

The final net camber is the combination of the camber loss with creep factor, dead load deflection, and the prestress deflection. Prestress deflection acts in the opposite direction of dead load deflection, which must be accounted for in the calculation of the final net camber.

The above calculation results in theoretical values that may vary with actual concrete strength (age), prestressing conditions, creep and prestress loss. No creep factor is assumed in calculating dead load deflection for the slab and parapet. Creep of concrete is the time-dependent deformation of concrete under a sustained load. In developing camber diagrams, the Designer should consider the differences in loadings on individual beams and girders, such as the effects of sidewalks, parapets, and barriers.

The deflections caused by the dead load from the concrete girders, forms and reinforced concrete deck are resisted by the concrete superstructure. Deflections caused by superimposed dead load are resisted by the composite section comprising the reinforced concrete deck and the beams. The fascia beam will not likely deflect to the same degree as interior beams. Consequently, a camber diagram must be provided for fascia beams as well as for interior beams. Because the screed rail for the deck-finishing machine is set from the fascia beam, camber of the fascia beam is critical to achieving the correct deck elevations, specified deck thickness and proper drainage.

Because of the potential hazard from ponding and freezing of water on the deck, the Designer must evaluate beam deflections, deck cross slope and roadway geometry, as well as scupper locations, to ensure that water drains properly.

19 Bridge Deck Slabs

19.1. Design Criteria

The bridge deck design must be in accordance with the latest American Association of State Highway and Transportation Officials (**AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications**.

The design of the overhang must also meet the following criteria:

- Maximum overhang is 1/2 of the beam spacing, or 4 feet, whichever is less
- In addition to the loading specified in **AASHTO LRFD**, overhangs must be designed for any special loading required during construction

19.1.1. Thickness

Slab thickness and reinforcement must be designed per **AASHTO LRFD** requirements. Cast-in-place concrete decks are conventional practice in the District. Precast deck construction will be allowed with approval from the Engineer. The deck must be a minimum of 8-1/2 inches including a 1/2-inch integral wearing surface, and a maximum of 10-1/2 inches. Standard concrete cover of the deck slab must be 2-1/2 inches for top reinforcement and 1-1/2 inches for bottom reinforcement. Use of permanent stay-in-place forms will not be allowed; only conventional removable forms will be allowed.

The integral wearing surface is not included in the structural thickness for design purposes, but must be included in the dead load for the design of the deck and other supporting elements. The superstructure design for bridges with one-course deck slabs must include a 25-pound-per-square-foot provision for a future overlay.

NOTE: A one-course concrete deck slab is to be used on all bridges except when an alternative is approved.

Open grated type decks may only be used with approval by the Chief Engineer.

19.1.2. Corrosion-Resistant Reinforcement in Deck Slabs

All concrete deck slab reinforcement steel must be corrosion resistant. All top and bottom layers of rebar in structural deck slabs must be epoxy coated or employ another corrosion protection method such as stainless steel or corrosion-resistant alloy steel with the approval of the Engineer. These bars include transverse bars, longitudinal distribution bars, corner bars, skew bars and header bars.

NOTE: The use of dissimilar metals as corrosion-resistant reinforcement for a bridge deck is not allowed in the District.

19.1.3. Reinforcement Steel

Reinforcement should be simplified wherever possible. For example, the bars may be straight, continuous, and of the same size and spacing in top and bottom of slab.

The Designer should consider the spacing of the deck reinforcement when detailing the shear studs.

For continuous beam spans, additional longitudinal bars must be provided over the interior supports. The reinforcement must be designed and distributed in accordance with **AASHTO LRFD.**

The main reinforcement pattern in the acute corners of skewed slabs and in the deck slabs of curved girder bridges should be given special consideration. In the acute corners of skewed slabs, some of the main reinforcement may have to be placed in a fanned arrangement extending into the corner of the deck slab. On curved girder bridges, the main reinforcement is generally placed radially.

19.1.4. Haunches on Beams/Girders

All steel beam/girder bridges with monolithic deck slabs must be provided with a haunch over each beam/girder that is monolithic with the slab. The minimum thickness of concrete over the top flange must be 1 inch. Haunch dimensions shown on the plans must be as measured from the bottom of the steel flange to the theoretical bottom of the slab at the edge of the flange on the low side of the deck cross slope. When determining the depth of the haunch, the Designer must consider the beam/girder camber tolerances, and profile and cross slope of the deck. Haunches deeper than 3-1/2 inches but less than 7 inches must be reinforced with U-stirrups per **DDOT Standard Drawings**. The minimum reinforcement size allowed is #5 stirrups at 12 inches. Haunches deeper than 12 inches must be designed in accordance with **AASHTO LRFD**.

Where field splices for beam/girder are shown on the plans or permitted in the specifications, the haunch must be a minimum depth of 1 inch over the splice plate. A 1-inch minimum clear cover must be maintained between the main steel reinforcement and the bolts.

Haunches of fascia beams of multi-span bridges must be set so that the top of the webs of fascia beams in adjacent spans line up.

The depth of the haunches must be labeled on the plans only at the centerline of bearings to enable the Contractor to verify the concrete seat elevations. After the superstructure steel has been erected, the Contractor will compute the depth of the haunch at other locations along the span.

19.1.5. Concrete Placing Sequence

The superstructure design must include details of the sequence of concrete placing. The Designer should consider the effect of plastic concrete on the girders when evaluating the need for a placing sequence. The Designer must consider beam or girder stresses and deflections in addition to bearing forces and rotations when developing the placing sequence. Deck concrete placement for continuous spans must begin at the low point on the deck and proceed up grade. The deck concrete placing sequence is determined by the Designer through stress calculations. Typical practice for continuous bridges is to place the positive moment region first, followed by the negative regions. If a single-span bridge cannot be placed in one continuous pour, then the Designer should consider placing the mid-span concrete first, followed by end closure pours.

The Contractor may be permitted to place the deck continuously with approval of the Engineer. Any deviation from the placing sequence must account for beam/girder deflections, stresses and bearing effects.

A concrete deck slab placing sequence must be shown on the plans for all bridges.

Details of the transverse construction joints for the deck placing sequence should be developed and shown on the plans. The joint must be keyed.

19.1.6. Machine Finishing

All bridge decks should be placed using finishing machines. The Designer should attempt to eliminate adverse geometrics from bridge decks during the design phase so that finishing machines may be used.

The Designer should minimize superelevation transitions on the bridge to improve machine finishing operations. Additionally, the crown or point of rotation should be kept at a constant width from the edge of the deck to maximize the area to be machine finished. Gores and other irregular areas on the bridge may have to be hand finished.

When the concrete or concrete overlay protective system on the deck surface has cured for a minimum of 14 days and has reached strength of at least 4000 pounds per square inch, transverse grooves should be saw-cut into the surface of the bridge deck. Requirements for the saw-cutting operation are provided in the **DDOT Standard Specifications for Highways and Structures**.

Grooving of skewed bridge decks must not overlap. Grooving passes on curved decks must be made radial to the center of the curve, with ungrooved gores at the outside of the curve. If the curve is such that the width of the gores exceeds 4 inches, the first pass of the grooving machine should be normal to the center line of the span at mid-span, with subsequent passes parallel to the initial pass.

See **Chapter 13** for additional requirements for overlays on structural rehabilitation projects.

19.2. Finished Deck Elevations

Finished deck elevations must be shown in the plans at the centerline of bearing over each abutment and pier line, and at 1/10th points or at 10-foot intervals, whichever is less, as follows:

- Longitudinally over each beam
- At the baseline
- At the face of the barrier/curb
- At the edge of the deck
- Longitudinally along the span at the break points in the cross slope of the deck

19.3. Approach Slabs

Approach slabs are required for all bridges. The end of the approach slab must be parallel to the skew. The width is measured from back-of-curb to back-of-curb of the bridge deck (unless the slab is bounded by concrete barriers, in which case measurement is from face-of-barrier to face-of-barrier).

When possible, the end of the approach slab should rest on a sleeper slab to prevent excessive movement. Other methods of support may be permitted with the approval of the Engineer. The excavation for the sleeper slab must be made after the compacted abutment backfill is placed. The sleeper slab must be founded on undisturbed compacted material. No loose backfill is allowed. Approach slabs must always be placed separately from the superstructure slab and placed on an aggregate base.

19.3.1. Approach Slab Design

Because fill placed behind abutments settles after the bridge is opened to traffic, DDOT's policy is to construct reinforced concrete approach slabs to span the fill area.

The approach slab must be designed as a structural slab, with a minimum 15-inch thickness, supported at each end. The length can vary from a minimum of 20 feet to a maximum based on the intercept of a 1-on-1 line from the bottom of the abutment excavation to the bottom of the approach slab. This length is to be measured along the centerline of the roadway.

Integral abutments must use approach slabs designed with specific attention to the slabs' interface with the approach roadway barriers and curbs. See Integral and Semi-Integral Abutment design in **Chapter** 16 of this Manual and the **DDOT Standard Drawings** for additional information.

19.3.2. Reinforcement in Approach Slabs

See **DDOT Standard Drawings** for approach slab details.

19.4. Medians

Unless precluded by profile and geometric considerations, the median area between parallel bridges should be "decked over" when the width between curb lines is 30 feet or less. When the median width is greater than 30 feet, the Designer should provide cost estimates for the alternative of "decking over" vs. "open well design." Although decking over is usually preferred, in certain cases, such as where there may be a safety concern for pedestrians walking under wide bridges, where the path may be dark, other options should be considered. The decision to deck over or to have an open well design should be based on information acquired during the preliminary design phase of the project. The live load design requirement for the median area is HL-93.

19.5. Longitudinal Bridge Joints

Longitudinal joints in bridge decks are not permitted in the District.

Longitudinal construction joints must be provided where necessary for staged construction and for compatibility with the deck slab placing sequence on wide structures with many lanes, or where necessary to accommodate transverse expansion on wide structures (generally for superstructures wider than 88 feet).

19.6. Construction Joints

Construction joints, either transverse or longitudinal, are permitted only at locations shown on the plans. A construction joint must be used at the break between sections of placed concrete, such as those required by the deck-placing sequence. Shear keys are required for construction joints and must be detailed on the plans. Vertical joints in parapets and barriers must be in accordance with **Standard Drawings**.

19.7. Bridge Joints

Bridge designs must allow for movements due to temperature. Both steel and concrete structures expand and contract because of temperature changes. Refer to Thermal Forces, in the **AASHTO LRFD Bridge Design Specifications**. Use a moderate climate temperature range for the District area.

19.7.1. Fixed Joints and Expansion Joints

Joints are constructed in bridges to accommodate movement (rotation, expansion and contraction). All joints must be sealed to prevent leakage of water onto the bearings and substructure. Attaining a watertight bridge joint is a difficult objective over the life of a bridge. Efforts should be made to reduce the number of deck joints on the bridge.

Transverse joints at fixed bearings are designed to accommodate movements of the span due to rotation of the bearing caused by loading. Transverse joints at expansion bearings are designed to accommodate expansion and contraction movements of the span caused by temperature changes and loading. The types of joints used by DDOT are:

- Strip seals
- Compression seals
- Finger/teeth joints

Transverse deck joints on most new bridge decks should consist of glandular type strip seals. The use of bolt-down armor attached to structural steel, hooked bar anchors into concrete and strip seal-type joints is recommended on projects involving deck joint reconstruction. Finger/teeth-type deck joints are recommended for joint movements in excess of 4 inches. Where finger/teeth-type deck joints are used, stormwater must be either collected or prevented from encountering the structural steel. To protect the concrete slab, all deck joints must have steel armoring on the edges. This includes deck joints on bridges to be rehabilitated or reconstructed. Compression seals smaller than 2-1/2 inches are generally recommended only for fixed end joints. Compression seal expansion joints must be in accordance with **DDOT Standard Drawings.**

19.7.2. Strip Seal Expansion Joints

In selecting strip seals, the Designer must consider the relationships among total movement, minimum and maximum joint widths, and installation temperature. Strip seal expansion dams consist of a molded neoprene rubber gland locked in the cavities of two parallel steel rail sections. The steel rail material must conform to **AASHTO M270/M270 M Grade 36** or **AASHTO M270/M270 M Grade 50W**. The neoprene gland must be continuous over the full bridge width, including sidewalks, parapets and median barriers.

Strip seal expansion dams will be used when the following conditions exist:

- The length contributing to expansion is less than 65 feet and the skew is greater than 35 degrees

- The length contributing to expansion is greater than or equal to 65 feet and less than or equal to 250 feet, and the skew is greater than 25 degrees
- In the area outside of the 4-inch-wide sealer limit on skews less than or equal to 25 degrees

NOTE: Special consideration is required when the length contributing to expansion is greater than 250 feet.

When a transverse strip seal intersects with a longitudinal compression seal, the joint subjected to the larger movement must remain continuous, and the other seal must butt up against it. Various factory-molded intersections are available for longitudinal and transverse strip seals that intersect. It is recommended that the Designer contact the strip seal manufacturers so that the most effective details can be specified for these situations.

It is essential to the operation of the strip seal that no form of hot- or cold-applied joint filler be placed over the top of the rubber gland. All sidewalk joints must have steel cover plates. Joints in parapets and median barriers should preferably, if possible, be designed without steel cover plates. In these cases, the steel rail sections must be angled upward into the parapet or median barrier, and the concrete tapered to the edge of the rail as required.

When approved, steel cover plates may be used on highly skewed structures or for specific project requirements. The maximum allowable joint width measured normal to the steel rail sections is 4 inches, with 3 inches preferred. The minimum joint widths shown on the construction plans for the superstructure must be set at a temperature of 70 degrees Fahrenheit. Joint widths must also be set based on the project requirements and the minimum installation width of the seal normal to the steel rail sections. The contract drawings must include a table showing the setting widths at 10-degree increments.

The Designer should closely analyze and provide details and configurations in problematic areas such as sidewalks, parapets, curbs and gutters. The potential for joint leakage is usually greater in these areas, and they are often difficult to construct and maintain.

Joint details at sidewalks, parapets, median barriers, curb and gutters must be shown on the plans. The joint anchorage into the deck should be designed per **AASHTO LRFD**. Strip seal expansion joints must be in accordance with **Standard Drawings.**

19.8. Deck Drainage

The bridge deck drainage system includes all drains located on the bridge deck and the means used to convey the water collected. A structural analysis may be required on all bridge components modified to accommodate the bridge drains. The drain locations may need to be adjusted to avoid bridge rail posts. The station and offset of each deck drain must be specified in the plans. Drainage from structures must be directed away from bearings, pier caps, abutment caps or pedestrian walkways. Deck drainage must be in accordance with Federal Highway Administration (FHWA) **Hydraulic Engineering Circular No. 21, Design of Bridge Deck Drainage (HEC-21)**. Bridge deck scuppers must be in accordance with **DDOT Standard Drawings.** See **Chapter 28** for drainage design requirements and calculations.

19.8.1. Cross Slopes

The cross slope on a bridge deck must be a minimum of 1.0 percent. A 2.0 percent cross slope is preferred. Cross slopes should match the roadway on both sides of the bridge deck for a smooth transition.

19.8.2. Grades

Bridge decks require adequate grade for proper drainage. This will allow chlorides to drain off the bridge deck and prevent ponding and freezing of water. In addition, proper drainage prevents hydroplaning on decks with little surface texture. The Designer must provide a minimum grade of 0.5 percent on bridge decks. If a design waiver is granted so that the longitudinal grade is less than 0.5 percent, additional drains or special sloping of the gutters may be required.

Sag vertical curves are not allowed on bridge decks. Follow **FHWA HEC-21** Section 4.5 for drainage design at sag vertical curve locations. To have adequate longitudinal drainage near the high point of vertical curves, the grade must not be flatter than needed to meet sight distance requirements.

20 Bridge Railings

20.1. General

Bridge railings are longitudinal barriers on bridges and culverts installed to protect an errant vehicle from running off of the edge. Unlike roadside barriers, bridge railings are an integral part of the structure and designed to have virtually no deflection when struck by a vehicle.

The requirements for bridge railings should evolve based on actual performance of railings in service, as well as the change in highway vehicle fleet characteristics. As such, it is important to revisit the industry resources pertaining to the establishment of bridge railing strength and geometric requirements. The following standards must be used when determining the appropriate barrier for a given bridge:

1. American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications, Latest Edition
2. AASHTO Roadside Design Guide
3. National Cooperative Highway Research Program (NCHRP) Report 350
4. AASHTO Manual for Assessing Safety Hardware (MASH), Latest Edition

20.2. Railing Test Levels and Types

Designers must determine which of the six Test Levels in **AASHTO LRFD** Article 13.7.2 to use, based on the road classification, geometry and vehicle type. All bridge railings used on the National Highway System must be crash tested per **MASH** or **NCHRP 350**. A minimum Test Level 3 (TL-3) crash test rating must be used. When there is a conflict between this DDOT manual and the Federal Highway Administration (FHWA) or AASHTO requirements, the most stringent will govern. FHWA has listings of several previously tested railings meeting full-scale crash test criteria (crashworthy railings), as shown in Table 20-1.

Table 20-1 | Railing Test Levels

Railing Type	Test Level
Metal Tube Bridge Rail	TL-2, 3, 4, 5
Vertical Concrete Parapet (open or closed)	TL-2, 3, 4, 5
F-Shape Concrete Barrier (single slope)	TL-4, 5

Application of Previously Tested Systems. A crashworthy railing system may be used without further analysis or testing after the proper documentation has been reviewed and accepted by the DDOT Engineer. Changing the geometry or the slope of the traffic face of a railing system or adding components that may come in contact with a vehicle during a crash is not allowed. If railing modifications result in a change in the moment and/or axial force transmitted to the deck, the deck slab design must be revised so that all specification requirements for the forces from the modified railing are met.

New Systems. New railing systems may be used when approved by the Engineer, provided that acceptable performance is demonstrated through full-scale crash tests in accordance with the latest **AASHTO MASH** evaluation techniques. The crash test specimen for a railing system must be designed to resist the applied loads in accordance with **AASHTO LRFD**. The testing criteria for the TL must correspond to vehicle weights and speeds and angle of impact outlined in **AASHTO LRFD**.

20.3. Barriers, Railings and Curbs

- The height of traffic barriers or railings must be at least 27.0 inches for TL-2, 32.0 inches for TL-3 and TL-4, and 42 inches for TL-5.
- The minimum height for a concrete parapet with a vertical face is 27.0 inches, excluding the height of metal rails, if installed.
- The minimum height of pedestrian and bicycle railings is 3 feet 6 inches, including the pedestrian/bicycle handrail.
- Open ornamental concrete barriers along sidewalks may be justified for aesthetic reasons for restoration of historic bridges or bridges in historic areas when approved by the Engineer. If the open-face ornamental concrete barrier does not meet the TL requirements, the Designer may provide a traffic barrier meeting the TL requirements to separate the traffic lanes from the sidewalk, and then design the ornamental fencing along the outside edge of the deck for the required pedestrian load.
- All parapets and railings must be oriented vertical regardless of cross slope and superelevation.
- The District uses 9-inch-high curbs for bridges with sidewalks, which must be tapered at the approach slab to match the 7-inch-high curb on the approach roadway. All curbs and curb ramps must meet the latest Americans with Disabilities Act requirements; curbs may be reduced to less than 7 inches to meet these requirements. The Designer should coordinate these details with the roadway engineer.

20.4. Barriers on Bridges without Sidewalks and Median Barriers

When there are no pedestrian sidewalks on the bridge, the following types of barriers at the bridge fascia, or median, meet the vehicular traffic requirements. Additional factors such as highway classification and design speed must also be considered when choosing a proper barrier.

- Crashworthy, F-shape barrier or railing, minimum height 32 inches (TL- 4) is recommended for typical applications.
- Crashworthy, F-shape barrier or railing minimum height 42 inches (TL-5) is recommended for highway-bridge medians and flyover ramps, and may be justified for bridges carrying high volumes of truck traffic.
- Careful consideration should be given to placing median barriers on city streets/parkways or other roadways with partial control of access. Problems are created at each intersection or median crossover because the median barrier must be terminated at these points. The number of crossovers, accident history, alignment, sight distance, design speed, traffic volume and median width should be evaluated before installing median barriers on highways. Each location should be evaluated on a case-by-case basis, with the prevailing reason for its installation being to avert crossover accidents. Installation of median barriers must be coordinated with **Section 30.13** of this manual. When it is determined that a median barrier is appropriate, a single, double-face concrete median barrier may be used. A split concrete median barrier may be used where a longitudinal open joint exists on the bridge.

20.5. Barriers and Curbs on Bridges with Sidewalks

A pedestrian walkway may be separated from an adjacent vehicular roadway by a barrier, traffic railing, or combination railing (i.e., pedestrian railing mounted on a traffic barrier). Traffic railings, barriers and combination railings must satisfy crash testing requirements to confirm that they meet the requirements of a specified railing TL.

When sidewalks are provided on a bridge for pedestrian and/or bike traffic, the following requirements apply:

- **Traffic Speeds ≤ 35 mph.** A raised sidewalk with a 9-inch curb at the edge of roadway must be provided with a crash tested, combination barrier at the bridge fascia. The clear width of the sidewalk or shared-use path (face of barrier to face of curb) must be approved by DDOT. Under special conditions as determined by DDOT and depending on the design speed, traffic volume and type of vehicles, a crash tested, combination barrier may be provide on the sidewalk at the edge of the roadway, and a pedestrian/bicycle barrier at the bridge fascia. The fascia barrier need not be crash tested.

- **Traffic Speeds > 35 mph.** A crash tested, combination barrier must be provided on the sidewalk at the edge of the roadway, and a pedestrian/bicycle barrier must be placed at the bridge fascia. The fascia barrier need not be crash tested. The clear width of the sidewalk or shared-use path (face of barrier to face of barrier) must be approved by DDOT.
- **Local Streets, Low-Speed Traffic (≤ 25 mph).** A raised sidewalk with a 9-inch curb at the edge of the roadway must be provided with a crash tested, combination barrier at the bridge fascia. The clear width of the sidewalk or shared-use path (face of barrier to face of curb) must be approved by DDOT. Under special conditions as determined by DDOT, and depending on the design speed, traffic volume and type of vehicles, a 9-inch barrier curb may be provided on the sidewalk at the edge of the roadway, and a pedestrian/bicycle barrier at the bridge fascia. The fascia barrier does not need to be crash tested. The accident history, alignment, sight distance, design speed, traffic volume and sidewalk width should be evaluated. Each location should be evaluated on a case-by-case basis and approved by the Chief Engineer.

20.6. Guiderail to Barrier Connections

The Designer should coordinate all barrier transitions and connections with affected disciplines such as roadway and drainage. When possible, the Designer should propose details shown in **DDOT's Standard Drawings**.

20.7. Architectural Treatment of Bridge Barriers

Ornamental barriers may be justified for aesthetic reasons for restoration of historic bridges or for bridges in historic areas. Refer to **DDOT Standard Drawings,** Historic Bridge Rail. Existing historic barriers may remain and be protected by installing crashworthy steel railings in front, when approved by the Chief Engineer and depending on design parameters.

Installing aesthetically pleasing railings and parapets will also be considered in heavily traveled pedestrian areas. Stone or brick facing may be considered. The type of protective coating on barriers will be determined by DDOT.

If appropriate to the location of the project and the nature of the architectural treatment, the Designer must coordinate with the District of Columbia State Historic Preservation Office, as discussed in **Section 31.7**, and the U.S. Commission of Fine Arts.

20.8. Safety Fence

- Safety fences are provided on selected bridges to prevent the throwing of debris onto vehicles passing beneath the bridge. Safety fences will be provided on a case-by-case basis and approved by DDOT.
- The Designer must also consider the warrants of a fence or other protective barrier on the approaches to a bridge with tall abutments. The purpose of the fence/protective barrier in this case is to prevent pedestrians or bicyclists from overcoming the approach roadway barrier and falling down the abutment embankment slopes. This is particularly of concern adjacent to the abutment, where the difference in grade elevation can be substantial. Refer to AASHTO publication **A Guide for Protective Screening of Overpass Structures** for additional guidance.
- The standard height for a safety fence is 7 feet 6 inches, including the angled section at the top of parapets for sidewalks and pedestrian bridges. Refer to **DDOT Standard Drawings** for safety fence.
- When assessing whether safety fencing is warranted, consider whether the following conditions exist:

Highway carrying grade separation or high-level bridges with facility for pedestrian traffic.
High number of recorded incidents of vandalism from a structure.
Existing or potential for pedestrian traffic nearby:

- Schools, churches, etc.
- Built up areas
- Shopping areas, malls

Locations where existing railing or parapet conditions are substandard with regard to pedestrian safety.
On overpasses where property beneath the structure, such as buildings or power stations, is subject to damage.
For structures over railroads, the Designer must refer to the requirements of the impacted railroad for safety fence. Also, the Designer must determine any special protection requirements including ones related to the presence of high-voltage lines.
Other locations as deemed necessary by the Engineer.

- Chain-link fence will not be permitted on bridge structures.

20.9. Sidewalks and Trails

If the approach roadway has sidewalks, the bridge sidewalk width must be a minimum of 2 feet wider on each side of the bridge in cross-section than the approach, not including posts, railings or other fixtures. Bridge sidewalks may be justified even where there is no approach sidewalk. These will be evaluated on a case-by-case basis considering the need, cost and right-of-way. Minimum width for pedestrian-use-only sidewalks on bridges is 6 feet clear.

When a shared used path/trail approaches a vehicular bridge with a sidewalk, the bridge sidewalk must be at least the width of the shared used path/trail width plus 4 feet.

Standalone pedestrian/bicycle bridges must be at least 12 feet wide.

20.10. Joints in Parapets and Railing Pedestals

20.10.1. Parapets

- Provide a 1/2-inch deep groove in concrete parapets on both sides to perform as control/contraction joints.
- Spacing of grooves is to be approximately 8 feet. If light support is used, grooves must be located approximately 4 feet from the centerline of the light support.
- Use a groove and deflection joint in concrete parapets at the location of piers. Grooves must be formed on both sides of the parapets. The deflection joint must be located between the interior and exterior grooves and 1/4 inch wide. See Figure 20-1 for details.
- Spacing of deflection joints must not exceed three groove spaces.
- If there are open joints at abutments or piers, they must also be formed in the parapet.
- The location of fence posts must be coordinated with the parapet joints and detailed on the bridge plans.

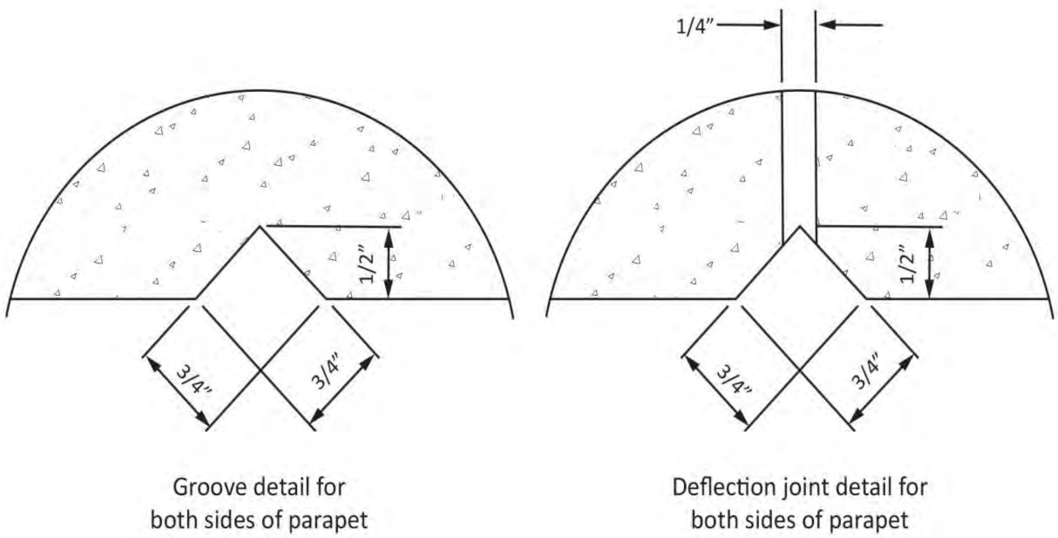

Figure 20-1 | Parapet Groove and Deflection Joint Details

20.10.2. Pedestals (1 Foot High or Less) under Metal Railings

- Provide a 1/2-inch-deep groove in the concrete pedestal on both sides to perform as control/contraction joints.
- The location of grooves must be coordinated with the rail posts. Grooves must be located the same distance from the centerline of the post, but the spacing must not exceed 8 feet.
- Use grooves on both sides of concrete pedestals at pier locations.
- If there are open joints at abutments or piers, they must also be formed in the pedestal.
- The location of rails and posts must be coordinated with the parapet joints and detailed on the bridge plans.

21 Bridge Bearings

21.1. Bearing Selection Evaluation

The design of bearings must be in accordance with the latest edition of American Association of State Highway and Transportation Officials **(AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications**, including all interims, except as modified herein.

- The bearing type selection must be based on achieving the most economical solution that will support all required movements. An initial evaluation will often reveal that elastomeric bearings or elastomeric bearing pads are the most economical solution and require the least maintenance.
- Economics must not be the sole category considered when selecting bearing types. Accommodating longitudinal, transverse and rotational movements must be evaluated, and skew must be considered in the bearing selection.
- Refer to **DDOT Standard Drawings** for additional information on bearings

Bearing devices are designed to transmit the loads from the superstructure to the substructure and to allow expansion, contraction, and rotation of the superstructure. The devices must be able to withstand forces from several directions simultaneously. The bearings must also accommodate movements of the structure that result from loads, temperature change, deflection and centrifugal force. The design should be such that the bearings are easy to maintain and require a minimum amount of maintenance. Consideration should also be given to the future need to jack girders to permit repair, lubrication, and maintenance of bearing devices.

Refer to **AASHTO LRFD Bridge Design Specifications** for guidance on choosing a bearing type. The types of bearings are discussed in this chapter.

21.1.1. Reinforced Elastomeric Bearings

Reinforced elastomeric bearings typically require the least maintenance, but are susceptible to deterioration from ozone and ultraviolet light. Reinforced elastomeric bearings are preferred to other bearing types in the District. Elastomeric bearings must be designed using AASHTO Method A. Refer to **AASHTO LRFD Bridge Design Specifications** for design procedures. See the **DDOT Standard Drawings** for typical elastomeric bearing details.

21.1.2. Neoprene Bearings

The use of unreinforced, single-material bearing pads is restricted to the fixed ends of voided slab and concrete box girder structures. The Designer must size neoprene bearings in accordance with the **AASHTO LRFD Bridge Design Specifications**.

21.1.3. Steel Sliding Plate for Expansion Bearings

Steel sliding plate type bearings may be a combination of steel plate, polished stainless steel sheet, and polytetrafluoroethylene (PTFE). These bearings are less vulnerable to ultraviolet and ozone deterioration than elastomeric bearings. Longitudinal movement is accommodated by either two polished surfaces sliding on each other or the stainless steel sliding on the PTFE surface. Rotation is provided by the curved surfaces sliding on each other or by deformation of the urethane pad on PTFE bearings. Refer to **AASHTO LRFD Bridge Design Specifications** for design of PTFE bearings.

21.1.4. Steel Plate for Fixed Bearings

Fixed bearings must be designed to permit only rotation movement. Rotation must be accommodated through sliding of the curved plates.

21.1.5. Rotational Bearings

Rotational bearings may be either fixed or expansion. Rotation is accommodated at the matched concave and convex surfaces of the bearing assemblages. Longitudinal movement for the expansion bearing is provided by sliding of the concave plate against the sole plate of the beam.

21.1.6. Pot Bearings

For pot bearings, a type of high-load multi-rotational bearing, the basic rotational bearing can be combined with a PTFE and stainless steel sheet to allow translation. The direction of translation can be controlled using guide bars. Pot bearings consist of a piston and pot arrangement similar to a hydraulic cylinder in which elastomer is used to accommodate the rotational deformation.

Refer to **AASHTO LRFD Bridge Design Specifications** for design of Pot Bearings.

21.2. Rocker Bearings

Rocker bearings will not be permitted on new bridges in the District. Rocker bearings may be replaced in-kind on existing bridges to retain consistency of bearing type at a support. Rocker bearing replacement or rehabilitation will be permitted with the approval of the Engineer.

21.3. Seismic Provisions

The provisions in Section 3 of the **AASHTO LRFD Bridge Design Specifications** must apply for the seismic design of bearings. According to AASHTO LRFD, the District is located in Seismic Performance Zone 1.

21.4. Anchor Bolts

For anchor bolt design and applicable seismic requirements, refer to **AASHTO LRFD Bridge Design Specifications**. See **Section 16.6.1.7**, Anchor Bolts in this manual, and refer to the **DDOT Standard Specifications for Highways and Structures** for further requirements.

22 Culverts

22.1. General

Culverts should be used where they are more economical than bridges. Pipe culverts and box culverts are the most common types in the District. Other types include reinforced concrete pipe culverts, corrugated metal pipe culverts and high-density polyethylene pipe culverts. Designers should use the alternative that best suits project needs. Pipe culverts are usually most economical, except when the site has insufficient space for them to operate effectively. Box culverts are likely to be economically viable in the following conditions:

1. The fill on the concrete box culvert is less than 30 feet and the concrete box culvert clear span is less than 23 feet
2. The fill on the concrete box culvert is less than 3 feet and the concrete box culvert clear span is less than 36 feet

Rigid frames are also acceptable. Further, designers are encouraged to consider a variety of culvert materials, including reinforced concrete, corrugated or spiral metal, and corrugated plastic. Culvert type and material must be discussed with the DDOT project team to confirm the Department's preference. Reinforced concrete culverts may be cast-in-place or precast.

22.2. Hydraulic Design Criteria

Applicable hydraulic design criteria can be found in **Chapter 28.** Additional requirements are listed below.

- Culverts 48 inches and larger in diameter should be provided with a headwall at the inlet to counter buoyant uplift forces
- All culverts with headwalls should be provided with cutoff walls at least 18 inches or deeper

To increase inlet performance and improve flow through the culvert, the bottom of the top slab and inner wall edges must be beveled at the entrance of the culvert as follows:

1. For single-cell box culverts, a 45-degree bevel of 1/2 inch per foot of culvert clear height must be provided for the top slab and bottom edge of the culvert entrance. A 45-degree bevel of 1/2 inch per foot of culvert clear width must be provided for both sidewalls and inside edges of the culvert entrance.

2. For twin-cell box culverts, in addition to the bevels specified above, the center wall must have a 45-degree bevel of 2-1/2 inches on both sides. This is based on a minimum 8-inch wall thickness. For every 1-inch increase in the center wall thickness, there must be a 1/2-inch increase of the bevel on both sides.

22.3. Culvert Selection

Rigid frames are concrete structures with three or more sides placed on precast or cast-in-place footings with or without a paved invert. Rigid-frame structures must be used to span streams and seasonal waterways where a natural streambed is preferred for environmental reasons. Rigid frames may be cast-in-place or precast. Using precast rigid frame sections can often expedite construction. There are three types of rigid frames: rectangular, trapezoidal and arch.

Rectangular and trapezoidal rigid frames are typically used for spans ranging from 12 to 25 feet. Concrete arches are typically used to accommodate long spans and low-rise site requirements. Typical concrete arch spans range from 30 to 50 feet.

For some projects, such as those where staging is required or when it is essential to restore normal vehicular or rail traffic quickly, the Special Provisions may require precast culvert construction. In such cases, the Designer should select opening sizes that are obtainable in standard precast concrete sections. Where possible, the Designer should propose the use of precast concrete culverts instead of cast-in-place concrete culverts.

22.3.1. Proprietary Culverts

During the development of the project, the Designer must coordinate with the DDOT Engineer to determine if proprietary designs will be permitted. Proprietary designs must only be used with the Engineer’s approval. If proprietary designs are permitted, then the Designer must develop a contract-specific Special Provision that outlines the generic design or performance criteria to ensure fair procurement. The Special Provision must specify the following requirements:

1. Geometric dimensions
2. Structural calculations
3. Minimum concrete strength
4. Minimum steel reinforcing
5. Performance requirements

This Special Provision must state that the construction Contractor is required to provide DDOT with a submittal, including calculations and lab test results, demonstrating that the Contractor intends to use an acceptable source.

The submittal should include documentation of long-term service to show durability. Typically, rigid frames support earth fills or hot-mix wearing surfaces, depending on the location and grade profile with respect to the top of the frame. A 2-inch asphalt wearing surface is required for precast rigid frames, but not for cast-in-place rigid frames. When determining wall heights for rigid frame structures, the following must be considered:

1. Size of the opening needed to meet the hydraulic requirements
2. The economics of a higher frame versus the cost of fill
3. Transportation costs of prefabricated elements
4. Transportability of the elements
5. Clearance for inspection, especially for flowing streams
6. General constructability

22.4. End Treatments

This section addresses culvert integrity as well as protection of drivers in errant vehicles. Soil stability must be evaluated in conjunction with depth of headwater to tailwater to determine necessary inlet and outlet protection. All calculations must be organized and available to DDOT upon request. Refer to **Chapter 28** for applicable stormwater requirements.

Acceptable end treatments include beveled headwalls, headwalls with wingwalls, end sections, riprap armoring, level spreaders and stilling basins. Culvert ends must be evaluated for scour and erosion potential, and must be designed to protect the inlet and outlet during the design storm. Culverts susceptible to frequent flash flooding may need more robust armoring.

Riprap is the most common outfall erosion control measure used in the District; for riprap protection requirements see **Section 28.3.1.**

In all cases, user safety must be paramount. Culvert end treatments must be located outside of the clear zone or protected with guiderail to prevent blunt-edge exposure to errant vehicles. Culvert ends must be aligned and embedded with the embankment slope. This reduces the risk to errant vehicles, and also maintains channel hydraulics by preventing stagnant zones from developing behind headwalls that extend into channels.

22.5. Structural Design

Structural design for all culverts must be in accordance with the American Association of State Highway and Transportation Officials **(AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications** (including current interims), as well as the following additional provisions:

- Concrete for cast-in-place concrete elements must follow the provisions of **Chapter 18**.
- Concrete for precast concrete elements must follow the provisions of **Chapter 18**.
- The minimum cover over reinforcing steel must be 2 inches for all types of concrete culverts. For additional cover requirements see **Section 13.2.2.**
- Reinforcing steel must follow the provisions of **Section 13.2.2** and conform to **AASHTO M31 Grade 60**.
- Welded deformed steel wire fabric, conforming to **AASHTO M221** and having a diameter of at least 3/8 inch, may be substituted for deformed bars.

When the earth fill above the top of the culvert is less than 2 feet, or the top slab is used as a roadway riding surface, dead load design capacity must include 25 pounds per square foot to allow future application of a 2-inch-thick wearing surface. The top and bottom reinforcement mats and the ties in the top slab must be corrosion-resistant.

For box culverts, the joint between the invert slab and the sidewalls must be detailed as a construction joint. In addition, when the clear distance between the top slab and the invert slab is 8 feet or less, a construction joint between the sidewalls and the top slab is optional. If greater than 8 feet, a construction joint between the sidewalls and the top slab is needed.

Wingwall footings must be designed without a construction or contraction joint at their junction with the invert slab so that the footing concrete is placed monolithically with the invert slab.

22.5.1. Precast Units

In addition to the criteria detailed in **Section 22.5**, precast units must also be designed to comply with the following:

1. The precast, reinforced concrete culvert units must be manufactured in steel forms and steam cured in conformance with the **DDOT Standard Specifications**.

2. The materials used for precast concrete box culverts must conform to the latest **DDOT Standard Specifications**.
3. A waterstop must be included to prevent water from entering vertical joints between the ends of precast culvert sections and any cast-in-place appurtenances such as wingwalls, cutoff walls, aprons and cast-in-place culvert end sections. A flexible, watertight rubber gasket must be detailed at the joint between the precast units. Gaskets must be continuous along the length of the joints. Details of the transverse joint between the culvert sections must be provided on the plans.
4. The use of precast end culvert sections, including headwalls, will be reviewed and approved on a culvert-by-culvert basis.
5. Precast end sections must not be used when the skew angle requirements result in a situation where the short wall of a precast end section is less than 36 inches long. Adequate provisions must be made for cast-in-place appurtenances such as wingwalls, aprons and cutoff walls.
6. Two rows of threaded inserts or bar extensions (longitudinal ties) must be provided in the precast end culvert section to facilitate the attachment of the culvert end section to the precast wingwalls. A detail of this connection must be illustrated on the plans. Furnish the same detail for the headwall attachment, if applicable.
7. If precast concrete units are used in parallel for culverts with more than one cell, the Designer must include a Special Provisions section specifying fill material between precast concrete units.
8. Placement of precast units:
    a) The precast units must be pulled against the prior installed section such that an adequate seal is obtained between the two connecting units and the rubber gasket.
    b) Prior to backfilling, a 24-inch-wide strip of filter fabric must be placed over the top and side transverse joints.
    c) To provide continuity and shear transfer between the precast box sections, longitudinal tie rods or prestressing strands must be designed and detailed on the plans.
    d) Specify a minimum of four longitudinal ties, one in each corner of the precast section.
    e) Longitudinal ties that are used to join precast units must be 3/4-inch-diameter, high-tensile strength steel bars conforming to **AASHTO M275** or 1/2-inch, 7-wire Grade 270 strands conforming to **AASHTO M203**.
    f) The anchorages and end fittings for the 1/2-inch, 7-wire strand and the corrosion protection method must be detailed on the plans.

g) All hardware associated with the end anchorage systems must be galvanized. After tensioning has been completed, the exposed parts of the end fittings must be coated with two coats of bituminous paint.

For precast reinforced concrete box sections:

1. The top slab of precast reinforced concrete box sections must not be used as a riding surface. A minimum 2-inch asphalt wearing surface, meeting **Section 27.4.2** requirements, must be used above the top slab.
2. The wall thickness for precast culverts must be a minimum of 8 inches. The top and bottom slab thickness must be a minimum of 10 inches.
3. A coarse aggregate layer must be placed under the precast reinforced concrete box culvert sections. The depth of the coarse aggregate layer must be a minimum of 24 inches. It must extend 12 inches on each side of precast reinforced concrete box culvert section.

22.5.2. Rigid Frames

For rigid frames, a haunch measuring at least 6 inches by 6 inches is required where the wall and slab join. Larger haunches, up to a maximum of 12 inches by 12 inches, may be permitted, but must be reinforced. Depending on site conditions, rigid frames may be placed on:

1. Cast-in-place spread footings
2. Pile-supported cast-in-place footings

Precast frames must have holes to allow placement of tie rods to hold adjacent rigid frame sections together. Tie rods must not be prestressed. Shear keys must transfer shear between adjacent sections. The keys must be sealed by filling the key with high-strength, non-shrink grout. Rigid frames must be damp proofed in accordance with the **DDOT Standard Specifications for Highways and Structures** before backfilling.

The minimum thickness of concrete for rigid-frame components is 8 inches.

22.6. Culvert Repairs

For retrofitting existing culverts, approved methods of rehabilitation are as follows:

1. Thread a smaller culvert or liner plate through the original culvert and grout the voids between the two culverts.

2. Use commercial products for relining the culvert with epoxy-coated fabric materials.

3. Repair spalls and cracks following the provisions of **Chapter 13**.

Additional retrofitting methods may be permitted upon approval by the DDOT Project Manager.

23 Bridge-Mounted Signs

23.1. General

Signs and sign supports may be placed on the bridge for viewing by drivers traveling across the bridge, or may be placed on the exterior (fascia beam) for traffic driving under the bridge (bridge overpasses). Depending on the location, coordination with the U.S. Commission of Fine Arts may be warranted.

The sign structures must be designed in accordance with the American Association of State Highway and Transportation Officials **(AASHTO) Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals**, latest edition including interims.

The bridge members affected by the sign structure must be designed in accordance with the **AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications**, latest edition including interims.

23.2. Location

The location of bridge-mounted sign structures must be approved by the Chief Engineer. The proposed bridge-mounted sign(s) must be shown on the preliminary bridge plans. If information on the signs is not available when the preliminary drawings are submitted, revised plans must be submitted for approval at a later date.

Sign placement must consider the presence of sidewalks and trails, and ensure that there is adequate vertical distance for users of sidewalks and trails (at least the minimum vertical clearance per clearance envelope of the sidewalk or trail being considered) and must meet Americans with Disabilities Act (ADA) requirements.

When bridge-mounted signs are to be installed on grade separation structures, close liaison between the Infrastructure Project Management Administration and the Transportation Operations Administration is required.

23.3. Signs Mounted Above Bridges

Overhead signs must be located as near as possible to the most advantageous position for traffic operation, while balancing the need for adequate structural support and detailing. The Designer must attempt to avoid locating signs and sign structures on bridges.

Preferable locations from a structural standpoint are usually near an abutment, bent cap, or other support. This will reduce the effect of loads on the bridge superstructure as well as vibrations.

For new bridges, the designer must consider locating signs on an extension of the pier cap rather than within the bridge span. When sign structures are located within a bridge span, the structural posts must be supported on deck "bump-outs". The deck and framing system must be designed and checked for the associated loading by the structural engineer.

23.4. Signs Mounted on Bridge Fascia

Support structures must be positioned on the lower limit of the maintenance walkway, and lighting must be a minimum of 15 inches above the underside of the fascia beam.

Where the sign will not extend above the top of parapet or railing, the installation of a sign on an overpass is generally not aesthetically objectionable.

Typically, signs should be placed parallel with the structure for skews up to 10 degrees. At greater angles of skew, support structures must be detailed to position the sign at approximately right angles to the roadway. When the roadway is on a tangent or horizontal curve, or there is a horizontal curve within the normal sight distance, the Transportation Operations Administration will determine the appropriate skew angle for the traffic based on the traffic speed and horizontal curve angle.

Support structures must be detailed to position the sign and maintenance walkway in a horizontal position regardless of the grade of the bridge beams.

23.5. Signs Mounted on Existing Bridges

The location of the proposed signs on existing bridges must be developed and submitted for approval by the Engineer. Design calculations demonstrating that the additional loads on the existing bridge members are acceptable must also be submitted.

To address the potential for detrimental effects on the fascia beams, installation of additional cross-frames or diaphragms between the fascia beam and at least the first interior beam may be required.

23.6. Structural Details for Signs on Bridges

It is preferred that supports for bridge-mounted signs to be steel tubes or structural steel members. Aluminum or other metals may be permitted. However, the Designer must consider the interface between dissimilar metals and potential galvanic action. Depending on location, coordination with the U.S. Commission of Fine Arts may be warranted.

Welding sign supports to steel members is not permitted. All connections must be bolted.

Drilling for inserts into prestressed concrete beams is not permitted.

Design and details of support structures must provide space for painting and inspection of stringers.

Maintenance walkways for bridge-mounted signs are generally not required.

24 Sheet Piling and Cofferdams

24.1. Introduction

This chapter provides guidelines for the design of sheet piling and cofferdams in the District of Columbia. These guidelines describe minimum design requirements; clarify the parties responsible for the design; and discuss geotechnical, structural and construction aspects. Additional information and applicable specifications on cofferdams and sheet piling can be found in the **DDOT Standard Specifications for Highways and Structures**. The guidelines presented herein do not supersede the contract documents and DDOT Standard Specifications for Highways and Structures.

Applicable permits for all work within bodies of water should be obtained by the Contractor before beginning the work. Water works should comply with U.S. Coast Guard policies and regulations.

24.1.1. References and Guidelines

Listed below are references used in the development of this chapter, and that are to be used in cofferdam and sheet piling design:

- DDOT Standard Specifications for Highways and Structures (Current Edition)
- Department of the Army U.S. Army Corps of Engineers, Washington, DC (1989), Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures, Engineering Manual (EM) 1110-2-2503
- Department of the Army U.S. Army Corps of Engineers, Washington, DC (1994), Design of Sheet Pile Walls, EM 1110-2-2504

24.2. Steel Sheeting

24.2.1. Temporary Sheeting

Temporary sheeting will be used where protection of property (embankment control), traffic (stage construction), utilities, construction safety code requirements, etc. is a construction concern. A structure with a service life in excess of 18 months qualifies as permanent and should be designed accordingly.

The Contractor is responsible for the design and detail of the temporary sheeting structure. The contractor's designer should review all existing site information including subsurface soil reports so that any adverse subsurface condition can be identified early in the design, including any difficulty that might be encountered during driving or removal of sheeting. The complete set of design calculations and drawings should be prepared as per contract documents and submitted for DDOT review and approval.

24.2.2. Permanent Sheeting

Permanent sheeting is intended to remain in place to function as part of the structure. The complete set of design calculations and drawings should be submitted for DDOT review and approval.

24.2.3. Subsurface Investigation

Soil test boring information is required for the centerline of the sheet pile structure in compliance with the requirements for retaining wall structures described in **Chapter 26** of this manual.

The subsurface exploration studies will indicate if site conditions impose driving difficulties, including the presence of boulders, compact materials, obstructions, artesian water pressures, and others. The subsurface investigation will determine soil permeability and seepage characteristics, where applicable.

24.2.3.1. Soil Design Parameters

The key soil parameters for the design of the steel sheeting should be based on the subsurface conditions. Sheet pile design documents should present, at minimum:

- Unit weight, for all soil strata
- Friction angle, for all soil strata
- Cohesion, for all soil strata
- Wall friction angle, for all soil strata
- Groundwater elevation

24.2.4. Sheet Piling Design Considerations

24.2.4.1. Earth Pressures and Loading

Lateral earth pressure distributions on sheet piling should be determined according to acceptable procedures. Wall movements should be enough to guarantee that passive earth pressures will be fully mobilized at the embedded length and that active conditions are achieved at the retained portion of the wall to reflect the earth pressure loading conditions adopted in the design. In addition to earth pressures, surcharge loads due to construction equipment, storage of construction materials, traffic loading, and any unbalanced hydrostatic pressure should be considered in the design of both temporary and permanent sheet piling. If existing footings are located adjacent to proposed sheet piling, the stress below the footing should be considered as additional surcharge load. Designs should clearly show assumed groundwater elevations for the design, and all assumed surcharge loads and their locations.

24.2.4.2. Anchored Sheet Pile Walls

Cantilever sheet piling relying only on the soil passive pressure at the embedded portion for stability should not exceed 15 feet in height, measured from the dredge line to the existing ground elevation. Sheeting exceeding 15 feet in height should include anchors having bond lengths penetrating at least 5 feet or one-fifth of the height of the wall, whichever is more, beyond the potential failure surface. The Designer should determine the earth pressure distribution in anchored sheet piling, taking into consideration the imposed displacements due to anchor installation, as well as anchor pullout capacity and anchor structural resistance.

24.2.4.3. Minimum Embedment

If penetrating sandy soils, the Designer has two options for determining the minimum embedment depth of cantilever sheet piling: (1) by applying a factor of safety for passive pressure; or (2) by increasing the calculated embedment by 30 percent. The minimum required factor of safety when considering passive pressures is 1.3 for temporary sheeting and 1.5 for permanent sheeting.

If penetrating clayey soils, earth pressure distribution at embedded sections is a function of soil undrained shear strength. In this case, a 50 percent increase in the calculated embedment is required (i.e., factor of safety equivalent to 1.5).

24.2.4.4. Structural Design and Limiting Driving Stresses

Steel sheet piling should be designed to resist the maximum bending moment and shear resultant from horizontal earth pressures, surcharge loads, water pressures and seismic loading. Determine the maximum stresses acting on the sheet piling based on the combined effect of bending and axial loads. A minimum section modulus of the sheet piling should be calculated based on the maximum bending moment and allowable bending stresses appropriate for the material. A buckling check of the sheet piling should be performed.

It is acceptable to design anchored sheet piling using a moment reduction because of the flexibility of sheet piling and the resulting stress redistribution. Moment reductions should not exceed 50 percent, i.e., the design moment ≥ 50 percent of the maximum theoretical moment.

Drivability analyses of sheet piling should be performed in accordance with procedures of **DDOT Standard Specifications for Highways and Structures**, except for the maximum allowable driving stresses, which are subjected to limits of the U.S. Army Corps of Engineers Engineering Manual **EM 1110-2-2504.** Steel sheet piling tip reinforcement is required if piling is to be driven into weathered rock or similarly hard materials. The subsurface exploration studies will indicate if site conditions impose driving difficulties due to the presence of boulders, compact materials, obstructions, artesian water pressures and others.

24.2.4.5. Stability Analysis

The following failure modes should be addressed, at a minimum:

- Rotational failure due to inadequate penetration
- Flexural failure of sheet piling
- Deep-seated failure
- Anchorage failure

The minimum factor of safety required against deep-seated failure is 1.3 for temporary structures and 1.5 for permanent structures. Bottom stability (piping and heave) and overall (global) stability should be evaluated for all stages of construction.

24.2.4.6. Material and Durability Aspects

Material for steel sheet piling should conform to American Association of State Highway and Transportation Officials **(AASHTO) M202** or **AASHTO M270**, Grade 50. Sheet piling that will be used in wet environments should conform to **AASHTO M270**, Grade 50. For such instances, it should be coated with a 406-micrometer application of coal tar epoxy per Society for Protective Coatings Paint Specification No. 16. The coating layer should cover the area in contact with fill materials and extend a minimum of 2 additional feet below and above fill limits. For sheet piling exposed to water, it is critical that the coating cover the splash zone and extend a minimum of 5 feet below the point where the sheeting remains submerged per current U.S. Army Corps of Engineers Engineering Manual **EM 1110-2-3400**.

In addition to coating, sacrificial steel thickness should be estimated in the design of permanent steel sheet piling based on an assessment of the corrosion potential of in-situ soils. The design should include sacrificial steel thickness, based on the expected loss of thickness of steel during the life expectancy of the structure. Steel sections shown in the contract plans and documents should include the required additional sacrificial steel thickness.

24.2.4.7. Deflection Criteria

Design of maximum wall deflections should take into consideration the serviceability of existing and proposed structures located within the zone of influence.

24.2.4.8. Scour

Scour of foundation soils along rivers and streams should be evaluated during design according to the provisions of the **AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Manual**. Accordingly, a minimum of 2 feet of wall embedment below anticipated scour elevations is required for all structures. Where scour problems are anticipated, adequate protective measures should be incorporated into the design.

24.2.4.9. Seepage Analysis

Where required, seepage should be controlled by installing a drainage medium behind the facing, with outlets at or near the base of the wall. Drainage panels should be able to maintain their drainage characteristics under the design earth pressures and surcharge loadings, and should extend from the base of the wall to a level at least 1 foot below the top of the wall.

24.2.5. Requirements for Submission Documents

A stamped set of drawings showing a complete design of the steel sheet piling with supporting calculations should be submitted for review and approval by a DDOT engineer prior to beginning construction. All drawings should comply with the current **DDOT Standard Specifications for Highways and Structures** and present the following:

- Plan location of the sheet piling placement
- Typical sections showing:
    - Sheeting top and toe elevations
    - Elevation of the bottom of the excavation
    - Minimum embedment below the bottom of the excavation
    - Cut-off elevation, if applicable
    - Location of bracing and associated supporting structures, if required
- Minimum sheet piling section modulus and moment of inertia
- Minimum section modulus for wales and sizes of bracing, if applicable
- Soil design parameters
- Profile views and plan views with cross sections
- Construction sequence
- Loading conditions considered in the design, including expected surcharge loads during construction
- Bracing calculations, if applicable

- Structural calculations
- Connection details
- Assumptions and reference materials that support sheet piling design
- General notes and construction specifications

24.2.6. Sheeting Construction Considerations

24.2.6.1. Construction Requirements

The use of previously used material is not acceptable for the construction of permanent sheeting. Sheeting should be constructed and maintained in accordance with the working drawings approved by a DDOT engineer. Subsequent to approval, any changes to the design proposed by the Contractor should be resubmitted for re-approval. The need to construct fender systems for waterfront sheet piling structures should be evaluated as to whether the structures need protection against the impact of moving vessels.

All construction stages should be documented, and any changes made during construction should be incorporated in the as-built drawings. Sheet piling structures should be inspected periodically to ensure structural integrity and to identify maintenance needs. Methods of inspection usually include visual inspection, magnetic particle inspection, ultrasonic inspection, radiography, and in some cases non-destructive testing. Typically, sheet piling structures are visually inspected, and accuracy therefore relies heavily on the inspector's experience and knowledge.

24.2.6.2. Geotechnical Instrumentation

Sheet piling movement monitoring by means of structure movement monitoring points, piezometers, inclinometers, strain gauges, or a combination thereof should be selected, as appropriate, for the structure type and safety requirements.

24.3. Cofferdams

This section provides guidelines for the design of cofferdam structures, which for the purposes of this discussion, are defined as water-retaining structures including gravity cofferdams (i.e., cellular cofferdams) that rely on the weight of the cell filling for stability.

The Designer should clearly identify at the preliminary submission when a steel sheet piling cofferdam system that is to remain in place is required. Any dewatering and bracing that will be needed to withstand external forces that will be sustained during construction of a project's substructure unit(s) should be evaluated to make this determination.

A complete design of the steel sheet piling cofferdam system should be included in the contract plans. This design should be created in compliance with the aforementioned design guidelines on sheet piling and the additional requirements that follow. Shop drawings for both temporary and permanent systems should be prepared by the Contractor to include further construction details and should be submitted for approval by a DDOT engineer. When applicable, a stream diversion plan should be included as part of the submission documents.

The use of proprietary cofferdam systems or alternate structures is subject to approval by DDOT. The use of industry-accepted software for the design of cofferdams is allowed.

24.3.1. Planning and Layout

The most economic cofferdam layout will depend on hydraulic and hydrologic study results, as well as subsurface conditions. These studies will also indicate the groundwater elevation to be adopted in the design of cofferdam systems. Design documents should clearly state adopted groundwater elevations and, if applicable, cofferdam design should include protection against overtopping based on the nature of the structure, likelihood of an overtopping event, and cost analysis.

Interior dimensions of cofferdams should provide enough clearance for the construction, inspection and removal of required construction forms, and also enough room to allow pumping outside the forms, if applicable. For cellular cofferdams, it is preferable to adopt a cell geometry that satisfies all design requirements and to use a similar geometry for all cofferdams cells.

24.3.1.1. Cell Fill Considerations

Although cellular cofferdams are not completely impervious structures, both the select fill material and the design and construction of water-tight sheeting and inter-cell connections should have sufficient resistance to water flow to be controlled by means of dewatering. Cofferdam cell fill should constitute clean, free-draining, coarse-grained materials with less than 10 percent material passing the No. 200 sieve.

24.3.1.2. Dewatering System

The Contractor is responsible for designing cofferdam dewatering systems using soil design parameters provided in the geotechnical report and the contract documents. If the flow of water cannot be controlled, a cofferdam system that utilizes a concrete seal should be provided. The thickness of the concrete seal should resist the uplift pressures resultant from the maximum expected differential water head in the structure. Concrete seal installation is subject to the guidelines in the **DDOT Standard Specifications for Highways and Structures** on depositing concrete underwater.

24.3.2. Subsurface Considerations

When planning the subsurface exploration for the construction of cofferdam structures, the Designer should identify soil stratigraphy, scour potential, groundwater levels and soil permeability parameters.

24.3.2.1. Soil Design Parameters

A minimum of one soil test boring per structure and additional test borings every 150 linear feet located along the centerline of the structure is required. Soil test borings should extend to a depth where stress increase due to estimated cofferdam load is less than 10 percent of the existing effective overburden stress at that depth, or twice the cofferdam height, whichever is more. If rock is encountered at grades above the proposed foundation elevation, it should be cored to a depth of at least 10 feet. Cone penetration and dilatometer testing may be used to obtain compressibility and strength parameters of foundation soils.

In addition to soil strength parameters, knowledge of the seepage characteristics of the foundation soil is essential for the effective design of cofferdams. Foundations under seepage are of concern mainly when the bottom of the cofferdam is founded on coarse-grained soils and, to a lesser extent, silty materials. Seepage forces obtained from flow net analysis should be assessed, and if necessary, installation of toe filters, berms or pressure relief systems should be considered.

24.3.2.2. Scour

Scour of foundation soils along rivers and streams should be evaluated. A minimum of 2 feet of wall embedment below anticipated scour elevations is required for all structures. Where scour problems are anticipated, adequate protective measures should be incorporated into the design. Acceptable methods of scour mitigation include installation of riprap and construction of deflectors at the outer corners of cofferdams.

24.3.2.3. Soil Permeability

It is acceptable to obtain soil permeability parameters by correlation with soil grain size distribution. However, available correlation tables provide conservative values and should be used with caution. If considered critical for design and justified economically, permeability tests should be performed.

24.3.3. Analysis and Design

24.3.3.1. Loading Conditions

Cofferdams will experience several loading conditions during the various construction stages and operational life of the structure. Various critical loading and saturated conditions during construction and while in service should be evaluated.

Surcharge loads due to construction equipment, storage of construction materials, traffic loading, and any unbalanced hydrostatic pressure should be considered in the design. Other surcharge loads include spoils, snow and lateral forces due to currents/wave action. Extreme loading events include vessel impact. If a possibility of large impact exists, cofferdam cells should be filled with tremie concrete to prevent loss of the cell fill.

24.3.3.2. Required Factors of Safety

Cofferdam design involves the interaction of the structure, soil and water. Cell diameter and fill properties should be dimensioned to maintain stability for all failure modes that could occur during and after construction. External stability of the cell should preclude sliding, overturning and deep-seated sliding. Internal stability should prevent pullout, interlock tension and vertical and horizontal shear. Minimum required factors of safety are based on information provided in the U.S. Army Corps of Engineers Engineering and Design Manual entitled **Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures**, as shown in Table 24-1.

Coefficients of safety against heave in cohesive soils and piping in cohesionless soils are calculated based on seepage or flow net analysis, performed considering the lowest water level attained after dewatering. Flow net analysis provides the maximum exit gradient along the perimeter of cofferdam walls, and should be compared to the critical hydraulic gradient. Preferable seepage mitigation procedures are as follows:

- Extend sheet piling to deeper levels
- Install a berm at the downstream surface
- Install a pressure relief system such as a well point system

Table 24-1 | Minimum Required Factors of Safety

Failure Mode	Loading Condition		
	Normal	Temporary	Seismic
Sliding	1.5	1.5	1.3
Overturning (gravity block)	3.0	2.5	2
Rotation (Hansen)	1.5	1.25	1.1
Deep-seated sliding	1.5	1.5	1.3
Bearing capacity in sand	2	2	1.3
Bearing capacity in clay	3	3	1.5
Interlock tension	2	1.5	1.3
Vertical shear resistance (Terzaghi)	1.5	1.25	1.1
Horizontal shear resistance (Cummings)	1.5	1.25	1.1
Vertical shear resistance (Schroeder-Maitland)	1.5	1.25	1.1
Pullout of outboard sheets	1.5	1.25	1.1
Penetration of inboard sheets	1.5	1.25	1.1
Bottom heave in clay	1.5	1.5	N/A
Piping in sand	1.5	1.5	N/A

Note: N/A = not applicable

24.3.4. Required Submittals

Prior to beginning the work, a complete set of plans of the cofferdam with supporting calculations should be signed and sealed by the Professional Engineer and submitted to DDOT for review and approval. Working drawings should comply with the specifications of the **DDOT Standard Specifications for Highways and Structures** and include the following:

- Plan location of the cofferdam structure
- Typical sections showing
    - Sheeting top and toe elevations
    - Elevation of the bottom of the excavation
    - Minimum embedment below the bottom of the excavation

- Location of bracing and associated supporting structures, if required

- Minimum sheet piling section modulus and moment of inertia
- Minimum section modulus for wales and sizes of bracing, if applicable
- Soil design parameters
- Detail of cell fill properties
- Profile views and plan views with cross sections
- Construction sequence
- Details of dewatering system, with assumed soil permeability parameters
- Loading conditions considered in the design, including expected surcharge loads during construction
- Bracing calculations, if applicable
- Structural calculations
- Connection details
- Assumptions and reference materials that support cofferdam design
- General notes and construction specifications
- Other requirements as per special provisions of the contract

24.3.5. Construction Considerations

Inspection of the cofferdam construction is required at all times. The field inspector should identify changes in subsurface conditions and communicate promptly so that any observable changes can be evaluated and, if necessary, readily incorporated into the design. The stages of the cofferdam construction should be documented and submitted by the Contractor as "as-built" drawings.

Construction practices are considered to cause most cofferdams performance issues and even failures. It is essential that the interlocking between sheet piles be done correctly to prevent loss of the fill, which could result in instability of the structure. Driving sheet piling through dense overburden soils or boulders will compromise the quality of the interlocking. Diver inspection of the interlocks after filling the cells is required.

Cofferdam structures should be monitored regularly during and after construction to ensure structural integrity and to identify maintenance needs. Methods of inspection usually include visual inspection, magnetic particle inspection, ultrasonic inspection, radiography, and in some cases non-destructive testing.

24.3.5.1. Geotechnical Instrumentation

A geotechnical and structural instrumentation program should be developed considering the structure type and safety requirements. Instrumentation may include structure movement monitoring points, piezometers, inclinometers, strain gauges, vibration meters, crack gauges, etc.

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26 Geotechnical Investigation

Geotechnical investigations are performed to gather detailed and accurate information about subsurface conditions throughout a project site so that engineering design can be technically sound and construction can be cost-effective. A subsurface investigation is typically required for DDOT transportation projects.

Geotechnical investigations involve subsurface field exploration/investigation, laboratory testing, geotechnical analysis, and preparation of a preliminary and/or final geotechnical engineering report (GER). This chapter contains guidelines for the planning, execution and reporting of geotechnical investigations to be conducted in the District of Columbia.

The scope of the subsurface investigation will depend on the project phase. If required by the DDOT Engineer, a preliminary soil survey report (PSSR) should be prepared to guide the subsurface exploration plan and preparation of GERs.

26.1. References

Listed below are references used in the development of this chapter, and that are to be used as the basis upon which geotechnical investigations are performed:

- American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specifications (Current Edition) AASHTO Standard Specifications for Transportation Materials and Methods of Sampling and Testing (Current Edition)
- American Society for Testing Materials. Annual Book of ASTM Standards (Current Edition)
- Department of Defense, Department of the Army, Army Corps of Engineers, Washington, DC (2001), Laboratory Soil Testing, EM 1110-2-1906.
- DDOT Green Infrastructure Standard (Current Edition)
- DDOT Standard Specifications for Highways and Structures (Current Edition)
- DDOT D.C. Temporary Traffic Control Manual Guidelines and Standards (Current Edition)
- District Department of Energy and the Environment (DOEE) Stormwater Management Guidebook (Current Edition)
- Federal Highway Administration (FHWA), U.S. Department of Transportation, Office of Bridge Technology Geotechnical Engineering Circular No. 5 (Publication No. FHWA NHI-01-031), Washington, DC, National Highway Institute (May 2002)

- FHWA, U.S. Department of Transportation Subsurface Investigations – Geotechnical Site Characterization (Publication No. FHWA-IF-02-034), Washington, DC, National Highway Institute (May 2002)

26.2. Geotechnical Study Submittals

All geotechnical reports prepared for DDOT projects should present accurate and relevant data concisely and professionally, and should be signed and sealed by a Professional Engineer registered in the District of Columbia. Depending on the size and nature of the project, a PSSR, a preliminary geotechnical engineering report (PGER) and a final geotechnical engineering report (FGER) may be required. The detailed scope of geotechnical reports should be approved by the DDOT Engineer.

26.2.1. Preliminary Soil Survey Report

When required by DDOT, a PSSR will be prepared. A PSSR consists of a desktop study that includes a literature review of existing site information and a summary of a site reconnaissance. PSSRs are normally prepared during early site planning, when roadway alignments and other construction details are preliminary. PSSRs do not usually include a subsurface investigation, although soil test borings may be performed as a part of a PSSR when approved by DDOT. A PSSR for DDOT projects should contain the following:

- Project description
- Review of existing test boring information for the proposed site and its vicinity, if available
- Review of existing project-related data sources (e.g., original plans and as-built drawings)
- Current and historical aerial photographs of the project site
- An environmental conditions assessment. Information on site uses and any hazardous materials, contamination or other adverse conditions should be documented. All available and pertinent files, records and aerial photographs, including site inspections and interviews conducted, should be reported with sources cited.
- Assessment of existing site conditions, with detailed information on existing structures, including pavement conditions, embankment and cut slope heights, slopes and cover types, site drainage conditions, presence of runoff and signs of erosion
- Identification of possible restrictions for subsurface investigations (e.g., existing utilities, dense vegetation, unusual conditions)
- Literature review of the geologic setting and soils at the project site and its vicinity, including geologic units and features, geologic hazard maps, mapped soil units and properties, expected

groundwater levels and seasonal variations, expected depths to bedrock, karst features if applicable, and wetlands and flood data

- Preliminary design recommendations, if required

The PSSR should identify any site-specific characteristics that could prevent or adversely affect the design or construction of the proposed project. The findings of the literature review and backup documentation of information collected for this report should be presented in the PSSR together with a site vicinity map and current site pictures.

26.2.2. Preliminary Geotechnical Engineering Report

A PGER should be submitted with the 30 percent design phase submission and should include relevant project information with soil test boring and soil laboratory test results. In some cases, a PGER may also be required with a PSSR, when requested by DDOT. A PGER for DDOT projects should include the following:

- Executive summary
- Site location, description, and geology
- Description of the project and proposed structures
- Site layout showing proposed structures (e.g., bridges, retaining walls, sound barrier walls, embankments)
- Anticipated structural loads
- An evaluation of subsurface conditions in the area of proposed site development
- Summary of all soil test boring information with soil test boring logs prepared in accordance with the requirements in **Section 26.3.5**
- Summary of soil laboratory testing
- Preliminary design recommendations

26.2.3. Final Geotechnical Engineering Report

The FGER should be submitted with the 65 percent design phase submission and should include a final subsurface exploration prepared according to **Section 26.3**. The FGER should also present a summary of previous subsurface exploration data, geotechnical engineering analysis and engineering recommendations. Engineering recommendations should be applicable for both the design and construction of foundations, slopes and other structures. The FGER for DDOT projects should contain whichever of the following is applicable to the project:

- Executive summary

- Site location, description and geology
- Description of the project and proposed structures
- Site layout showing proposed structures (e.g., bridges, retaining walls, sound barrier walls, embankments)
- Anticipated structural loads
- An evaluation of subsurface conditions in the area of proposed site development, including metal corrosion and concrete attack potential of on-site soils
- Soil test boring logs should be provided in the format presented in **Section 26.3.5**
- Summary of all soil test boring information
- Summary of soil laboratory testing
- Soil parameters, including depth, thickness and variability of soil strata, identification and Unified Soil Classification System (USCS)/AASHTO classification of soils, shear strength, compressibility, stiffness, permeability, frost susceptibility and expansion potential
- Rock parameters, including depth to rock, identification and USCS classification of rock, rock quality and compressive strength
- Foundation recommendations per **Chapter 15**. Both shallow and deep foundations, as well as ground improvement techniques, should be evaluated. Estimated total and differential settlements should be provided for each foundation system along with their calculations. Refer to **Chapter 15** for further details on foundation design.
- Recommendations for design and construction of proposed retaining walls and sound barrier walls, including recommended wall types, soil design parameters, lateral earth pressures, bearing capacity, backfill material and compaction requirements, and drainage requirements
- An assessment of subgrade conditions for support of flexible and rigid pavements
- Design parameters for flexible and rigid pavement sections
- Earthwork recommendations for construction of structural fill, including an assessment of on-site soils to be excavated for re-use as fill
- Rock excavation requirements for site development, including monitoring of existing adjacent structures during construction
- Recommendations for temporary and permanent excavation supports for site development, including maximum allowable slopes
- Global stability analysis of the proposed and existing slopes and retaining walls, including recommendations to enhance slope stability

- Recommendations regarding construction of stormwater management facilities, including embankment, outlet foundation support, embankment fill construction and internal seepage devices such as anti-seep collars and filter diaphragms
- Recommendations for instrumentation and monitoring requirements during construction
- Recommendations on the feasibility of managing stormwater using infiltration, including estimated infiltration rates based on field tests and correlations with soil classifications
- Comments on utility installations, including excavation support requirements and subgrade bearing materials
- Unsuitable soil mitigation recommendations

26.2.4. Report Attachments

The following documentation should be attached at the end of the reports to support engineering recommendations:

- Soil test boring logs in the format presented in **Section 26.3.5**
- Rock core pictures and pavement core pictures
- A location map showing the site with respect to the general area (site vicinity map)
- Exploration location plan showing existing and proposed structures and the approximate locations of soil borings
- Soil and rock laboratory test results
- All engineering calculations and backup information to support design such as slope/global stability analyses, bearing capacity calculations, settlement calculations, pile/drilled shaft lateral load analyses, pile/drilled shaft axial load capacity

26.3. Subsurface Exploration

A subsurface exploration should be conducted to gather all relevant data for preparing the PGER and FGER. Data to be gathered should include detailed information on soil profiles, soil strength and compressibility parameters based on soil laboratory test results and in-situ testing. When determining locations and frequency of soil test borings for the subsurface exploration, any soil test borings previously performed at the project site should be considered.

A subsurface exploration program containing a final boring location plan and a preliminary soil/rock laboratory testing program should be submitted to DDOT for approval before the start of the field exploration. Submitted documents should accurately convey information of existing site conditions, project design information, and means and methods of the work to be performed.

Site accessibility and the need for traffic control should be identified before starting field work. Proposed access pathways, all anticipated site disturbance (e.g., grubbing and clearing of vegetation, removal of gates or guiderails) and temporary maintenance of traffic plans should be submitted to DDOT for review and approval of a DDOT temporary occupancy permit. Traffic maintenance is subject to the regulations of the **DDOT D.C. Temporary Traffic Control Manual**. Subsurface exploration work is subject to the regulations in the District of Columbia, and all required permits must be obtained before starting field work.

26.3.1. Investigation Requirements

The number of soil test borings depends on project size, the variability of geologic conditions throughout the site, and exploration scope. The subsurface exploration plan should meet the minimum requirements presented in **Table 26-1**, or as approved by the DDOT Engineer.

Table 26-1 | Minimum Frequency and Depth of Soil Test Borings

Proposed Structure	Frequency and Location of Soil Test Borings	Required Depth of Soil Test Borings
Roadways (Cuts and Fills Not Exceeding 25 Feet in Height)	A minimum of one soil test boring per structure. Additional soil test borings every 250 feet of roadway length. Examples of soil test boring layouts are presented in Figure 26-1 and Figure 26-2.	Soil test boring depth of at least 10 feet below the proposed subgrade elevation in cut areas. In fill areas, the boring should advance at least to a depth equal to the height of fill with a minimum depth of 10 feet below the existing grade.(1)
Cut Slopes Greater Than 25 Feet in Height	A minimum of two soil test borings, one at the toe and one at the crest of the slope. Additional soil test borings every 250 feet of slope length placed one at the top and one at the bottom of the slope. Examples of soil test boring layouts are presented in Figure 26-3 and Figure 26-4.(3)	Soil test boring should penetrate at least 10 feet below the minimum elevation of the cut. If rock is present above the minimum elevation of the cut, the rock should be cored to a minimum depth of 10 feet.(1)
Embankments More Than 25 Feet in Height	A minimum of two soil test borings. Additional soil test borings every 250 feet along the centerline of the embankment and along the toes. Examples of soil test boring layouts are presented in Figure 26-3 and Figure 26-4. (3)	Each soil test boring should be advanced to a depth of at least twice the embankment height unless rock is encountered at shallower depths. If rock is encountered at grades above the proposed foundation elevation, it should be cored to a depth of at least 10 feet.(1)

Proposed Structure	Frequency and Location of Soil Test Borings	Required Depth of Soil Test Borings
Retaining Walls, Sound Walls and Anchored Walls	A minimum of two soil test borings located at the centerline of proposed walls. Additional soil test borings every 100 feet of wall length for retaining walls and every 200 feet or less of wall length for sound walls. For anchored walls, additional borings in the anchorage zone spaced at 100 feet. For soil-nailed walls, additional borings at a distance of 1 to 1.5 times the height of the wall behind the wall spaced at 200-foot intervals along the wall.(3)	Soil test borings should extend to a depth where stress increase due to estimated foundation load is less than 10 percent of the existing effective overburden stress at that depth or twice the wall height, whichever is more. If rock is encountered at grades above the proposed foundation elevation, it should be cored to a depth of at least 10 feet.(1)
Bridge Piers and Abutments on Shallow Foundations	A minimum of one soil test boring per pier and a minimum of two soil test borings per abutment, located at the centerline of substructure. Additional soil test borings every 100 feet of abutment length.(2)	Soil test boring should advance to at least the depth where effective stress increase due to estimated foundation load is less than 10 percent of the existing effective overburden stress at that depth.(1) If bedrock is encountered prior to that depth, boring depth should penetrate a minimum of 10 feet into the bedrock.(4)
Bridge Piers, Abutments and Sign Structures on Deep Foundations	A minimum of two soil test borings per substructure; borings should be located at either the centerline of the substructure or one boring at each pier location if supported by a single pile or shaft. Additional soil test borings every 100 feet of abutment length.(2)	In soil, the depth of soil test borings should extend below the anticipated pile or shaft tip elevation by a minimum of 20 feet, or twice the maximum pile group dimension, whichever is deeper.(1) For piles bearing on rock, a minimum of 10 feet of rock core should be obtained at each soil boring. For shafts supported on or extending into rock, a minimum of 10 feet of rock, or a length of rock core equal to at least 3 times the shaft diameter for isolated shafts or twice the maximum shaft group dimension, whichever is greater, should be cored below the shaft tip elevation.(4)
Stormwater Best Management Practices (BMPs)	Test pit and/or soil test boring requirements per **DOEE Stormwater Management Guidebook**.	Depth requirements per **DOEE Stormwater Management Guidebook.**

Proposed Structure	Frequency and Location of Soil Test Borings	Required Depth of Soil Test Borings
Storm Drains and Culverts (Greater Than or Equal to 36 Inches in Diameter)	A minimum of one soil test boring at each end wall and at 200-foot intervals along the length of the pipe or culvert. Foundation investigation is not required for pipes and culverts less than 36 inches in diameter unless the PSSR identifies soft, compressible, or organic-rich soils, or rock near a proposed pipe location.	Soil test borings should be advanced to at least one pipe diameter below the invert elevation of the pipe or culvert unless rock is encountered at shallower depths.(1)
Trenchless Pipes	A minimum of one soil test boring at each jack and receiving pit and additional soil test borings at 100-foot intervals along the length of the pipe.	Soil test borings should be advanced to at least the height of excavation on each pipe extremity and at least one pipe diameter below pipe invert along the pipe alignment unless rock is encountered at shallower depths.(1)

(1) Boring depths should fully penetrate unsuitable natural soils (i.e., peat, organic materials, soft fine grained soils, loose coarse-grained soils) or existing fill to reach a minimum of 10 feet of penetration into the underlying suitable material (e.g., hard or dense materials).
(2) Additional soil borings should be provided if unusual subsurface conditions are encountered.
(3) In situ testing and/or collection of undisturbed soil samples may be required to meet laboratory testing requirements of this manual.
(4) If highly variable bedrock conditions are encountered, or if project site geology indicates the presence of large boulders, more than 10 feet of rock core may be required to verify that adequate quality bedrock (e.g., rock quality designation [RQD] above minimum value established by the geotechnical engineer) is present.

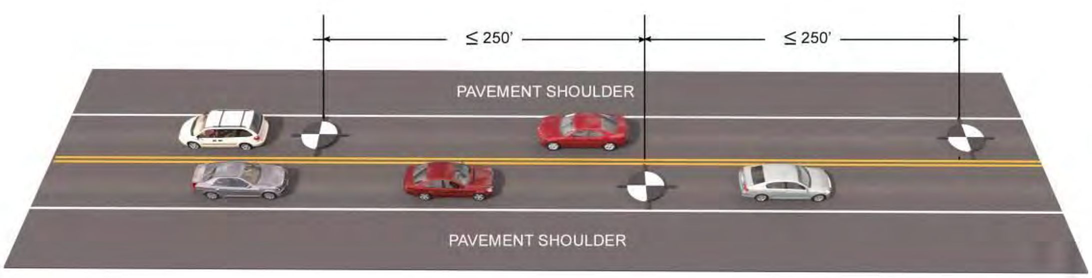


Figure 26-1 | Example of Soil Test Boring Layout for a Two-Lane Road

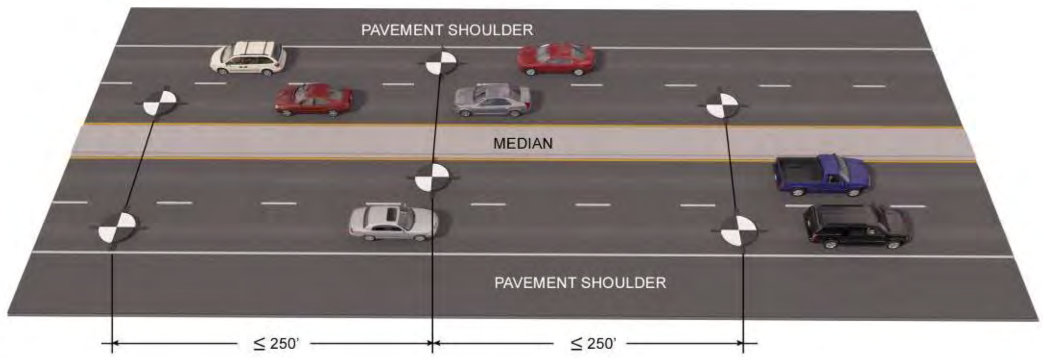


Figure 26-2 | Example of Soil Test Boring Layout for a Four-Lane Road

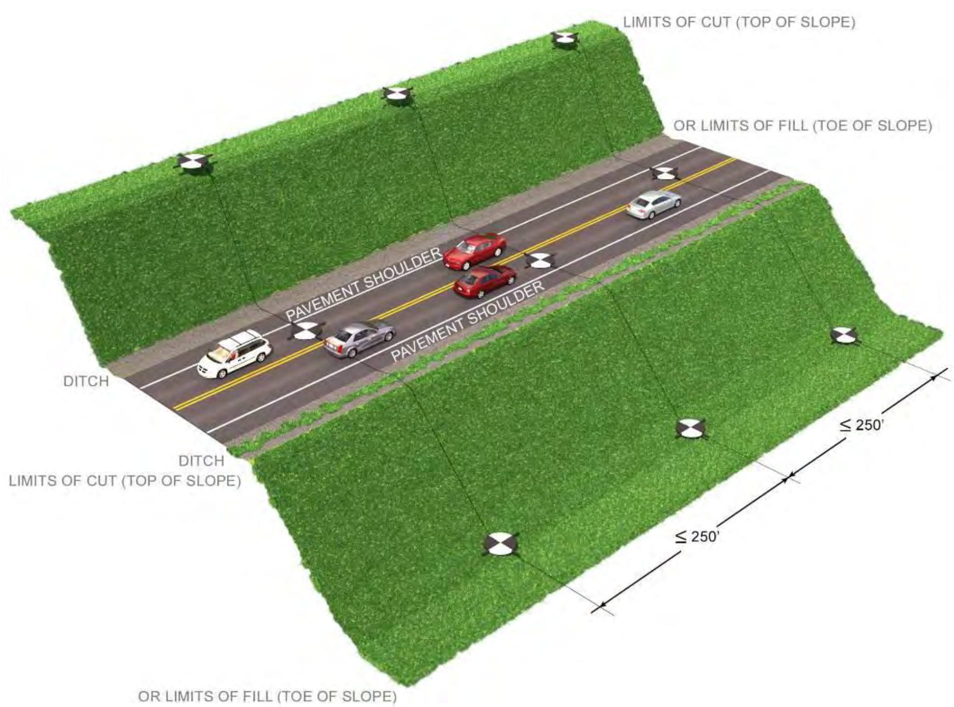


Figure 26-3 | Example of Soil Test Boring Layout for a Two-Lane Road Constructed over Embankment and/or Cut Slope Higher Than 25 Feet

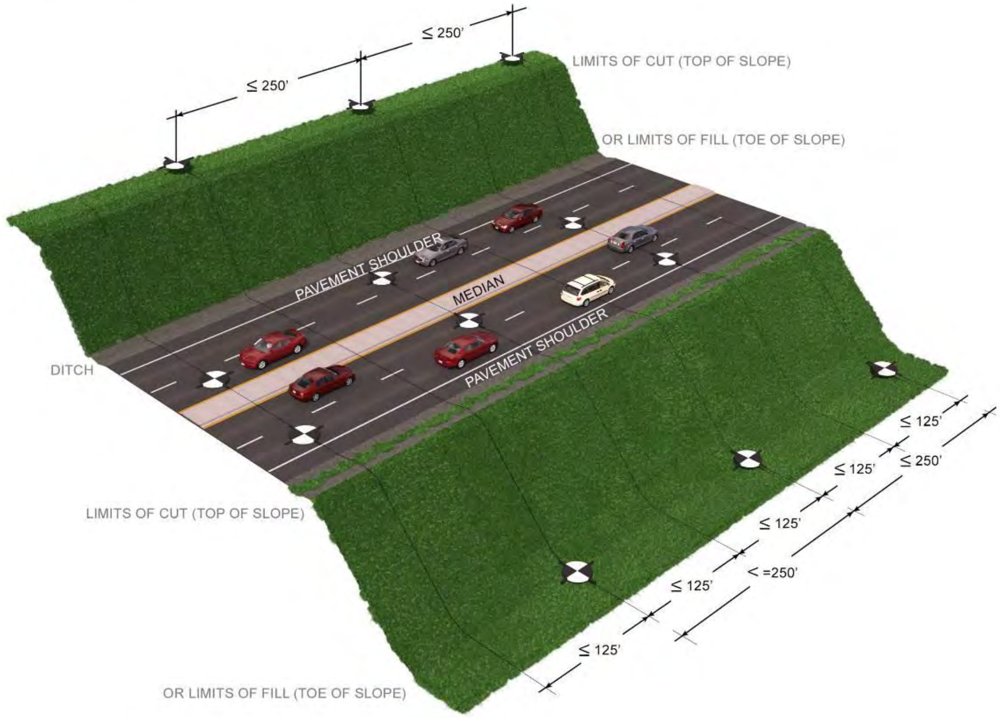


Figure 26-4 | Example of Soil Test Boring Layout for a Four-Lane Road Constructed over Embankment and/or Cut Slope Higher Than 25 Feet

Drilling for subsurface investigations in the District should be performed in accordance with applicable ASTM or AASHTO standards. All drilling and sampling should be performed under the supervision of a field engineer, geologist or soil scientist.

Soil test borings specified in Table 26-1 should include a Standard Penetration Test (SPT) per **ASTM D1586** or **AASHTO T206** standards. The preferred drilling method is hollow-stem augers per **ASTM D6151** or **AASHTO T306** unless adverse subsurface conditions are encountered. When properly justified, the use of rotary drilling techniques per **ASTM D5783** or other standard methods may be acceptable on condition that soil testing requirements of this manual are not compromised.

During drilling, the field engineer or geologist will record information on ground cover and its thickness (topsoil, asphalt, concrete, etc.), changes in soil type by stratum (soil visual classification according to **ASTM D2488**), color or gradation, soil type and classification, drilling method and equipment type, type of hammer, drilling time, sample recovery, driller's name, observations from auger cuttings, changes in drilling mud consistency, observed groundwater levels, cave-in depth and water levels immediately after the extraction of the auger, and other relevant information. Groundwater levels and cave-in depths should be recorded to the nearest 0.1 foot.

Where clays and silts with pre-existing shear surfaces are present, the depth of fissures or slicken-sided joints in split spoon and Shelby tube samples should be recorded during field investigation and reported in soil test boring logs. An appropriate laboratory test method should be selected to assess properties of slicken-sided clays; see recommended laboratory tests in **Section 26.4**.

In some circumstances, geophysical methods have been proven effective for site characterization purposes. Standard procedures for selecting geophysical methods can be found in **ASTM D6429**. Geophysical testing should be used in combination with soil test borings. A qualified and experienced geophysical testing consultant should be contracted to plan and execute the geophysical testing program.

Appropriate underwater drilling techniques should be employed to permit access to soil test borings in bodies of water or water crossings. When working platforms are necessary for drilling, their selection should be based on site configuration, geological and environmental conditions, type of sediment expected at the site, typical wave heights and currents, water level/tide fluctuations, capabilities of drilling equipment, expected quality and depth of samples, and cost. Underwater drilling techniques should meet all sampling and testing requirements described in this manual. All necessary permits, including U.S. Coast Guard permits, should be obtained before beginning work. Water works should comply with U.S. Coast Guard policies and regulations.

For consistency, soil test borings should be labeled with a prefix followed by a number (e.g., BR-17). Prefixes should identify proposed structure or testing type, for example, “RW” for retaining wall borings, “PB” for pavement borings, “SL” for slope borings, “BP” for bridge pier borings, “BR” for bridge abutment borings, “CPT” for cone penetration tests, and “DMT” for dilatometer tests.

26.3.2. Groundwater Monitoring

Groundwater level information is needed to determine if hydrostatic pressures will affect the design of proposed structures. Water levels also indicate possible construction difficulties and the level of dewatering effort required during site excavation.

Groundwater elevations should be recorded during drilling, at completion of drilling, after pulling the augers, and at a minimum of 24 hours after the completion of all soil test borings. The requirement for the 24-hour reading is waived if the open borehole is a safety concern.

A standpipe with screen should be installed for cut and embankment slopes more than 25 feet high. Depending on the type of structure, the geotechnical engineer can consider installing groundwater monitoring wells so that water level measurements can be continuously taken. Monitoring well installation and termination procedures should comply with District of Columbia regulations.

26.3.3. In-Situ Soil Strength Testing

In-situ soil testing methods are used to obtain strength, friction and pore water information for soils in their existing state. The methods result in disturbance and displacement of the soil. In many cases the information obtained can be correlated to other design parameters.

ASTM D5788, D6635, D4719 and D2573 (AASHTO T223) present information on the Cone Penetrometer Test, Flat Plate Dilatometer Test, Pressuremeter Test and Field Vane Shear Test, respectively.

26.3.4. Sampling Requirements

Each soil, rock and pavement sample should be identified with project name and number, depth, and date. Labeling, preservation and transportation of soil and rock core samples should comply with **ASTM D4220** and **ASTM D5079**, respectively. Samples should be stored until approval of the FGER is granted by DDOT. For bridge projects, samples must be stored for at least 1 year after approval of the final design.

26.3.4.1. Split-Spoon Sampling Requirements

Split-spoon sampling should be performed in accordance to **ASTM D1586** or **AASHTO T206**. Split-spoon samples should be taken continuously in 2-foot intervals for the soils immediately below proposed bearing elevations up to a depth of 10 feet, and then in 5-foot intervals as measured from the top of consecutive samples. Sampling should continue until depths in Table 26-1 are attained or until auger and split-spoon refusal. Split-spoon sampler refusal is defined as 50 blows or more per 1 inch or less of penetration in any of the 6-inch sampling intervals.

In the event slabs or obstructions that cannot be penetrated with ordinary soil drilling equipment are encountered at a depth of 5 feet or less, the test boring should be offset and re-drilled. The offset test boring should be located within 10 feet of the original test boring. Soil borings deeper than 5 feet may be terminated upon auger refusal.

Sample recovery should be measured to the nearest 1/2 inch and be recorded in field test boring logs. If no soil sample is recovered in first attempt then sample recovery should be re-attempted.

Split-spoon samples should be preserved in moisture-sealed jars with the recorded number of blows (N number) required to drive the sampler and sample recovery. In areas where topsoil is present, all material from the first split-spoon sampler should be retained in moisture-sealed jars.

26.3.4.2. Thin-Walled Tube Sampling Requirements

Thin-walled tube soil samples, also known as Shelby tubes, are considered undisturbed samples and are used to obtain engineering properties of soil, such as strength, compressibility, permeability and density. Shelby tube samples should be taken in accordance with **ASTM D1587** or **AASHTO T207**. All relevant information should be recorded by the field engineer or geologist when obtaining Shelby tube samples, including the sampling depth, length of sampler advancement, and recovery.

Extra care is required when handling and transporting Shelby tubes to prevent disturbance of the sample. Shelby tubes should be sealed with wax on both ends to prevent loss of moisture, and appropriate packing materials should be placed in the remaining tube space to prevent disturbance of the sample.

26.3.4.3. Sampling Requirements for Pavement Design

Bulk samples of soils should be taken at the proposed finished subgrade elevation for California Bearing Ratio (CBR) and moisture-density relationship testing. A sufficient number and volume of bulk samples should be collected from each representative soil stratum of the subgrade. A moisture-sealed jar containing representative material from the bulk sample should be placed inside the bulk bag for determination of moisture content.

26.3.4.4. Stormwater Best Management Practices Sampling Requirements

Sampling and testing requirements can be found in the **DOEE Stormwater Management Guidebook.**

26.3.4.5. Scour Sampling Requirements

Scour is of concern when the proposed structure is located near a river or steam crossing. Potential scour issues should be identified when preparing the subsurface exploration plan. Representative soil samples for scour analysis should be collected from the stream/river bed material.

Labels on bulk sample bags for scour analysis should note the project name and number, bulk sample identification (test boring name or station number), depth and date.

26.3.4.6. Soil Description

The field engineer or geologist should review published geologic maps to identify and understand the soil characteristics of each project site before beginning field work.

When identifying soil in the field, the field engineer or geologist should record all information and present the following on the soil test boring log:

> *Geologic Origin*, color, gradation, SOIL GROUP NAME PER ASTM D2488, minor or other components, consistency/apparent density, moisture **(GROUP SYMBOL)**

Geologic origin of soil (fill, terrace deposits, colluvial, residual, etc.) can explain general soil deposition characteristics. The term "Weathered Rock" is used for residual materials displaying SPT N-values above 60 blows per foot. Relative density and soil consistency should be defined as shown in Table 26-2.

Table 26-2 | Soil Relative Density and Consistency

Sands		Silts and Clays	
N-value	**Relative Density**	**N-value**	**Consistency**
0–4	Very Loose	**0–1**	Very Soft
5–10	Loose	**2–4**	Soft
11–24	Medium Dense	**5–8**	Medium Stiff
25–50	Dense	**9–15**	Stiff
>50	Very Dense	**16–30**	Very Stiff
		31–60	Hard
		>60	Very Hard

Adapted from **FHWA Geotechnical Circular No. 5**, dated April 2002

Gradation reflects the size of coarse particles present in a soil sample, generally described as fine (f), medium (m) or coarse (c), following the definitions of **ASTM D2488.** It is acceptable to describe gradation using a range of sizes such as fine to medium (f-m).

Rock core samples should be obtained in accordance with **ASTM D2113 or AASHTO T225**. The best method for identifying rock is to refer to a geologic map before going to the field. This will assist in predicting what types of rock may be encountered during the field investigation. When identifying rock in the field, the field engineer or geologist should record the following at minimum:

> Weathering, color, hardness ROCK TYPE, other features

Rock core information should be displayed in the soil test boring logs containing at least run depths, percentage of rock core recovery (per **ASTM D2113 or AASHTO T225**) and rock quality designation (RQD) per **ASTM D6032**.

Descriptors of hardness, weathering and degree of fracturing of rock should follow **FHWA Geotechnical Engineering Circular No. 5**.

Retrieved rock core runs should be placed in wooden boxes (Figure 26-5), and labeled with project name, project number, test boring number, box number, which runs are in the box, and top to bottom depths. The first run should start at the top left and proceed to the right. The top and bottom depths should be clearly written at the extremities of each run. Mechanical breaks that occurred during rock handling or made to fit the run into the box should be marked by a pair of parallel lines spanning the break.

Photographs of rock cores depicting the rock in a wet state, a scaling device such as a ruler or object of known size, and clearly labeled box (Figure 26-5), should be presented in the GER. If a particular run is not fully recovered, a spacer block indicating the bottom elevation of the run should be installed between runs.

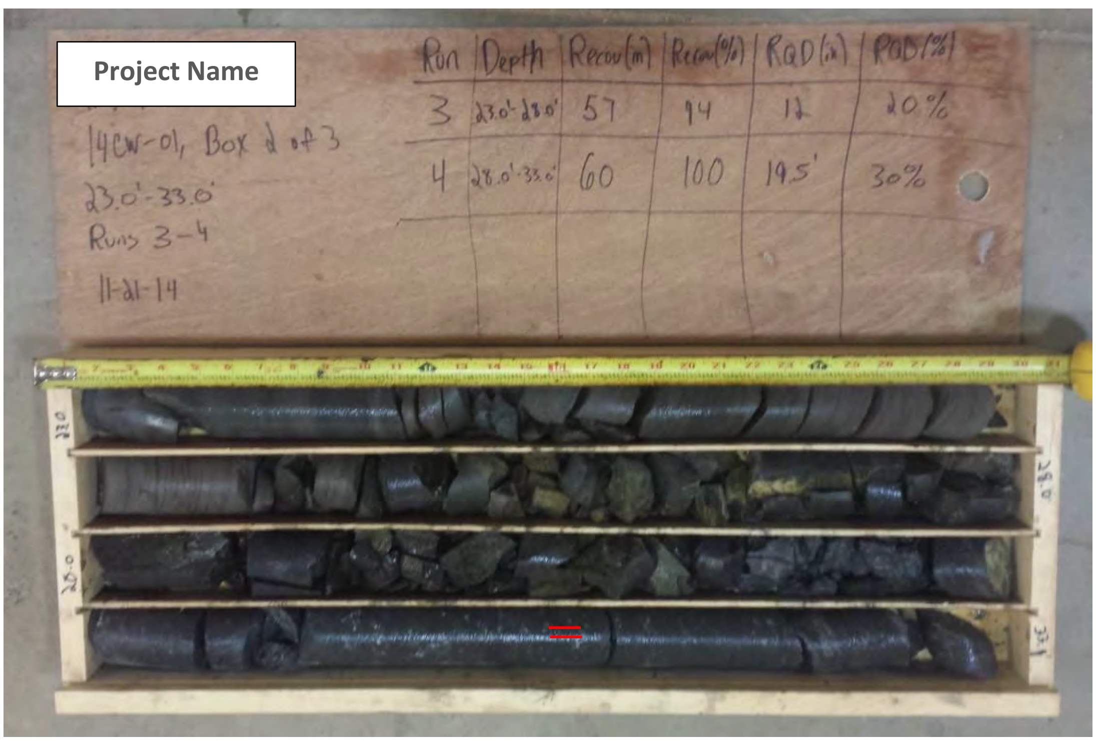


Figure 26-5 | Example of Rock Core Box Information

26.3.4.7. Pavement Core Description

Pavement cores should be obtained for the full pavement depth, including subbase materials, until the soil subgrade is reached. Pavement core information to be collected and attached to the report includes the following:

- Pavement core number
- Pavement material type (e.g., asphalt, concrete)
- Thicknesses of discernible asphalt layers (e.g., surface mix, intermediate mix and base mix) measured to the nearest 1/4 inch
- Descriptions and thicknesses of subbase materials (e.g., open-graded drainage layers, concrete treated aggregate)
- Remarks on the pavement core condition

A picture displaying the pavement core with identifying label and a scaling device such as a ruler oriented from the top to bottom of the core, preferably taken with a white background, should be presented in the GER (see Figure 26-6). Stated pavement core layer thicknesses should agree with the displayed scale in the picture.

Figure 26-6 | Example of Pavement Core

26.3.5. Boring Log Requirements

Boring logs should be prepared under the direct supervision of a District of Columbia-licensed professional engineer or certified geologist. Boring logs should contain all relevant information collected and recorded during the subsurface exploration program and laboratory testing. Boring logs should display the project name, project number, site address, name of the drilling contractor, name of field inspector, name of drilling crew, soil test boring number, date and time of start, date and time of completion, existing ground surface elevation, geographic coordinates (in accordance with **Chapter 11**), station number with offsets from the station centerline of the actual soil test boring/rock coring, drilling equipment model and type, drilling method, hammer information, depth to groundwater with recorded dates and times, and description of strata.

Boring logs should include soil and rock type descriptions with consistent symbols for each type, SPT N-values, sample depths and laboratory testing information.

Figure 26-7 shows an example of a typical test boring log. Specify in all boring logs the bottom of borehole depth and elevation. Auger refusal and split-spoon refusal should be indicated.

26.4. Laboratory Testing Program

The laboratory testing program will determine the engineering properties of subsurface materials and be used to verify on-site visual soil classifications. All laboratory tests should conform to AASHTO or ASTM standards and be performed in certified laboratories.

The soil laboratory testing program will depend on the variability of soil conditions throughout the project site, the scope of the investigation, and the magnitude of the predicted induced stresses on the soil mass from the proposed construction. Engineering judgment and experience is essential when outlining the soil laboratory testing program. Refer to Table 26-3 as a guideline for laboratory testing for different report types. Additional testing may be necessary for unusual design situations or at the discretion of the DDOT Engineer.

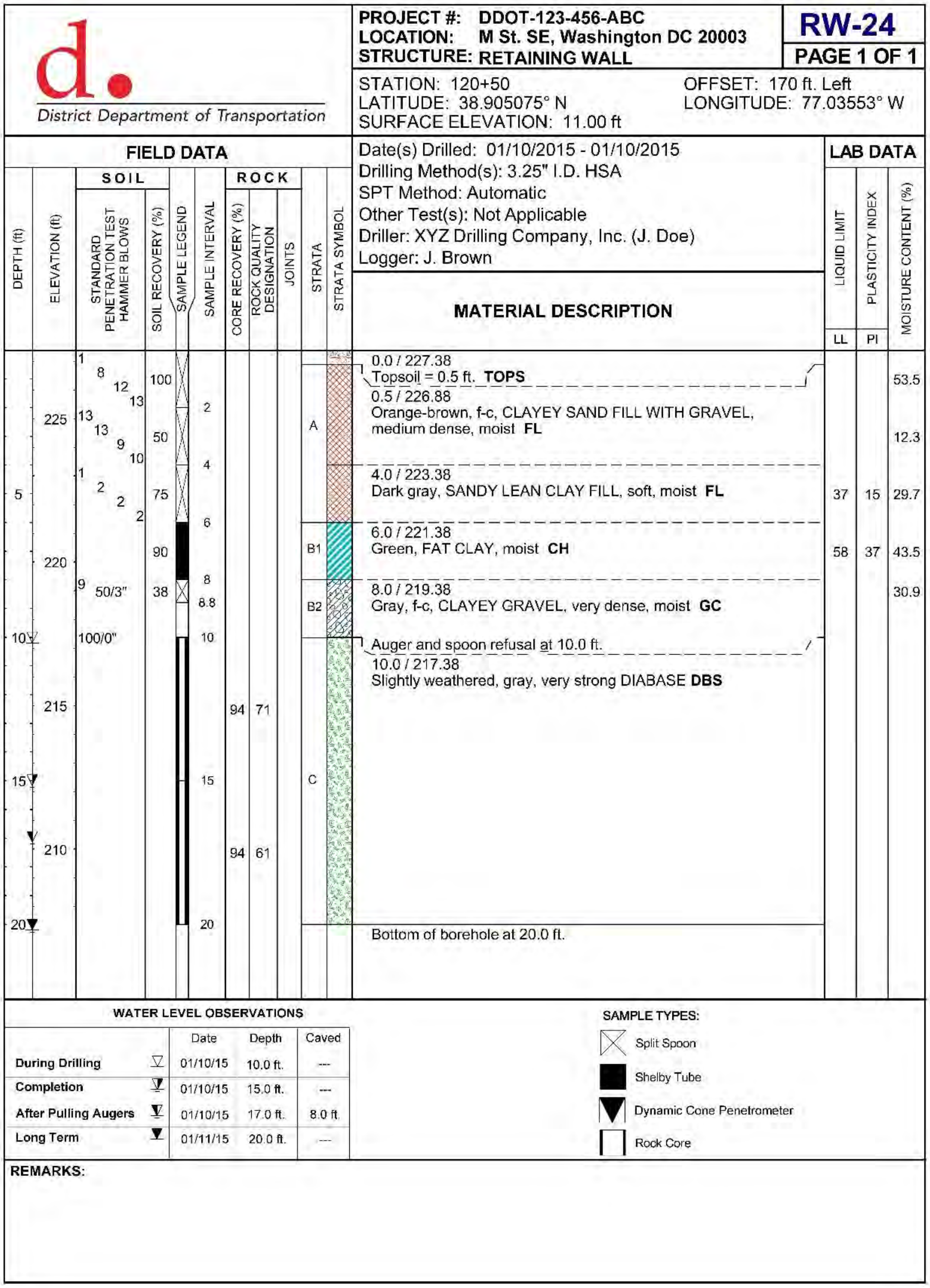


Figure 26-7 | Example of a Test Boring Log

Table 26-3 | Laboratory Testing Guidelines

Test	Preliminary Soil Survey Report (PSSR)(1)	Preliminary Geotechnical Engineering Report (PGER)	Final Geotechnical Engineering Report (FGER)
Visual Classification (ASTM D2488)	X	X	X
Atterberg Limits (ASTM D4318 or AASHTO T89/90)		X	X
Moisture Content (ASTM D2216 or AASHTO T265)	X	X	X
Particle Size Analysis (ASTM D422 or AASHTO T88	X	X	X
Sieve Analysis (ASTM C136 or AASHTO T27)	X	X	X
USCS/AASHTO Classification (ASTM D2487 or AASHTO M145)	X	X	X
Subgrade Support		X	X
CBR (ASTM D1883 or T193)		X	X
Swell Evaluation		X	X
Percentage of Soluble Sulfates			X
SPT (ASTM D1586 or AASHTO T206)	X	X	X
Groundwater	X	X	X
Bedrock Level	X	X	X
Corrosion Potential		X	X

(1) Testing is applicable if soil test borings are requested.

General guidelines for laboratory testing per application are presented in Table 26-4. Unless approved by the DDOT Engineer, adequate number of soil samples for DDOT projects should be tested for natural moisture content Per **ASTM D2216 or AASHTO T265** and soil classification per **ASTM D2487**. Additionally, undisturbed samples may be tested for unit weight. Soils samples visually containing organic matter should be tested for determination of organic content according to **ASTM D2947 or AASHTO T267**.

Table 26-4 | Soil and Rock Laboratory Testing Guidelines

Application	Soil Testing Guidelines	Rock Testing Guidelines
Pavement Subgrade	USCS and AASHTO soil classification, CBR and moisture density relationship test for each stratum of the in-place materials or materials to be re-used as pavement subgrade.	--
Cut Slopes, Embankments or Retaining Walls Higher Than 25 feet	USCS and AASHTO soil classification, direct shear or triaxial tests per ASTM. One-dimensional consolidation tests per ASTM if soft and saturated cohesive soils are encountered.	Rock compressive strength per ASTM if rock is encountered.
Bridge Piers, Abutments, and Sign Structures on Deep Foundations	USCS and AASHTO soil classification, direct shear or triaxial test per ASTM. One-dimensional consolidation tests per ASTM if soft or saturated cohesive soils are encountered.	Rock compressive strength per ASTM if rock is encountered.
Stormwater BMPs	Subject to requirements of the **DOEE Stormwater Management Guidebook**	
Storm Drains and Culverts (36 Inches in Diameter or Greater)	Minimum of one pH, resistivity, and soil classification per pipe segment or 1000-foot interval, test on samples near the bedding elevation. USCS soil classification at pipe outlets within 2 to 3 feet below bottom of pipe elevation to assess potential soil erodibility due to stormwater discharge.	--
Scour Analysis	USCS/AASHTO soil classification combined with grain size distribution (hydrometer) per **ASTM D422** if sample contains more than 20% fines (passing No. 200 sieve) in weight. Additional tests per DDOT scour requirements.	--

Soil particle size analysis should be performed according to **ASTM D422** and **AASHTO T88** unless the U.S. Department of Agriculture soil textural test is required. Rock compressive strengths and elastic moduli should be obtained per **ASTM D7012**.

Where over-consolidated clays are present, residual direct shear tests should be performed on at least three representative samples of the over-consolidated clays. A controlled and slow sample shearing rate should be employed to ensure drained conditions. The Torsional Ring Shear Test according to **ASTM D6467** is the preferred method for determining the residual shear strength of the over-consolidated clays, using a maximum shearing rate of 0.0008 inch/minute. Residual direct shear testing per the Army Corps of Engineers' procedure EM 1110-2-1906 is also acceptable with a maximum shearing rate of 0.0003 inch/minute.

CBR tests should conform to **AASHTO T193** or **ASTM D1883**. The Modified Proctor test per **AASHTO T180** or **ASTM D1557** is required for obtaining moisture density relationships.

Corrosion potential of on-site soils should be assessed based on sample pH (**AASHTO T289**) and resistivity (**AASHTO T288**) values, unless not required by the DDOT Engineer. Corrosion protection methods, if used, should be described in the PGER and/or FGER.

26.5. Geotechnical Analysis

Upon completion of the field investigation and laboratory testing program, geotechnical analysis should be conducted by a geotechnical engineer according to the most recent **AASHTO LRFD Bridge Design Specifications**. Where design methods are not provided in **AASHTO LRFD** specifications, other design manuals may be used to perform required analysis. Supplemental information on foundation design is presented in **Chapter 15**.

26.5.1. Soils for Embankments and Subgrades

Unsuitable soils (e.g., compressible or loose soils, more than 5 percent by weight organic matter or soils with a swell greater than 5 percent) are not to be used for direct support of proposed roadways and embankments.

For requirements on undercutting of unsuitable soils, embankment fill and compaction, refer to **DDOT Standard Specifications for Highways and Structures.**

Total embankment settlement should be less than 1 inch if embankment fill is located within 100 feet of bridge abutments. Settlement of embankment fill located beyond 100 feet of bridge abutments should not exceed 2 inches. The use of soil stabilization, improvement or reinforcement methods should be considered by the geotechnical engineer. Appropriate methods to reduce or accelerate consolidation settlement should be recommended in the preliminary and/or final GER.

26.5.2. Slope Stability Analysis

Slope stability should be evaluated using limit equilibrium methods or other widely accepted slope stability analysis methods.

Slope stability analysis should be performed for all cut and roadway embankment fill slopes exceeding 5 feet in height and/or steeper than or equal to 2H:1V. Slope stability should be analyzed using applicable soil parameters for all of the following conditions:

- End of construction
- Long term
- Rapid drawdown, if applicable
- Earthquake, at the direction of the DDOT Engineer

The evaluation of overall stability (drained and undrained conditions) of earth slopes with or without a foundation unit should be investigated. The resistance factors presented in Table 26-5 are required unless otherwise approved by the DDOT Engineer.

Table 26-5 | Resistance Factors for Soil Slopes

Application	Resistance Factor (ϕ)
Where geotechnical parameters are well defined, and the slope does not support or contain a structural element	0.75
Where geotechnical parameters are based on limited information, or the slope contains or supports a structural element	0.65

Adapted from **AASHTO LRFD Bridge Design Specifications**, 7th Edition, Section 11.6.2.3

26.5.3. Soil Mitigation Methods

Any special problems found during soil investigations (expansion, frost, soluble sulfates, shallow bedrock, heave, groundwater, soil instability, utility backfill, etc.) should be addressed in the PGER and/or FGER. Prior to implementation, all mitigation procedures should be approved by the DDOT Engineer.

If the average swell of pavement subgrade materials is 5 percent or more, the pavement design report should provide mitigation measures. Mitigation measures are intended to reduce swell potential to an acceptable level. The swell test report should specify sample conditions, surcharge pressures, and other key testing factors. Mitigation procedures are subject to approval by the DDOT Engineer.

27 Pavement Design

27.1. Pavement Design Policy

The pavement design process consists of a pavement condition assessment, geotechnical investigation, pavement design and pavement analysis. A pavement design report should be submitted to the DDOT Engineer for review and approval.

27.1.1. Pavement Condition Assessment

Pavement condition assessments are required for all streets except those under construction. Typically, a pavement condition assessment consists of a field inspection of the proposed project site to collect information on pavement conditions and all other pertinent features that could affect the pavement design and/or roadway design. The pavement condition assessment should be performed by DDOT or a design consultant and included in the pavement design report.

27.1.2. Geotechnical Investigation

The design consultant will perform a variety of field and laboratory tests to identify subgrade soil conditions and evaluate the pavement foundation. Please refer to **Chapter 26** of this manual for the required geotechnical tests and investigation. Geotechnical design parameters should be included in the final pavement design report.

27.1.3. Pavement Design Analysis

The analysis and procedures used to arrive at the selection of pavement type or rehabilitation method should be documented in a pavement design report. At a minimum, the report will include the following:

- Distress survey of existing pavements when pavements are to be replaced or realigned
- An analysis supporting the pavement type selection or rehabilitation method
- Pavement thickness calculations of alternate designs
- Life-cycle cost analysis of alternate designs
- Final recommendations for typical sections

NOTE: The final pavement design should be reviewed and approved by the DDOT Engineer.

27.2. Regulations and Guidelines

This chapter is based on criteria from the following references:

4. American Association of State Highway and Transportation Officials (AASHTO) Guide for Design of Pavement Structures, 1993
5. Supplement to the 1993 AASHTO Guide for Design of Pavement Structures, 1998
6. AASHTO, AASHTOWare DARWin 3.1 Pavement Design and Analysis System User's Guide

27.3. Pavement Design Procedure

Pavement design should follow the **AASHTO Guide for Design of Pavement Structures** (1993) and the **1998 Supplement to the 1993 AASHTO Guide for Design of Pavement Structures**, altogether hereafter called the **93 AASHTO Design Guide**. The companion software, DARWin 3.1, or other approved equivalent software, may be used in pavement design.

All new construction and reconstruction of local streets should be done using a pavement type as outlined in **Section 27.8** of this chapter unless directed otherwise. Reconstruction of existing roadways that were constructed with special materials at historic sites requires special design considerations.

27.4. Flexible Pavement Design

27.4.1. Design Variables

Several variables need to be considered when designing flexible pavements. This section summarizes these variables.

Pavement Design Life

Table 27-1 summarizes design life of pavements by street classification .

Table 27-1 | Pavement Design Life

Functional Classification of Street*	Initial Construction Design Life (Years)	Initial Overlay Design Life (Years)
Freeway/Parkway	30	12
Principal Arterial	30	12
Minor Arterial	20	10
Collector Street	20	10
Local Street	20	10

*** The DDOT functional classification map may be used, or the DDOT Project Manager may be contacted to determine the functional classification of the project site.**

Lane Distribution Factor

Table 27-2 summarizes traffic distribution by number of lanes.

Table 27-2 | Lane Distribution Factors

Number of Lanes per Direction	Distribution Factor (%)
1	100
2	90
3	70
4 or more	60

Annual Traffic Growth Rate

If the annual traffic growth rate for the pavement design life is not provided by DDOT Transportation Operations Administration, use the following equation to estimate the traffic annual growth rate:

$$AGR = [\left(\frac{ADT_f}{ADT_i}\right)^{\left(\frac{1}{f-i}\right)} - 1\,] \times 100$$

Where:

AGR = annual growth rate;
f = future year for ADT;
i = initial year for ADT;
ADT_f = average daily traffic for future year; and
ADT_i = average daily traffic for initial year.

If the annual traffic growth rate is provided, the following equation can be used to estimate the future ADT:

$$ADT_f = ADT_i\,(1 + AGR)^{(f-i)}$$

Equivalent Single-Axle Load (ESAL) Factors

The ESAL factors shown in Table 27-3 should be used.

Table 27-3 | ESAL Factors

Vehicle Classification	ESAL Factor
Cars	0.0002
Single-Unit Trucks	0.37
Tractor-Trailer Trucks	1.28

ESAL Calculation

A compound growth factor is used to calculate design ESALs. The truck growth factor can be assumed to be 0 unless informed otherwise. ESAL reliability is summarized in Table 27-4 and serviceability is summarized in Table 27-5.

Table 27-4 | ESAL Reliability

Design ESALs	Reliability (%)
ESAL ≥ 6 Million	95
6 Million > ESAL ≥ 2 Million	90
2 Million > ESAL ≥ 1 Million	85
ESAL < 1 Million	75

Table 27-5 | Serviceability

Functional Classification of Street	Initial Serviceability	Terminal Serviceability
Freeway/Parkway	4.2	3.0
Principal Arterial	4.2	2.9
Minor Arterial	4.2	2.8
Collector Street	4.0	2.5
Local Street	4.0	2.0

Standard Deviation

The standard deviation of 0.49 is used in DARWin for flexible pavement design.

Structural Layer Coefficients

Table 27-6 lists structural coefficients by material layer.

Table 27-6 | Structural Layer Coefficients

Material	Coefficient
Asphalt Layer	0.42
Cement-Treated Aggregate	0.20
Cement/Lime-Treated Soil	0.18
Graded Aggregate Base Layer	0.12

Drainage Coefficients

When the quality of the soil drainage and duration of pavement saturation are known at the project location, refer to **93 AASHTO Design Guide Table 2.4** for drainage coefficients. Otherwise, use a value of 1.0.

Design Subgrade Resilient Modulus (M_r)

The subgrade resilient modulus is a key parameter in pavement design, and caution should be used in deriving the design resilient modulus. Soil data should be evaluated to understand the subsurface soil profile and the variation of soil properties. When laboratory testing is performed, the coefficient of variance (Cv) should be calculated. If Cv is less than 10 percent, an average M_r should not be used as the design M_r. If the Cv is greater than 10 percent, then the pavement engineer should look at sections with similar M_r values and design each section based on that average M_r. If no such sections clearly exist, then use the average M_r times 0.67 to obtain the design M_r. However, for locations with an actual M_r less than the design M_r, the pavement engineer should consider either creating a separate design for that location or undercutting the area.

If a resilient modulus from either field or laboratory testing is not available, use the following correlations:

For fine-grained soils with a soaked California Bearing Ratio (CBR) between 5 and 10:

$$\text{Design } M_r \text{ (pounds per square inch [psi])} = 1500 \times CBR$$

For coarse-grained soil with a soaked CBR greater than 10:

$$\text{Design } M_r \text{ (psi)} = 3000 \times CBR^{0.65}$$

When a falling weight deflectometer test is conducted, the design M_r can be estimated from the back-calculated M_r as:

$$\text{Design } M_r \text{ (psi)} = \text{Back-calculated } M_r \div 3$$

If both laboratory CBR M_r results and the back-calculated M_r are available, use the smaller value as the design value for pavement design.

Based on local experience in the District of Columbia, the recommended maximum design M_r for pavement design is 15,000 psi. If the design consultant proposes a higher resilient modulus, approval should be obtained from DDOT Engineer prior to designing pavement with the higher design M_r. If the CBR is less than 5, it is recommended that the in-situ subgrade soil strength be improved by stabilization or other means prior to designing the pavement structure.

27.4.2. Design Requirements

Minimum Pavement Sections

These pavement section depths are applicable to freeway/parkway, arterial, and collector street classifications only, and do not apply to local streets. Table 27-7 through Table 27-9 summarize minimum asphalt thicknesses, asphalt binder types and lift thicknesses, respectively.

Table 27-7 | Minimum Asphalt Pavement Sections

Material	Thickness (inches)
Asphalt Wearing Surface Course	2
Asphalt Surface Course	5
Aggregate Base Layer	6
Full Depth Asphalt Pavement*	7 (DDOT pre-approval required)

*** NOTE: "full depth asphalt pavement" refers to a pavement structure of asphalt laid directly on top of subgrade soil with no aggregate base.**

Table 27-8 | Selection of Asphalt Binder

Functional Classification of Street	Asphalt Binder
Freeway/Parkway	PG 70-22
Principal Arterial	PG 70-22
Minor Arterial	PG 64-22
Collector	PG 64-22
Local Street	PG 64-22

Table 27-9 | Pavement Lift Thickness

Material	Design Use	Lift Thickness Range (inches)	Recommended Lift Thickness (inches)
Hot Mix Asphalt (HMA) Superpave 9.5 mm	Surface Course, Leveling Course	1.0–1.5	1.5
HMA Superpave 12.5 mm	Surface Course	1.5–2.0	2.0
HMA Superpave 19.0 mm	Base Course	2.0–4.0	3.0
HMA Superpave 25.0 mm	Base Course	3.0–5.0	5.0
Aggregate Base	Base Layer	3.0–6.0	6.0

All asphalt surface, intermediate and base courses should be specified in 0.5-inch increments. Aggregate base should be specified in 1-inch increments.

27.5. Rigid Pavement Design

The rigid pavement design discussed in this section focuses mainly on Jointed Plain Concrete Pavement design. The other type of rigid pavement, Continuously Reinforced Concrete Pavement, has rarely been used in the District, so it will not be covered in this chapter.

27.5.1. Design Variables

Several variables need to be considered when designing rigid pavements. This section summarizes these variables.

Pavement Design Life

Table 27-10 summarizes design life of pavements by street classification.

Table 27-10 | Pavement Design Life

Functional Classification of Street	Initial Construction Design Life (Years)	Initial Asphalt Overlay Design Life (Years)
Freeway/Parkway	30	10
Principal Arterial	30	10
Minor Arterial	30	10
Collector Street	30	10
Local Street	30	10

Lane Distribution Factors

Table 27-11 summarizes traffic distribution by number of lanes.

Table 27-11 | Lane Distribution Factors

Number of Lanes per Direction	Distribution Factor (%)
1	100
2	90
3	70
4 or more	60

Annual Traffic Growth Rate

If the annual traffic growth rate for the pavement design life has not been provided, use the following equation to estimate the traffic annual growth rate:

$$AGR = [\left(\frac{ADT_f}{ADT_i}\right)^{\left(\frac{1}{f-i}\right)} - 1\,] \times 100$$

Where:

AGR = annual growth rate;
f = future year for ADT;
i = initial year for ADT;
ADT_f = average daily traffic for future year; and
ADT_i = average daily traffic for initial year.

If the annual traffic growth rate has been provided, the above equation can be transformed to estimate the ADT in the future as:

$$ADT_f = ADT_i\,(1 + AGR)^{(f-i)}$$

Equivalent Single-Axle Load (ESAL) Factors

The ESAL factors shown in Table 27-12 should be used.

Table 27-12 | ESAL Factors

Vehicle Classification	ESAL Factor
Cars	0.0003
Single-Unit Trucks	0.56
Tractor-Trailer Trucks	1.92

ESAL Calculation

A compound growth factor is used to calculate design ESALs. The truck growth factor can be assumed to be 0 unless informed otherwise. ESAL reliability is summarized in Table 27-13 and serviceability is summarized in Table 27-14.

Table 27-13 | Reliability

Design ESALs	Reliability (%)
ESAL ≥ 8 Million	95
8 Million > ESAL ≥ 3 Million	90
3 Million > ESAL ≥ 1.5 Million	85
ESAL < 1.5 Million	75

Table 27-14 | Serviceability

Functional Classification of Street	Initial Serviceability	Terminal Serviceability
Freeway/Parkway	4.5	3.0
Principal Arterial	4.5	2.9
Minor Arterial	4.5	2.8
Collector Street	4.5	2.8
Local Street	4.5	2.8

Standard Deviation

A standard deviation of 0.39 is used for rigid pavement design.

Portland Cement Concrete (PCC) Material Properties

Two strength properties are used in rigid PCC pavement design: the modulus of rupture and the modulus of elasticity.

The modulus of rupture, also called flexural strength, is derived from a flexural beam test, i.e., third-point loading, and is used to estimate the PCC slab thickness. Typically, the flexural strength ranges from 550 psi to 850 psi. The typical 28-day mean value for roadway rigid pavement design is 650 psi.

The other PCC strength property used in rigid pavement design is the modulus of elasticity. It ranges from 3,000,000 psi to 8,000,000 psi. The typical 28-day mean value for rigid pavement design is 4,000,000 psi.

If lab tests have been conducted for these strength properties, the actual values should be used for pavement design. Otherwise, these typical values can be used.

Design Modulus of Subgrade Reaction (k)

Design modulus of subgrade reaction is also called k-value and is measured in units of psi/inch (pci). There is a relationship between resilient modulus of the subgrade and the modulus of subgrade reaction as represented in the following equation:

$$k\ (pci) = \frac{M_r}{19.4}$$

If the design resilient modulus is obtained from a CBR test, all steps required to select a design resilient modulus described in **Section 27.4** are applicable here.

The typical range of the k-value is from 50 pci to 500 pci. If the k-value is greater than 500 pci, then use 500 pci as the design value.

Drainage Coefficient

Use a value of 1.0 for rigid pavement design.

Load Transfer Coefficient (J)

The load transfer coefficient, J, is a factor used in rigid pavement design to account for the ability of a concrete pavement structure to transfer (distribute) load across discontinuities, such as joints or cracks. Load transfer devices, aggregate interlock, and the presence of tied concrete shoulders all have an effect on this value. The load transfer coefficient for rigid pavement is shown in Table 27-15.

Table 27-15 | Rigid Pavement Load Transfer Coefficients

	Load Transfer Coefficient (J)	
Pavement Type	**Asphalt Shoulder**	**Tied PCC Shoulder or Wide Lane**
Jointed Plain or Jointed Reinforced	3.2	2.8

27.5.2. Design Requirements

Minimum Pavement Sections

These pavement section depths are applicable to freeway/parkway, arterial, and collector street classifications only, and do not apply to local streets. Table 27-16 summarizes the thickness of rigid pavement per layer.

Table 27-16 | Minimum Rigid Pavement Sections

Material	Thickness (inches)
PCC Surface Layer	10
Aggregate Base Layer	6

All PCC pavements must be reinforced with wire mesh as described in the **DDOT Standard Specifications for Highways and Structures** latest edition. Table 27-17 shows the required and recommended lift thickness for aggregate base.

Table 27-17 | Lift Thickness

Material	Design Use	Lift Thickness Range (inches)	Recommended Lift Thickness (inches)
Aggregate Base	Base Layer	3.0–6.0	6.0

The PCC surface layer and the aggregate base should both be specified in 1-inch increments.

27.6. Composite Pavement Design

Composite pavement as discussed in this section refers to pavements with an asphalt surface on top of a PCC base. However, this procedure can also be used for an asphalt overlay over jointed plain concrete pavement or jointed reinforced concrete pavement.

In composite pavement design, first the difference between the thickness required for future traffic and the proposed thickness of the PCC base (or the effective existing slab for an overlay design) is calculated. Then this difference is converted to an equivalent asphalt layer thickness through a conversion factor, A:

$$A = 2.2233 + 9.9 \times 10^{-3}\left(D_f - D_{eff}\right)^2 - 0.1534(D_f - D_{eff})$$

Where D_f = slab thickness for future traffic (inches)

D_{eff} = effective pavement thickness of existing slab (inches)

The required thickness, D_{OL}, of an asphalt overlay is calculated using the following equation:

$$D_{OL} = A\ (D_f - D_{eff})$$

For composite pavement, although the asphalt surface thickness is part of the result, rigid pavement design equations should be used to calculate the effective structure capacity and future structure capacity.

27.6.1. Design Variables

The design variables described in **Section 27.5.1** should be used for composite pavement design.

For asphalt overlay design, the load transfer factors shown in Table 27-18 can be used.

Table 27-18 | Load Transfer Factors for Asphalt Overlay

Pavement Type	Percent Load Transfer *	Load Transfer Coefficient (J)
Jointed Plain or Jointed Reinforced	> 70%	3.2
	50–70%	3.5
	< 50%	4.0

*** Percent load transfer is estimated using the deflections measured at both sides of a joint or crack. For more detail, refer to** 93 AASHTO Design Guide**, Part III, Section 5.6.5.**

27.6.2. Design Requirements

Table 27-19 summarizes the minimum pavement thickness for composite pavement per layer.

Table 27-19 | Minimum Composite Pavement Sections

Material	Thickness (inches)
PCC Base Layer	8
Aggregate Base Layer	6
Asphalt Layer	2

For local streets, an 8-inch PCC base for a composite section may be considered on a case-by-case basis when approved by the DDOT Engineer.

27.7. Shoulder Design

27.7.1. Shoulder for Flexible Pavement

Shoulders for flexible pavements should be constructed of the same materials and thickness as the mainline pavement for all interstates, freeways, expressways and other multi-lane facilities.

For other roadways and streets, shoulders can be constructed of different materials and thickness from the mainline pavement. The shoulder pavement should be designed using 2.5 percent of the design ESAL and following the same flexible pavement design procedure used for the mainline pavement.

Regardless of shoulder type, shoulder base and subgrade should direct drainage away from the pavement rather than towards it.

27.7.2. Shoulder for Rigid Pavement

When PCC shoulders are used, they should have the same PCC slab and base thickness as the mainline roadway. Additionally, the shoulder and mainline roadway PCC should be tied together with deformed steel bars.

27.7.3. Edge of Mainline and Shoulder Pavement

The edges of pavement layers must extend beyond the edges of the above layers to provide suitable support.

Flexible Pavement

These requirements apply when the shoulder has the same structure as the mainline pavement. At the edge of mainline pavement, aggregate base should extend 6 inches beyond the edge of the bituminous base course above if the bituminous base course is 9 inches or less in thickness; otherwise, aggregate base should extend 12 inches beyond the edge. Within the asphalt surface layer, the base course should extend beyond the edge of the intermediate course a distance equal to the thickness of the surface course plus the intermediate course or 5 inches, whichever is greater. However, the outside edge of the intermediate course should be in alignment with the outside edge of the surface course.

Where shoulders are constructed with a buildup different from the mainline pavement, the outside edge of each course should extend 6 inches beyond the edge of the overlying course.

Rigid Pavement

The aggregate base for a rigid pavement should meet the following requirements.

When curb and gutter or integral curb is not used, the aggregate base should extend to the greater of the following two conditions

- 18 inches beyond the outside edge of the porous backfill over the pipe underdrain,
- 6 inches beyond the outside edge of the paved shoulder.

Where curb and gutter or integral curb is used, the aggregate base should extend to the greater of the following two conditions

- 24 inches beyond the face of the curb,

the outside of the porous backfill over the pipe underdrain

27.8. Pavement Type Selection

The following types of pavement are used in the District:

- PCC pavement
- Asphalt pavement
- Composite pavement
- Special pavement (cobblestone, etc.)

As the Nation's Capital, both aesthetic and functional aspects of the pavement need to be considered when selecting the type of pavement for the project site. Avoiding stakeholder and citizen complaints about vibration, noise and appearance should also be factored into the pavement type selection.

The flowchart shown in Figure 27-1 can be used in conjunction with the downtown area map in Figure 27-2 to select the type of pavement for local streets.

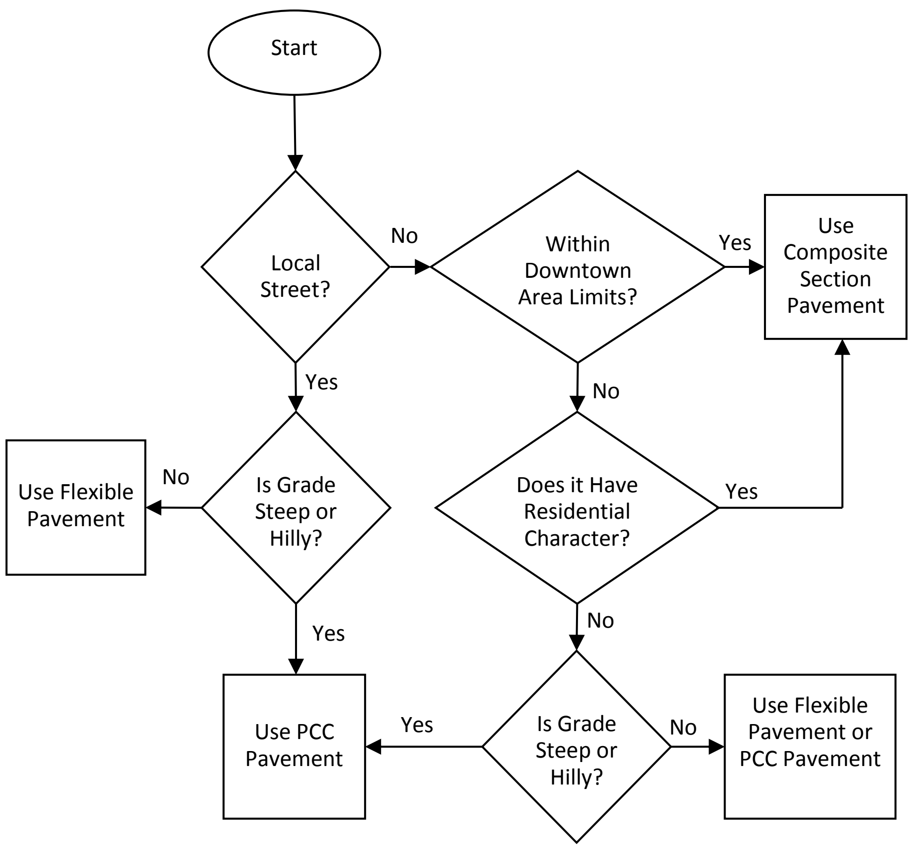


Figure 27-1 | Flowchart for Selecting Pavement Type for Streets

Figure 27-2 | Limits of Downtown Area

27.9. Special Pavement

In the District, the roadway project may be located within or close to historic districts and/or special districts. The design team may encounter certain types of special pavement, such as cobblestone. The procedures for developing designs for such special pavement are not covered in this chapter and should be discussed with the DDOT Project Manager on a case-by-case basis.

One type of special pavement is permeable pavement, including pervious concrete pavement, porous asphalt pavement, and permeable interlocking concrete paver pavement. For design of permeable pavement, refer to **Chapter 28** in this manual.

28 Drainage, Stormwater Management and Hydraulics

28.1. General

Proper drainage from roadways and bridges is critical to providing safe roadway conditions and maintaining the integrity of the transportation infrastructure. The design of drainage structures must adequately convey design flows while meeting the needs of the multi-modal roadway users. Additionally, designs must provide consideration for environmental concerns, including reducing pollutants and attenuating peak flows, by using Green Infrastructure (GI) practices. Furthermore, bridges and culverts need to be protected from scouring, undermining, or overtopping during design flow conditions. Finally, proper soil erosion and sediment control (SESC) measures need to be in place during construction to keep sediment from entering rivers and streams and prevent further erosion.

This chapter explains the design requirements and provides guidance for managing water in the public right-of-way (ROW). Stormwater retention and treatment methods must be included to meet regulatory requirements in District of Columbia Municipal Regulation **(DCMR) Title 21-5**, and are generally achieved using GI practices such as bioretention, permeable pavement, trees, and other best management practices (BMPs). This chapter also addresses the design of culverts and bridge structures, and SESC measures.

28.1.1. Regulations and Guidelines

All current federal and District of Columbia regulations pertinent to the design of drainage and stormwater management are applicable to this chapter unless the provisions in this design manual are more stringent. If differences exist between the District and federal regulations, the more stringent of the two will apply. For any deviation from the design standards outlined in this chapter, please refer to **Section 12.8, Design Exceptions and Waivers**.

In the absence of information on criteria and requirements in this manual, the Designer, in consultation with and approval of DDOT, must use, at a minimum, requirements and guidelines established in other guidelines and manuals. These documents include:

- American Association of State and Highway Transportation Officials (AASHTO) Highway Drainage Guidelines (2014 or latest version)
- Current District of Columbia Municipal Separate Storm Sewer System (MS4) Permit
- DC Sustainable DC Plan (2013)
- DC Water Standard Design Guidelines, Drawings, and Specifications

- District of Columbia Municipal Regulation (DCMR Title 21, Chapter 5, Water Quality and Pollution)
- District Department of Energy and the Environment (DOEE) Stormwater Management Guidebook (2013 or latest version)
- DOEE Soil Erosion and Sediment Control Handbook (2003 or latest version)
- DDOT Environmental Policy and Planning Manual
- DDOT Complete Streets Policy
- DDOT Low Impact Development Action Plan (2010)
- Federal Highway Administration (FHWA) publication Hydraulic Engineering Circular (HEC) No. 11, Use of Riprap for Bank Protection
- FHWA HEC No. 14, Hydraulic Design of Energy Dissipators for Culverts and Channels
- FHWA HEC No. 18, Evaluating Scour at Bridges
- FHWA HEC No. 20, Stream Stability at Highway Structures
- FHWA HEC No. 21, Bridge Deck Drainage
- FHWA HEC No. 22, Urban Drainage Design Manual (2013 or latest version)
- FHWA HEC No. 23, Bridge Scour and Stream Instability Countermeasures

28.1.2. Stormwater Design and Construction Responsibility

DC Water owns and maintains the storm sewer system, including all storm inlets, catch basins, sewer manholes, sewer connect pipes, sewer service pipes, sewer mains and pump stations.

DDOT may construct storm inlets, catch basins, manholes, sewer connect pipes and sewer mains as part of capital road and bridge construction projects. The DDOT/DC Water Memorandum of Understanding (MOU) guides design, construction, and cost sharing responsibilities.

DDOT owns and maintains all roads, alleys, bridges, sidewalks, curbs, and gutters in the public ROW. DDOT installs and maintains bridge scuppers and catch basins on elevated roads and highways. DDOT installs and maintains bioretention, permeable pavement, and other BMP facilities in public ROW as part of the capital improvement and stormwater retrofit program.

Stormwater BMPs installed in the ROW by private property owners, other government agencies and private organizations must be maintained by the entity that installed the BMP or its designee. A stormwater maintenance covenant, agreement, or MOU is required to document the legal responsibility for maintenance.

The Department of Public Works is responsible for sanitation in public space, mowing of public grass areas, and street sweeping.

Drainage issues within the ROW are reviewed by DDOT to determine the source of water flow and which agency has jurisdiction to resolve the problem. Surface water flowing from private property is regulated by the DC Department of Consumer and Regulatory Affairs (DCRA), water retention and treatment on private property is regulated by DOEE, broken water and sewer pipes are the responsibility of DC Water, and DDOT is responsible for mitigating water flowing from streets, sidewalks, and alleys into private property.

28.1.3. Interagency Coordination

Stormwater management, drainage and hydraulic design must be coordinated with local and federal agencies as follows:

- DC Water reviews and approves the design and relocation of stormwater system elements such as inlets, catch basins, connecting stormwater pipes, manholes, and stormwater pumps at each design submittal.
- DOEE is the permitting authority for the Stormwater and SESC plans. Submit design plans for review and approval as outlined in this chapter and in the **DOEE Stormwater Management Guidebook**.
- The U.S. Army Corps of Engineers reviews and issues permits for all work within waters of the United States and on or across flood protection levees.
- The National Park Service reviews and issues permits to all elements of design that fall within or adjacent to National Park lands, including the riverbeds of the Potomac and Anacostia Rivers.
- The U.S. Coast Guard has plan approval and permit-issuing authority for bridges and causeways across navigable rivers.

28.1.4. Design Submittal Requirements

Drainage design reports must be submitted along with the design packages at the 30 percent, 65 percent, 90 percent, and Final (100 percent) milestones of design. The drainage report should include a narrative, existing and proposed hydraulic analysis, and any necessary design appendices. The narrative should include the project overview, project purpose, design criteria, assumptions, and any additional design justification.

The 30 percent design report should include at a minimum:

- Pre- and post-project drainage area maps

- Spread calculations and interception for all inlets and catch basins with drainage areas affected by the project
- Outfall protection and adequacy information
- Floodplain information

The 65 percent design report and all subsequent submittals should include, at a minimum, the following:

- Pre- and post-project drainage area maps
- Spread calculations and interception for all inlets and catch basins with drainage areas affected by the project
- Pipe sizing and hydraulic grade line calculations
- Open channel calculations
- Culvert calculations
- Outfall protection and adequacy information
- Floodplain information

28.2. Roadway Drainage

28.2.1. Hydrology

28.2.1.1. Rainfall Design Frequency

- The design frequency for the interstate system is 25 years.
- The design frequency for underpasses and depressed highways is 50 years.
- The design frequency for bridge decks is 5 years.
- The design frequency for all other city streets not listed above, including local streets, collector streets, minor arterials, and major arterials, is 15 years.

28.2.1.2. Runoff

For drainage areas to inlets and small (18 inches in height or smaller) culverts, calculate the peak runoff using the rational method. The rational method runoff equation is as follows:

$$Q = CiA$$

Q = Peak Runoff (cubic feet per second [cfs])

C = Runoff Coefficient

0.9 for pavement

0.3 for grass

i = Rainfall Intensity (inches per hour [iph])

A = Drainage Area (acre)

The drainage area and runoff coefficient used should be the delineated area and land cover that contributes to the inlet, catch basin, or culvert. Refer to Table 28-1 for the rainfall intensities for the Washington DC area (iph):

Table 28-1 | Rainfall Intensity (iph)

TIME OF CONCENTRATION	FREQUENCY				
(Duration in Minutes)	**5 years**	**10 years**	**15 years**	**25 years**	**50 years**
5*	6.07	6.79	7.16	7.69	8.36
10**	4.87	5.43	5.72	6.13	6.66

*Roadway calculations
** Open field calculations
Source: NOAA Atlas 14, Volume 2, Version 3

28.2.2. Design Criteria

28.2.2.1. Gutter Capacity and Curb Inlet Spacing

- Design Frequency: Refer to **Section 28.2.1** for rainfall design criteria.
- Maximum allowable spread for all DDOT-maintained roadways: 1/2 travel lane from edge of pavement (X + Y + 1/2 Z), as shown in Figure 28-1 (Y may be a bicycle lane or a dedicated parking lane).
- Manning's value (n): 0.015.
- Maximum allowable carryover:
  - 10 percent of gutter flow, except at intersections.
  - 0 percent of gutter flow at intersections. Water is not permitted to flow through the crosswalks or across intersections.
- Recommended grades for drainage flow are:
  - Longitudinal: 0.5 percent (minimum)
  - Cross Slope (curb lane): 2 percent (minimum)
- Maximum allowable spacing of inlets on city streets is the length of the block.
- The depth of flow must be maintained below the top of curb.
- Design elements from **Section 28.8** may be incorporated into the gutter capacity and curb inlet spacing where applicable.

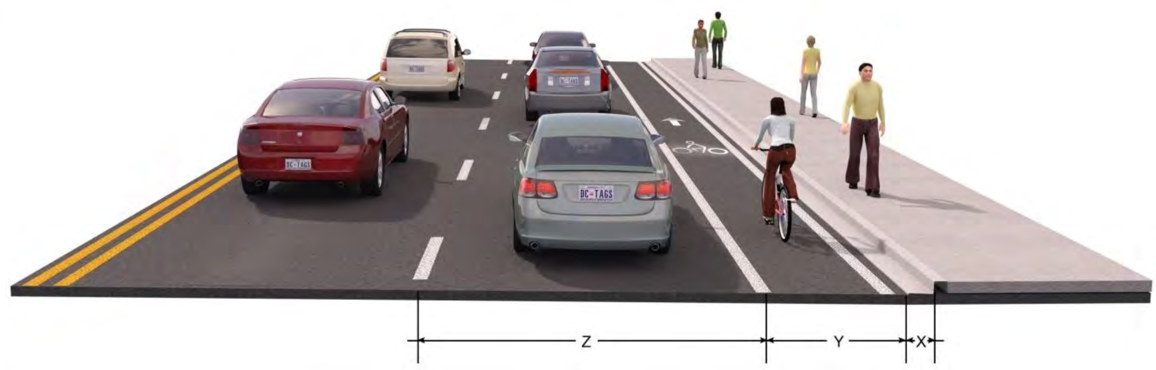


Figure 28-1 | Maximum "Spread" for DDOT-Maintained Roadways

28.2.2.2. Sidewalk Chases

Concentrated stormwater discharge must drain to storm manholes or other methods approved by DDOT and DC Water. Stormwater must not flow over sidewalks or pedestrian routes. A sidewalk culvert must not be located within a curb ramp, curb cut, or driveway.

Refer to the District Plumbing Code for stormwater discharge requirements from properties.

28.2.3. Drainage Control Methods

28.2.3.1. General

This section describes design requirements for storm drainage system design within the street/highway ROW.

28.2.3.2. Stormwater Inlets

There are several types of inlets approved for use by DC Water. Inlets are classified as being on a continuous grade or in a sump. The term "continuous grade" refers to an inlet located such that the grade of the street has a continuous slope past the inlet and ponding does not occur at the inlet. The sump condition exists when the inlet is located at a low point. A sump condition can occur at a change in grade of the street from negative to positive or at an intersection as a result of the crown slope of a cross street.

Grated inlets should be bicycle-friendly; grates should be perpendicular to the travel direction.

General Requirements for Inlets

- All basins are to be located a minimum of 5 feet (8 feet is preferred) from the point of curvature (PC) of corner radii, except to drain sags where one basin may be placed on the PC.

- At a "T" intersection, inlets should be avoided where crosswalks meet the top of the "T."
- With few exceptions, place one inlet at the low point in the sag and place one flanking inlet on each side 3-1/2 inches above the low point.
- A trap or special catchment chamber must be provided for all inlets tying directly into a storm sewer for debris-trapping purposes.
- A water quality catch basin must be used in the Separated Sewer System area where no other retention or treatment device is used to treat runoff in that drainage area.
- A water seal connection must be provided for all inlets. DC Water must approve the connection.
- All basin inlets must connect directly to a manhole.

Standard Curb Opening Inlets

Use standard inlets as required by DC Water. If a basin larger than the Triple Standard basin is required, construct an auxiliary basin and manhole approximately 50 feet upstream from the proposed basin. Maintain a smooth and level surface in bike lanes.

Highway with Full Control of Access

Use a gutter opening inlet with safety grate (paved shoulders with barrier curb) as detailed in the **DDOT Standard Drawings**.

Depressed and Elevated Highways

Use a combination curb and inlet with P-grate or special design (limited lateral clearance).

Field Inlet

Use a standard inlet with safety grate as detailed in the DDOT Standard Drawings.

28.2.3.3. Connecting Pipe

- Basin to manhole connecting pipe must be at least 15 inches in diameter. Check for conflicts with existing utilities.
- Length of connecting pipe must be 50 feet or less.
- Cover over connecting pipe must be a minimum of 3 feet from top of pipe to finished grade.
- No more than three connecting pipes are allowed to tie into any one manhole.

28.2.3.4. Storm Sewer Pipe

- Design frequency must be:

  - 15-year storm with pipe flowing full
  - 50-year storm for pipes draining to a low point in a sag

- Size of storm sewer pipe must be at least 18 inches in diameter.
- Velocity must be at least 3 feet per second.
- Cover over storm sewer pipe must be at least 5 feet from the top of pipe to the finished grade; 5-1/2 feet is desirable.
- Sewer lines must be on a straight alignment and have uniform slope between manholes.
- For hydraulic grade line calculations, use the soffit of the nearest available downstream pipe as the starting water surface elevation.

28.2.3.5. Sewer Manholes

Manholes must be placed over sewer lines at the following locations:

- All points of change of slope or alignment
- Upper end of sewer lines
- Spaced a maximum of 400 feet from other manholes
- Appropriate locations for inlet connecting pipes

28.2.3.6. Adjust and Reset Sewer Structures

Sewer and water items such as manholes, drop inlets, and water valve casings may need to be adjusted or reset to meet proposed grades and elevations. When an existing roadway is to be reconstructed, the sewer manhole may be adjusted by the addition or removal of up to three courses of sewer brick (approximately 12 inches). To raise the elevation of water valve casings, two precast Portland cement concrete rings may be used.

If the roadway is to be salvaged, the sewer and water structures must be reset as described in the specifications.

On resurfacing and overlay projects, cast iron adapter rings may be used to raise the manhole to grade. Only one ring (1-1/2 inches to 3-1/2 inches in depth) may be used for each structure and must be secured as directed.

28.2.3.7. Bridge Deck Drainage

The bridge deck drainage system includes all drains located on the bridge deck and the means used to convey the water collected. A structural analysis may be required on all bridge components modified to accommodate the bridge drains. Girder spacing or drain locations may need to be adjusted due to the proximity of bridge rail posts. The station and offset of each deck drain must be specified in the plans. Drainage from structures must not flow onto bearings, pier caps, abutment caps, or pedestrian walkways.

Bridge decks require adequate grade for proper drainage. This will ensure that chlorides drain off the bridge deck and will prevent ponding and freezing of water. In addition, proper drainage prevents hydroplaning on decks with little surface texture. Provide a minimum grade of 0.5 percent on bridge decks. If the longitudinal grade is less than 0.5 percent, additional drains or special sloping of the gutters may be required.

Sag vertical curves should be avoided on bridge decks to prevent hazards from flooding and icing, and for aesthetic reasons. To have adequate longitudinal drainage near the high point of vertical curves, the grade must not be flatter than required for sight distance requirements.

Inlets/Scuppers and Downspouts

Generally, the number of inlet bridge drains should be kept to a minimum. Bridge drains can become a maintenance problem over time.

Since drainage systems are susceptible to blockage by debris, only the DDOT's approved system will be used.

Bridge drains are generally not recommended on structures less than 400 feet long if they have full-width shoulders, adequate cross slopes, and adequate catch basins on the bridge approaches, unless adverse geometric considerations dictate.

Structures that do not have full shoulders will require bridge deck drains at intervals as determined by design calculations for the allowable spread of 1/2 of the width of the outermost travel lane. As a practical guideline, deck drains should be placed near and upslope from expansion joints on the bridge deck to keep storm drainage out of the joints and away from bridge members.

Bridge drainage systems over streams must be located midway between diaphragms or cross frames and must not discharge directly into the stream. Drainage directly onto unpaved embankments or natural ground where erosion could undermine structural elements is not permitted.

Bridge drainage systems over land must avoid horizontal runs of drainpipe if a reasonable modification to the design scupper spacing permits the placement of drains adjacent to piers at the low end of spans. Scuppers must not discharge to embankments or any traveled way (either vehicular or pedestrian). When applicable and feasible, drainpipe must be hidden from the view of oncoming traffic.

Long runs of outlet pipe on flat grades must be avoided. Where horizontal runs of drainpipe cannot be avoided, the pitch must be at least 8 percent.

Drainage from bridge superstructures or embankments must not discharge on or across a railroad ROW, National Park Service land, or other private property without property owner approval.

Downspouts, where required, must be fabricated from galvanized steel alloy pipe or fiberglass pipe and must have a minimum diameter of 8 inches. Galvanized steel alloy pipe does not require painting. Pipe must be provided with readily accessible cleanouts and must be located such that no water is discharged against any portion of the structure. The pipe must discharge to a drainage system that conducts the water away from the structure.

Downspouts must be located such that they discharge away from traffic. Downspouts must not be cast inside of or within any substructure limits.

Bridge scuppers should not create a hazard to bicycle users. Bicycle-safe grates must be used for all inlets. Grates and covers should be located such that severe or frequent maneuvering by the bicyclist is minimized.

Catch Basin System at Bridge Ends

Unless cross-slopes or superelevation precludes flow on one side of the roadway, any bridge that is on a grade or in a sag, where it may collect highway drainage, should have catch basins provided adjacent to the upgrade end of the bridge in each gutter.

Inlets placed upslope of the bridge must be designed and placed to intercept 100 percent of the approach flow using the rainfall design frequency selected for the roadway system. The capacity of most bridge drainage systems is marginal, and additional water from the approach roadways should not be imposed on them.

Water should be prevented from running down a crack at the paving notch and undermining an abutment or wingwall. A similar nuisance is created when water runs down a median strip, between parallel roadways and parallel bridges, and washes out the slope paving underneath.

28.3. Culverts

- Culverts should be sized to accommodate design flows with rainfall design frequencies depending on the road classification as follows:

- Freeways 50 Years
- Principal Arterials 50 Years
- Minor Arterial/Collectors 25 Years
- Local Streets 10 Years

- Culverts should be aligned with the natural channel as much as possible. Where such alignments result in skewed culvert, the degree of skew for pipe culverts should be kept less than or equal to 30 degrees. The degree of skew is measured between the culvert alignment and a line perpendicular to the roadway centerline.
- Culverts 48 inches and larger in diameter should be provided with headwall at the inlet to counter buoyant uplift force.
- All culverts with headwalls should be provided with cutoff walls with a minimum height of 1.5 feet.
- Culvert outfalls must be protected from scouring and erosion for the design discharge.
- Maximum outlet velocity should be same as the stream natural channel velocity at the design discharge. If the natural channel velocity is exceeded, channel stabilization and/or energy dissipaters must be used to reduce the exit velocity.
- Culverts should be designed for a minimum velocity of 3 feet per second to avoid sedimentation.
- No storage is allowed in culvert design.
- Freeboard to roadway surface should be 6 inches minimum; 1 foot is preferred.

28.3.1. Culvert Outfalls

Culvert outfalls should be evaluated for erosion potential, and if necessary, measures must be designed to minimize erosion at outfalls. Riprap is the most common outfall erosion control measure used in the District. Refer to **FHWA HEC No. 14, Section 10.2, Riprap Apron**, for guidance on apron design. Median diameter, D_{50} , must be calculated using equation 10.4 or 10.5 as given in **FHWA HEC No. 14**; however, riprap class (Class 0, Class I, Class II, or Class III) must be specified according to **DDOT Standard Specifications for Highways and Structures**, latest edition. The Designer will need to use engineering judgment to make a translation between FHWA riprap classes and DDOT's riprap classes.

28.4. Hydraulic Design of Openings and Channels (Culvert or Bridge)

The design of roadway drainage requires a hydrologic analysis to determine the magnitude and frequency of storm runoff and a hydraulic analysis to locate and size the drainage facilities. If a roadway structure crosses a stream channel:

- Work with the Environmental Program staff to identify the necessary environmental assessment.
- Identify floodplain impacts, including any significant encroachments into floodplains, and prepare mitigation, if required by regulation.
- Make preliminary estimates and finalize structure design based on expected scour and erosion protection needed, as well as calculated stormwater runoff and any associated storm drainage structures needed.
- Identify underground utilities near existing and proposed drainage features.

The channel cross section and channel length, normally 500 feet upstream and downstream from the roadway alignment centerline, must be surveyed. An analysis of capacity adequacy should be conducted for the existing structure and associated roadway alignment (horizontal and vertical). A drainage basin survey using United States Geological Survey (USGS) maps, drainage reference maps, plans and profile sheets, and geology evaluations should be conducted. For additional information on surveys, refer to **Section 11.7** of this manual.

If environmental factors will be affected by hydrology, a complete assessment should be documented and submitted to the Project Manager.

- Culverts with 100-year flow rate of less than 500 cfs should be designed following procedures from HDS-5 (Hydraulic Design of Highway Culverts).
- Culverts with 100-year flow rate greater than or equal to 500 cfs and bridges should be designed using HEC-RAS (River Analysis System) or other channel modeling procedures.

28.4.1. Hydraulic Design Criteria

- Culverts: Design storm is determined by roadway classification. See **Section 28.3**.
- Bridges: Design storm is determined by roadway type:
    - Freeway/principal arterial: 50-year
    - Minor arterials: 25-year
    - Local/collectors: 10-year
- Freeboard to roadway surface: 6 inches minimum, 1 foot preferred
- Culvert headwater ratio: 1.5

28.4.2. Waterway Openings

All matters concerning size of waterway openings will be in liaison with DC Water.

28.4.3. Hydraulic and Hydrologic Data

The tabulation shown in Table 28-2 must be completed and shown on culvert plans and final bridge plans:

Table 28-2 | Hydraulic and Hydrologic Data

DRAINAGE AREA (SQ. MI.)				
DESIGN DISCHARGE (FT^3)				
DESIGN WATER SURFACE ELEVATION (FT)				
ENERGY LINE ELEVATION (FT)				
FREQUENCY	10-YR.	25-YR.	50-YR.	100-YR.

28.5. Scour at Bridges

28.5.1. Scour, General or Contraction

In a channel, general/contraction scour usually affects all or most of the channel width and is typically caused by contraction of the flow. Pertinent definitions include:

Scour, Local. Scour in a channel or in a flood plain that is localized at a pier, abutment or other obstruction to the flow.

Thalweg. A line extending down the length of a channel that follows the lowest elevation of the bed.

Refer to **FHWA HEC No. 20, Stream Stability at Highway Structures**, for additional definitions regarding stream geomorphology and scour.

28.5.2. General

- All bridges spanning a waterway must be designed to resist scour through methods outlined in **FHWA HEC No. 18 Evaluating Scour at Bridges**, and **FHWA HEC No. 20 Stream Stability at Highway Structures**.
- All bridge foundations must be designed to withstand the effects of scour from a 100-year flood criterion that is expected to produce the most severe condition. A factor of safety of 2 to 3 must be used to account for the effects of this flood. The foundation design must be checked for a 500-year superflood, or 1.7 times a 100-year flood. If 500-year superflood information is not available from published sources, and then modifications to the foundation design are to be

made where required. All foundations should have a minimum factor of safety of 1.0 under the superflood conditions. When evaluating existing bridges, the superflood criterion must be the 100-year discharge, which is expected to produce the most severe condition. However, in some cases a flood discharge greater than the 100-year flood criterion may be necessary. These cases will be evaluated on a bridge-by-bridge basis.

- If required, the preliminary submission must include a Hydraulic and Scour Report to establish a design procedure for scour resistance. Structural element information, including low chord, abutments and foundation, should be addressed in this report.

28.5.3. Clearance

For streams that carry a large amount of debris, the elevation of the lower chord of the bridge should be increased a minimum of 2 feet above the normal freeboard for a 100-year flood.

28.5.4. Abutments

- Rock riprap, guide banks (spur dikes) and other scour countermeasures as outlined in **HEC No. 18 Chapter 7** must be considered for use on a project-by-project basis on bridge rehabilitation projects as determined by a bridge scour evaluation.
- When designing abutments, the engineer should consider that the channel may shift, and scour may occur at the abutment.

28.5.5. Foundations

- Bridge foundation analysis must be performed assuming that all stream bed material in the 100-year scour prism above the total scour line has been removed and is not available for bearing or lateral support.
- When designing pile foundations, the piles must be designed for reduced lateral restraint and column action requirements due to the increase in unsupported pile length after scour occurs. Additional lateral loads due to stream pressure should be included in the pile design. Shorter piles should be favored over longer piles for supporting bearing loads because this will provide a greater factor of safety against pile failure due to scour at little or no increase in cost.
- For spread footings on soil, ensure that the top of the footing is at or below long-term degradation, contraction scour and lateral migration elevations. Place the bottom of the footing below the total scour line.
- For spread footings on erodible rock, consult an Engineering Geologist to determine the rock quality and local geology. Estimate the potential scour depth, and place the footing base below

that depth. Place the final footing in contact with the sides of the excavation, and fill the excavation above the footing with riprap.

- For spread footings on tremie seals and soil, place the bottom of the footing below the total scour line and ensure that the top of footing is at or below the sum of long-term degradation and contraction scour. This will minimize obstruction during flood flow and minimize any local scour.
- For deep foundations (drilled shafts or driven piles) with footings or caps, place the top of the footing below the stream bed at a depth that is equal to the estimated long-term degradation and contraction scour to minimize obstruction during flood flow and minimize any local scour.
- Local scour holes at piers and abutments should not overlap (top width of a scour hole can be as much as 2.8 times the depth of scour).

28.5.6. Integral Abutment

Integral abutment bridges provide fixity between the superstructure and substructure and protect against translation and uplift better than conventional bridges. The DDOT Bridge Scour Evaluation Program and Structure Inventory and Appraisal Inventory records must be studied to verify scour potential at a project site. To address the potential impact of scour on proposed integral abutment bridge sites, the stream velocity should be reviewed and analyzed where scour potential exists.

28.5.7. Stream Velocity

Any history of erosion or scour at the bridge site must be reviewed and a determination made if the new structure will alleviate any problems (alignment, restricted opening, etc.) that may contribute to scour. Where a scour history is determined, the potential positive effects of an integral abutment bridge should be noted. Scour information may be obtained by researching the DDOT Bridge Scour Evaluation Program and Structural Inventory and Appraisal coding records.

In addition, the Designer must review existing information available at DDOT, including existing bridge inspection reports, scour evaluation and other materials, and provide a report after analyzing data per the latest AASHTO and FHWA specifications and/or guidelines.

28.6. Stream Bank Protection and Stabilization

Protection should be provided at stream banks as erosion control against high velocities in the vicinity of structures (bridge or culvert). Grade control structures should be designed using **FHWA HEC No. 23** design guidelines to provide a stable stream bed elevation in the vicinity of structures and protect it from degradation.

Material used depends on height of drop, width of channel and material availability.

28.6.1. Rock Riprap

The most common method of bank or slope protection is rock riprap. The sides of the bank or embankment are lined with large rocks to prevent erosion along the bank and at the toe. Appearance of the rock riprap is natural, and in time, vegetation will grow between the rocks. Construction must be accomplished in a prescribed manner to ensure proper behavior. The factors to consider in the design of rock riprap protection are:

- Durability and density of the rock
- Magnitude and direction of stream velocity
- Angle of the side slopes
- Size of the rock
- Shape and angularity of the rock

Filter blankets are used as reverse filters to prevent piping damage to the riprap caused by movement of small particles up through the larger stone as a result of decreased hydrostatic pressure from flowing water. Stone bank protection should terminate with a buried toe.

Design guides for estimating rock size for channel and stream bank protection are included in the **DOEE 2003 Soil Erosion and Sediment Control Handbook**. The velocities noted in the Figure 3 of Section H of the **Soil Erosion and Sediment Control Handbook** are considered to be the average velocity over the hydraulic section, and the local velocity computed at a specific sub-area. The charts are simple approximations for estimating purposes only. Use the procedures in **FHWA HEC No. 11, Use of Riprap for Bank Protection**, or **HEC No. 23, Bridge Scour and Stream Instability Countermeasures**, for final design.

Specify a minimum 18-inch-thick blanket of riprap for embankment protection and 24-inch-thick layer for slope protection along stream banks and for streambeds. Where unusual problems are anticipated or the adequacy of ordinary practice is uncertain, a complete detailed design of the riprap gradation and filter blanket is recommended.

28.7. Pump Stations

Stormwater pump stations will be required to remove stormwater from roadway sections that cannot be drained by gravity. However, since pump stations come with high capital cost and associated potential problems in operations and maintenance, they should be used only where other systems are not feasible.

Stormwater pump stations should be designed in coordination with, and approved by, DC Water.

28.8. Stormwater Retention and Green Infrastructure

28.8.1. General

This section describes how to design stormwater retention to meet regulatory requirements using Green Infrastructure (GI) while also meeting infrastructure requirements in the public ROW. GI also includes Low Impact Development (LID) techniques. Standard GI practices to be used in the public ROW are permeable pavement, bioretention, and swales. Other BMP types may be used with approval by DDOT and DOEE. In addition, refer to **Chapter 37** of this manual for street tree plantings, bioretention tree plantings, and associated soil volume requirements.

Signage for public awareness of GI facilities must be included in the design when directed by DDOT.

Stormwater management designs will use the unified approach to sizing stormwater management facilities in the District, as described in the **DOEE Stormwater Management Guidebook**. The design requirements herein are in addition to those described in the **DOEE Stormwater Management Guidebook**, and are intended to refine and clarify what design practices are acceptable, allowable or standard within the public ROW. The GI and BMP facilities provided for stormwater retention may be incorporated into drainage calculations to determine inlet spacing and spread calculations.

28.8.2. Design Criteria

- The design rainfall depth for stormwater retention citywide is 1.2 inches (90th percentile storm).
- The design rainfall depth for stormwater treatment in the Anacostia Waterfront Development Zone (AWDZ) is 1.7 inches (95th percentile storm).

28.8.3. Requirements and Calculations

28.8.3.1. Designing to the Maximum Extent Practicable – Overview

Projects in the existing public ROW are required to implement stormwater retention in accordance with District stormwater regulations to the Maximum Extent Practicable (MEP). This process must be a serious attempt to comply with the regulation to achieve the full retention of the regulated stormwater volume. In situations where the full regulated stormwater volumes cannot be met, the project must meet the maximum stormwater treatment volume practicable, considering every opportunity within and adjacent to the project limits. Construction projects in the ROW have a multitude of site constraints that vary widely. Limited space outside of the roadway restricts opportunities for infiltration and evapotranspiration, and in many cases, the width of the roadway cannot be reduced to create additional space. The specific steps that must be explored for MEP design are stipulated in the **DOEE Stormwater Management Guidebook**, and include:

- Identify drainage areas and calculate stormwater retention volume
- Evaluate infiltration
- Demonstrate full consideration of opportunities with existing infrastructure
- Demonstrate full consideration of land cover conversions and optimum BMP placement
- Size BMPs
- Address drainage areas where no retention practices are installed

The **DOEE Stormwater Management Guidebook** defines the applicability of the design steps described below to DDOT public ROW projects and to parcel development projects that reconstruct the adjacent existing public ROW as a portion of the project (Type 1 and Type 2 projects, respectively).

28.8.3.2. Stormwater Management Submissions

For Type 1 projects in the public ROW, Stormwater Management Plan (SWMP) submissions will be made with the 30 percent, 65 percent, 90 percent and Final (100 percent) design packages. The SWMP will contain a stormwater management map (SMM), MEP worksheet and project narrative.

The submissions will include increasingly more detail commensurate with the design stage. See Sections 28.8.3.4, 28.8.3.5 and 28.8.3.6 for details on submittals at the 30 percent, 65 percent and 90 percent design phases, respectively. The submission will be reviewed by the DDOT Project Manager prior to submission to DOEE. The SWMP is first submitted electronically through the DOEE Stormwater Database at the 30 percent stage. After the SWMP is uploaded and a Stormwater Plan Number assigned, submit a building permit application at the DCRA Permit Intake Center. At each remaining design phase, submit the SWMP to the DOEE reviewer through the DOEE Stormwater Database. Paper copies may be required at the first stage and final stage of the design review. Each DOEE plan review may take up to 30 business days. The final plan must be submitted through the DCRA Intake Center for DOEE Permit Stamp approval.

28.8.3.3. Design Process for MEP – Planning Phase

Prior to Project Design:

Before the project reaches the design stage, the following items will be identified and incorporated into the Designer's scope of work:

1. **Level of Disturbance:** The total area of disturbance will determine whether the project qualifies as a major land disturbance, thus triggering the stormwater retention requirements.
2. **Ownership of Land Adjacent to Rights-of-Way:** Designers must identify public lands and public ROWs adjacent to the project's limits of disturbance (LOD). DDOT will consult with adjacent public property owners and managers to evaluate opportunities to direct stormwater runoff from the project drainage area to adjacent public lands. (This step applies only to MEP Type 1 projects).
3. **Feasibility to Use Public Parking Zone:** DDOT will define whether the public parking areas (between the sidewalk and the ROW line) are feasible for land conversion or BMP placement to capture runoff from the public ROW.
4. **Feasibility to Use "Paper Streets," "Paper Alleys" and Adjacent Traffic Islands:** Any undeveloped or green space within or adjacent to the LOD of public ROW projects will be evaluated for stormwater retention opportunities prior to design.

Planning Phase:

During the planning phase of a project, identify areas for stormwater retention to the planning project level. The steps in the 30 percent design phase should be used to accomplish as much advance planning as the project allows. Items to identify at the planning phase include available space, safe access issues, pedestrian circulation requirements, impervious surface removal, locations of existing utilities, existing trees, soil characteristics, candidate BMP and Land Conversion Areas, and street profile analysis.

28.8.3.4. Preliminary Stormwater Management Plan – 30 Percent Design Phase

MEP Design at 30 Percent

During the 30 percent design phase, the following steps will be followed and incorporated into the submission.

1. **Project Survey:** Full topographic survey for the project is conducted with contour lines at 1- or 2-foot elevations in areas of proposed BMPs.
2. **Available Space for BMPs and Land Conversions:** One of the first steps of the process will be to finalize the dimensions of lane widths, sidewalks and other zones within the public ROW cross section. This step may occur prior to design (during planning), or it may result from an alternatives study during the preliminary design stage. Other spaces to be considered include medians, bump-outs, intersection islands and cul-de-sacs.
3. **Safe Access Issues:** Maintenance access areas should be identified for all BMPs. In city streets, this may be the parking lane. A project involving high-speed, high-volume traffic should include a site assessment to identify vehicle travel lanes and areas of specific safety hazards for maintenance crews. Subsequent steps in the preparation of the SWMP for the project should avoid placing BMPs in these areas.
4. **Pedestrian Circulation Requirements:** The pedestrian circulation requirements of the project, including egress zones behind the curb adjacent to on-street parking, will be defined in the 30 percent design phase. Maximum ponding depth of BMPs near pedestrian facilities should also be defined based on circulation conditions.
5. **Impervious Surface Removal:** As part of the preliminary geometric design, areas of existing pavement that may be candidates for land conversion will be identified.
6. **Drainage Areas, Limits of Disturbance and Stormwater Retention Volume:** The drainage boundaries of the project and preliminary limits of disturbance will be determined, plotted and measured. Drainage areas are usually defined as the area draining to a catch basin or inlet structure. The Stormwater Retention Volume (SWRv) is to be calculated based on areas of impervious cover, compacted cover and natural cover from the proposed conditions within the LOD.
7. **Anacostia Waterfront Development Zone:** If the project is within the AWDZ, calculate the treatment volume required.
8. **Location of Existing Utilities and Storm Drains:** Existing utilities and storm drains will be delineated on plan view. BMP locations will be influenced in part by the existence of utilities and storm drains and required offsets. See **Section 28.8.4.4** for utility clearances at GI facilities.
9. **Existing Trees:** Existing trees to be saved will be identified in the preliminary stage.
10. **Soil Characteristics:** Soils within the LOD will be identified based on Natural Resources Conservation Service (NRCS) Hydrologic Soil Group Type A, B, C, D, Urban Land, or a combination of these where the Soil Survey designates multiple soil names within a map unit. In Type D soil

areas, it is accepted that BMPs will not infiltrate, and soil infiltration testing is not required in these areas.

11. **Candidate BMP and Land Conversion Areas:** Based on the available space within the project limits, all potential BMP and land conversion areas will be identified in the plan.
12. **Street Cross Section:** For areas within the project limits with a deficit of probable BMP sites, consider changing the drainage profile of the street to introduce new candidate BMP locations. Examples include a roadway with a lengthy median sufficient in dimension to install a bioswale (including necessary freeboard). The facilities are not sized at this stage, but identified as candidate locations.

Stormwater Management Plan Submission at 30 Percent Design Phase

The SMM will include:

1. Full topographic survey including storm drain elevations, and utility designation Level C (minimum)
2. Existing contour lines at 1- or 2-foot spacing either from survey or GIS
3. Drainage area boundaries of either existing catch basins or proposed catch basins if designed (this may be provided at a different scale to show a larger area)
4. Drainage area ID #s (to correspond to worksheet)
5. Limits of disturbance
6. ROW lines
7. Adjacent public lands
8. Soil boundary lines based on NRCS Hydrologic Soil Group (A, B, C, D, Urban Land)
9. Hot spots (gas stations, contamination, etc. as further described in the **DOEE Stormwater Management Guidebook**)
10. Locations of existing tree to be retained with a summary chart giving size, species and condition
11. Candidate BMP and land conversion areas, with legend

The MEP worksheet must be completed per the standard template and will include:

1. Regulated SWRv calculations based on land uses within the LOD. The drainage areas can be subdivided into drainage areas, drawing numbers, blocks, or other logical unit at this stage.
2. Off-site (i.e., beyond the LOD) retention volumes calculated where it is presumed that on-site SWRv cannot be managed or treated to meet the regulated volume requirement
3. Hydrologic Soil Group (A, B, C, D or Urban Land)

4. Hot spot identification, if any
5. Preserved existing large-canopy trees
6. Whether BMP candidates are identified for each drainage area

The narrative will include:

1. Description of the project
2. Documentation of extent of impervious area (e.g., lane widths based on design speed/road classification, sidewalk widths based on neighborhood plan or public realm guidance)
3. Summary of known hot spots
4. Qualitative discussion of areas available for land conversion and BMP placement, including what areas are noted as high-probability candidates, and areas that have challenges that may eliminate them as design is developed. The narrative should note whether public lands are adjacent to the project LOD and should include a description of whether the lands are available for SWRv (and why/why not). The feasibility of a street cross section change should be described if it is needed to capture more runoff volume.
5. Description of known conflicts that prevent placement of a BMP or a land conversion, from DDOT and DOEE agreed-upon conflicts or if not on the list, rationale of why the site is not deemed viable.
6. Optional attachments to help reviewers understand the context of the site:
   - Aerial map depicting adjacent land uses, if not fully shown on SMM, with limits of the project noted
   - Copy of soil survey map from Web Soil Survey with limits of the project noted

28.8.3.5. Intermediate (Pre-Final) Stormwater Management Plan – 65 Percent Design Phase

MEP Design at 65 Percent

When the project reaches the 65 percent design submission, the BMP locations may be revised based on project changes and detailed design. BMP size and retention values should be calculated based on the planned depths, infiltration feasibility and known conflicts. The following steps and refinements to the prior design assessment will take place and be incorporated into the submission.

- **Available Space:** The available space for BMP facilities may be reduced or expanded.

- **Pedestrian Circulation Requirements:** The layout of pedestrian circulation elements will be more developed, which in turn may inform where BMP and land conversion opportunities can be implemented.
- **Impervious Surface Removal:** Impervious surface removal and other land conversions will become more defined.
- **Drainage Areas, Limits of Disturbance and SWRv:** The drainage areas, LOD and land cover measurements will be refined at the 65 percent design stage to match the current design elements.
- **Location of Existing and Proposed Utilities and Storm Drains:** At the 65 percent design stage, vertical information for existing utilities may be determined though further survey and utility investigation. Utility relocation corridors are also defined, and proposed storm drains are laid out. Horizontal and vertical locations of utilities within and adjacent to each BMP should be reviewed. These elements will affect the final placement and sizing of BMPs.
- **Existing Trees:** As design progresses, the existing trees to be preserved may change and new trees identified.
- **Soil Characteristics/Geotechnical Testing:** Soil borings and infiltration tests will be performed at each BMP area per the requirements of the **DOEE Stormwater Management Guidebook**. These results will be used in the 65 percent design to determine infiltration capacity, underdrain placement and retention value. Designers will review soil boring and infiltration test results to help define whether infiltration can be incorporated into the BMPs and if a standard or enhanced BMP design should be used. Where soil characteristics permit, infiltration should be used (unless in a hot spot or other area that prohibits infiltration).
- **Longitudinal Slopes:** The suite of BMPs that may be installed on steeper road sections is more limited. Any project design grade changes will be determined, and effects on BMPs should be addressed.
- **Select and Size BMPs:** The size of all potential BMPs will be calculated per the **DOEE Stormwater Management Guidebook** according to BMP type, resulting in a storage volume (Sv) and retention value for each BMP. The allowable retention volume achieved in each practice must be no more than 1.7 inches of runoff volume over the drainage area to the BMP.

Stormwater Management Plan Submission at 65 Percent Design Phase

The SMM will include all information from the 30 percent stage, amended to include:

- Proposed catch basin/storm drain system and corresponding drainage area boundaries

- Revised drainage profile, if needed and determined to be physically viable
- BMPs carried forward, including those proposed on adjacent public land, if needed and determined to be viable
- Sub-drainage area boundaries of BMPs
- Proposed trees whose canopy size at maturity will qualify for given retention volumes
- Soil boring locations
- Vertical information on utilities and storm drain systems, such as proposed storm drain profiles or schedules, or test hole locations and results for utilities. (Storm drain profiles and test hole results can be attachments.)

The MEP worksheet will include all information from the 30 percent stage, amended to current design and as described below:

- SWRv will be defined by drainage area ID # (typically by catch basin)
- Soil boring test results, including infiltration rates, water table and bedrock
- Summary of BMP sizing and resultant retained volume in proposed BMPs (including proposed trees). Include both storage volume of practice (Sv-practice) and retention value from the **DOEE Stormwater Management Guidebook**.
- Where there is a deficit in any one drainage area, revisit BMPs where additional volume can be accommodated by capturing runoff from off-site contributing areas of the BMP, or over-managing the LOD area to attain its maximum volume. This calculation is performed only when the BMP size is greater than what is needed for the regulated volume.
- Total required retention volume and maximum achievable retention volume, including deficit if applicable.

The narrative will include all information from the 30 percent stage, amended to current design and include:

- Description of conflict areas that reduced BMP storage volume or eliminated candidate BMP sites from further consideration
- Description of why public lands were eliminated as candidates for BMP, if applicable
- Supporting narrative of soil boring and infiltration results if not fully conveyed on the worksheet (e.g., multiple soil tests per drainage area or practice with varying results). Include the geotechnical report as an attachment.
- Supporting narrative of the BMP sizing results if not fully conveyed on the worksheet

Calculations will include individual BMP sizing calculations for:

- Storage volume and retention value achievable based on physical size, depths, infiltration rates and placement of underdrains
- Hydraulic traits such as inflow and overflow velocities, freeboard and conveyance calculations

Specific BMP facility design information to be included with the 65 percent design submittal and subsequent design submittals will include:

- Plans with the types, locations and dimensions of all stormwater management facilities and associated planting plans with the underdrain connection point shown
- The depths of all BMP material layers, ponding depths and pipes
- Sections and profiles to show any steps, underdrains and utility lines through the facility
- Maintenance schedule on plans per DOEE requirements and **DDOT Green Infrastructure Standards**

Landscape and Planting Plan Submittal – 65 Percent Design Phase

Additional information for tree space design must be included with the 65 percent design submittal and subsequent design submittals to include:

- Plans with the types, locations and dimensions of all tree spaces
- Plans clearly depicting the locations, dimensions, open and covered soil areas and soil volumes needed for each tree
- Detailed illustration of the overall size, depth, soil composition and drainage of the planting space
- Calculations showing contributing drainage area ratios for each facility
- Calculations of soil rooting volume requirement and volume achieved per street tree
- Statement from an engineer or soil scientist relative to anticipated infiltration rates in the subsoil or NRCS Soil Survey Report

28.8.3.6. Final Stormwater Management Construction Plans, Specifications and Cost Estimates – 90 Percent and Final Design Phases

MEP Design at 90 Percent and Final Design

When the project reaches the final design submission phase, updates and refinement to the prior design assessment may take place. The following items may be updated or refined and incorporated into the 90 percent and final submissions:

- Available space
- Impervious surface removal
- Drainage areas, limits of disturbance and SWRv
- Locations of existing and proposed utilities and storm drains
- Existing trees to remain
- BMP locations, sizes, SWRv and retention value
- Water quality treatment devices. For drainage areas in the project LOD where retention practices cannot be put into place, if they are within the MS4, water quality catch basins or other treatment technologies must be used to provide water quality treatment for the SWRv.

Additional BMP facility design information to be included with the 90 percent design submittal and subsequent design submittals will include:

- Plans, sections or profiles with the following elevations depicted:
  - Inflow elevation
  - Outflow elevation (for online facilities)
  - Invert elevation of bioretention surface
  - Top of ponding elevation
  - Bottom of reservoir/stone layer (bottom of storage)
  - If applicable, underdrain connection point with the tie-in invert elevation
- Profiles to show any steps, underdrains and utility lines through the facility

SWMP Submission at Final Design Phase

- Update the SMM, narrative, MEP worksheet and calculations to incorporate changes that have occurred since the last milestone due to newly determined constraints or newly found opportunities

- Provide a final summary of retention volumes required and achieved
- Identify areas where zero retention is achieved and the BMPs used

28.8.4. Design Guidance and Control Methods

28.8.4.1. Design Guidance for Low Impact Development

Choice of stormwater facilities should be based on the context of the surrounding streetscape. In addition to the benefits to stormwater quality and quantity, multi-purpose design of stormwater facilities can add aesthetic value to the City by providing varied landscaping, visually appealing pavement design and enhanced community spaces on streets. They can also be combined with traffic calming features.

The process for selecting and designing GI facilities in a roadway project begins with site analysis:

1. Identify the street layout. The dimensions of the travel lanes, location of medians, islands and buffer strips, and all elements related to the functionality of the roadway will be established in the design plan.
2. Include other transportation modes. The requirements for pedestrian traffic, cyclists, mass transit and other possible modes are incorporated into the ROW as well.
3. Choose stormwater facility locations and types. Implement stormwater facilities that can capture and treat the runoff from impervious surfaces prior to entering the storm drain system. Consider spaces between curbs and sidewalks, behind sidewalks, in channelized islands and on medians for vegetative practices. Consider parking lanes, alleys, sidewalks and other roadways for permeable pavement. Maximize tree space. GI facilities should be placed to maximize volume capture. Adjacent GI and BMP facilities should be closely reviewed to ensure they will receive water flow from the design storm.

Stormwater practices can add health and value to the urban ecology by enhancing the linkage of existing parkways and parks for improved aesthetics and neighborhood community spaces. In addition, these localized vegetated areas can create new habitat for wildlife, particularly birds and butterflies. The end result of implementing these street improvements is a more sustainable and attractive urban environment.

28.8.4.2. Permeable Pavement

Permeable pavement may be proposed for use in place of impervious pavement in appropriate locations. The DDOT Infrastructure Project Management Administration must approve any use of permeable pavement at specific locations in DDOT roadways, alleys and trails.

Types of Permeable Pavement Facilities

The types of permeable pavement facilities and appropriate uses are tabulated in Table 28-3 Types subjected to vehicular traffic loads include porous asphalt, pervious concrete and permeable unit pavers. Using other types of permeable pavement requires approval from DDOT and will be reviewed on a case-by-case basis.

Table 28-3 | Permeable Pavement Facilities

Type / Application	Alley	Roadway*	Sidewalk	Covered Soil Volume for Plants	Trail
Porous Asphalt	●	●			●
Pervious Concrete	●	●	●	●	●
Permeable Interlocking Unit Pavers	●	●	●	●	
Other Unit Pavers **				●	
Porous Flexible Pavement			●	●	●
Porous Bound Aggregate			●	●	
Porous Grass Pavement	●			●	

*** Appropriate for low-volume roadways and dedicated parking lanes; not currently allowed for collectors, arterials and freeways**
**** Spaced to allow infiltration**

Contributing Drainage Area to Permeable Pavement

The ratio of maximum contributing drainage area to permeable pavement surface area should meet **DOEE Stormwater Management Guidebook** requirements, unless otherwise approved by DDOT. Stormwater runoff from pervious areas often contributes sediment and leads to clogging and increased maintenance requirements for permeable pavement. Pervious areas draining to permeable pavement should be avoided to the maximum extent possible. At least 90 percent of the area draining to permeable pavement should be impervious, not including the permeable pavement area itself. If less than 90 percent of the contributing drainage area is impervious, DDOT will consider installing permeable pavement on a case-by-case basis; pretreatment, drainage area stabilization and specific maintenance program options should be considered to prevent clogging of pavement.

Permeable Pavement Base Design

All Permeable Pavement Systems:

- The wearing surface is the pavement material plus any required bedding layers under the surface and inside of the joints, in accordance with all applicable standard details, specifications and manufacturer recommendations as applicable. The wearing surface must meet the latest Americans with Disabilities Act (ADA) requirements.

Vehicular Use Permeable Pavement Systems (Roadway, Alleys):

- The choker layer is an open graded stone, typically #8 or #57 stone, between the wearing surface and the reservoir layer, for providing separation and preventing migration between the layers due to the differences in material and void sizes underneath.
- The reservoir layer is an open graded stone, typically #2, #3 or #57 stone, under the choker layer, for meeting the 1.2-inch retention volume requirement (to the maximum extent practicable, where applicable). The depth of the stone will be determined in part based on the required storage volume for the site, drawdown times and pavement design requirement.

Pedestrian Use Permeable Pavement Systems (Sidewalk, Trail, Covered Soil Volume):

- The aggregate base layer is an open graded stone under the pavement for meeting the 1.2-inch retention volume requirement (to the maximum extent practicable, where applicable). The depth of the stone will be determined based on the required storage volume for the site, with a minimum of 6 inches where above tree soil volume, and a minimum of 4 inches otherwise.
- Beneath the aggregate base layer in sidewalk and trail areas, the subgrade must be scarified where feasible, and not compacted when infiltration is desired. When the subgrade is not compacted, the aggregate base layer should be increased to 6 inches for additional support.
- Beneath the aggregate base layer in covered soil tree space areas, there is a layer of structural soil as described in **Chapter 37** of this manual (see also **DDOT Green Infrastructure Standard Drawings 621.73–621.76**).

Geotextiles and Liners:

- Geotextile meeting requirements of the current DDOT specification for use in stormwater facilities must be placed on the sides of open graded stone to prevent migration of adjacent fine material into the permeable pavement stone.
- Impermeable waterproof membranes should be used in permeable pavement systems as follows:
    - On the side adjacent to any facilities within 10 feet of a structure (e.g., an existing building)
    - At the interface between pervious pavement and traditional pavement
    - In areas where infiltration is not permitted, such as hot spots and for utility protection as necessary
    - In facilities designed for water re-use or harvesting
    - Where the installation is located on expansive soils, as determined by a geotechnical engineer

Stormwater Conveyance and Retention for Permeable Pavement

Stormwater conveyance from all impervious areas including standard pavement must, to the extent feasible, drain to permeable pavement as sheet flow. Otherwise, pre-treatment for energy dissipation and sediment control may be required where any concentrated flow is directed onto permeable pavement. Level spreaders may be designed to convert concentrated flow to sheet flow into the permeable pavement facility.

Reservoir and Underdrain Sizing for Retention Volume

Permeable pavement must be designed to store water volumes that meet the requirements of the **2013 Stormwater Rule**, including applicable MEP procedures. Storage design must meet the following:

- Subsurface drainage will consist of a 4-inch- to 6-inch-diameter perforated underdrain in the reservoir layer or a separate layer of open graded stone below the reservoir layer. Subsurface drainage must be installed beneath all vehicular use permeable pavement installations unless otherwise approved by DDOT. Permeable pavement may be installed in alleys and low traffic-volume roads without underdrains if infiltration rates are sufficient and underdrain connections are not feasible.
    - For sites where native soil design infiltration rate is sufficient to drain the volume below the underdrain within 48 hours, the subsurface pipes may be elevated to create infiltration

sumps of reservoir stone. Raising the underdrain is encouraged and enhances retention. An alternative approach to a raised underdrain is an underdrain with an up-turned elbow outlet.

  - For designs with a waterproof membrane on the bottom as required in the “Geotextiles and Liners” section above, the minimum slope of the subsurface drainage pipes is 2 percent and must match the bottom (invert) slope of the facility.
  - For designs without a waterproof membrane, the minimum slope of subsurface drainage pipes is 0.5 percent when placed above the frost line.
  - Clean-outs are required for all permeable pavement facilities with underdrains. Clean-outs should be spaced at 100-foot maximum intervals. Where a storm drain structure such as a catch basin, manhole or overflow structure is within 100 feet of a clean-out, the structure may be used as a clean-out.
  - Observation wells are required for facilities without underdrains and must be shown on design plans. Observation wells should be spaced at 100-foot maximum intervals.

- Drawdown time for 1.2 inches of runoff volume over the contributing drainage area is 48 hours maximum. Drawdown time is calculated using the **DOEE Stormwater Management Guidebook** equations.
- The reservoir should be sized to accommodate the 2-year, 24-hour frequency storm below the wearing surface at all points along the length of the facility.

  - Overflow conveyance for higher-frequency storms should be designed to flow into existing or new storm sewer systems adjacent to the permeable pavement.

- To achieve the design volume, the profile of the pavement should be designed in one of the following scenarios, which will be selected based on topography of the site, location of utilities and other underground features, project budget, and any other constraints related to the specific site:

  - Continuous bottom slope, 2 percent maximum.
  - Terraced invert with 2 percent maximum slope between steps. The vertical drop of a terraced invert should generally be 6 to 12 inches, but can vary to achieve design requirements.
  - Check dams with variable bottom slopes located so that the 2-year, 24-hour runoff volume does not surcharge the low end of the wearing course. Check dam material options include waterproof membrane, polyvinyl chloride (PVC) sheeting, acrylic sheeting, plastic lumber,

rocks, concrete or other material explicitly approved by DDOT. Membranes and sheeting are the most cost-effective and generally preferred options. A transverse underdrain may be needed in check dam systems if the base of a step does not slope to the longitudinal underdrain or if the permeable pavement system is very wide.

Permeable Pavement Structural Design

For alleys, driveways and parking lanes using permeable pavement, the **DDOT Green Infrastructure Standard Drawings** will be used.

For other pavements subjected to vehicle traffic loading, pavement design calculations are required. Pavement design may result in modifications to the pavement cross section in the DDOT-approved standard drawings to meet or exceed the pavement strength requirements. The following methods should be used for structural design of each type of permeable pavement:

- Pervious concrete: AASHTO methods for rigid pavement design
- Porous asphalt: AASHTO methods for flexible pavement design
- Interlocking permeable unit pavers: AASHTO methods for flexible pavement design, with appropriate layer coefficients as applicable to the interlocking, shape and thickness of the pavers. Guidance for layer coefficients is provided by the Interlocking Concrete Pavers Institute.

Testing of the bearing capacity for underlying soils is required for all permeable pavements for vehicular use, is site-specific, and must be in accordance with **ASTM D4429-09a, Standard Test for California Bearing Capacity of Soils in Place**.

Other requirements for pavement design include:

- Edge restraints must be used for all permeable unit pavers. Edge restraints may also be used for porous asphalt and pervious concrete as necessary.
- In soft soils with low bearing capacity where infiltration is planned, geo-grid is preferred over removal of the material and placement/compaction of select backfill.

Limitations of Permeable Pavement

- The bottom of permeable pavement systems, including storage layers and underdrains, must be located at least 2 feet above the seasonally high water table.
- Permeable pavements with infiltration are not allowed in hot spots as defined in the **DOEE Stormwater Management Guidebook**.

- Permeable pavement requires more frequent maintenance if it is installed where sand use is expected, such as in residential areas where adjacent homeowners may treat walkways with sand. Avoid installation of permeable pavements in these areas or ensure, during design, that the required level of maintenance will be achieved after installation.

28.8.4.3. Bioretention

When applicable, bioretention may be installed in a public ROW to retain or treat stormwater runoff. Bioretention should be placed in existing or proposed vegetated areas and landscaped with a selection of plants from the current DDOT-approved planting list. The Designer will select areas for bioretention using the MEP process as detailed in the **DOEE Stormwater Management Guidebook** and in **Section 28.8.3**. Possible areas for bioretention include tree space, parking lanes, bump-outs for traffic calming, intersection triangles, open areas and areas adjacent to sidewalk.

Bioretention design must be consistent with the **DOEE Stormwater Management Guidebook** with the following additional requirements.

Types of Bioretention Facilities

- **Bioretention Basins in Open Areas:** This type is a subset of DOEE's Traditional Bioretention and is a moderate to large-scale bioretention cell with ponding depths up to 18 inches. These facilities will include shrubs and groundcover, and sometimes tree plantings. Basins in open areas will typically have sloped sides, and can be online or offline as defined by the **DOEE Stormwater Management Guidebook**.
- **Curb Extension Bioretention:** This type is a subset of DOEE's Streetscape Bioretention and is generally placed in locations where a new curb is constructed into a parking lane to create an opportunity for bioretention, which may or may not incorporate a portion of the street tree space. Curb extensions may have sloped or vertical sides. In most cases, curb extensions will be designed as online facilities.
- **Streetscape Bioretention Planters:** This type is a subset of DOEE's Streetscape Bioretention and is typically a small-scale bioretention cell, often located between the curb and sidewalk. These facilities may include tree, shrub and groundcover plantings. Streetscape bioretention planters usually have vertical sides, but may have sloped sides if sufficient space is available. In most cases, bioretention planters will be designed as offline facilities.
- **Bioswales:** This facility type is consistent with DOEE's Dry Swale/Bioswale category, and includes a drainage channel or linear infiltration basin adjacent to either the roadway or the sidewalk, and vegetated with trees, shrubs, groundcover or turf. Bioswales may be designed to convey or

retain stormwater. Swales adjacent to roadways that receive stormwater runoff from roadway surfaces must be designed according to the requirements of the **DOEE Stormwater Management Guidebook** as open channels. Bioswales without curbs are online facilities.

Bioretention Cross Sections

Soil types used in bioretention facilities must be in accordance with the DDOT-approved soil specification (**DDOT Green Infrastructure Standard Specifications**).

In addition to following DOEE requirements, bioretention facilities must be designed as follows:

- A layer of 3 inches of triple shredded mulch is placed on top of bioretention media.
- The soil profile within basins, curb extensions, planters and bioswales must consist of 18 to 36 inches of bioretention soil (per **DOEE Stormwater Management Guidebook** for Filter Media, Chapter 3.6.4), sized to meet the retention volume requirements to the maximum extent practicable (where applicable). Areas with trees must contain a minimum of 24 inches of soil, and 30 inches is preferred.
- For underdrain layers, see “Bioretention Sizing and Hydraulic Design Requirements for Stormwater Retention Volume” later in this section.
- Additional stone may be placed beneath the underdrain layer, or beneath the bioretention soil in cases where no underdrain is present, to enhance the infiltration volume of the facility and achieve additional stormwater retention volume.
- Impermeable liners are required in bioretention facilities as follows:
    - Facilities within 10 feet of a structure (e.g., an existing building) must be lined on the side adjacent to the structure.
    - Facilities within 5 feet of the roadway face of curb must be lined on the side adjacent to the roadway.
    - Facilities in specified clearances from utilities are described in **Section 28.8.4.4**.
    - In areas where infiltration is not permitted, such as hot spots, facilities must be lined on all sides. In this case, subsurface drainage is required.

Contributing Drainage Areas

The impervious cover areas that drain into bioretention facilities should be limited in size to prevent excessive saturation of soils and the consequent development of anaerobic soil conditions. The maximum contributing impervious area to bioretention surface area ratio is recommended as follows:

- For bioretention basins, curb extensions and streetscape bioretention planters without subsurface drainage: 20:1
- For bioretention basins, curb extensions and streetscape bioretention planters with subsurface drainage: 33:1
- For other bioswales and open drainage channels: based on engineering design

For ratios above these limits, the runoff inflow to the bioretention area must be controlled to not allow excessive water into the facility.

Allowable Ponding Depths

- Allowable ponding depths in bioretention facilities will be determined based on the adjacent land use, expected pedestrian activity and the associated need for barriers around the facilities as described in the "Safety and Access" section below. The maximum allowable ponding depth in bioretention is 18 inches. The average ponding depth across a bioretention surface must meet the requirements set in the **DOEE Stormwater Management Guidebook**.
- Bioretention in high-volume pedestrian and residential areas will typically have a 6-inch maximum ponding depth. The ponding depth may vary based on slope conditions.
- Bioretention basins may be designed at depths that will require safety barriers or fencing.
- Bioswales must be designed with depths and/or side slopes that do not require barriers.
- Streetscape bioretention planter and curb extensions may be designed at depths that will require railings or curb.

Bioretention Sizing and Hydraulic Design for Stormwater Retention Volume

Bioretention facilities must be sized with volumes to meet the regulatory requirements promulgated by DOEE, including applicable MEP procedures. Storage design must meet the following:

- Maximize bioretention soil depth (filter depth).
- Design for a maximum drawdown time of 72 hours for the designed runoff volume. Drawdown time must be calculated using the **DOEE Stormwater Management Guidebook** equations.
- Where subsurface drainage is required by **DOEE Stormwater Management Guidebook**:
    - A choker layer consisting of a minimum of 3 inches of sand and gravel must be placed beneath the bioretention soil to prevent the soil from migrating into the underlying stone.

  - A reservoir layer of 10 to 12 inches of open graded #57 stone must be placed beneath the choker layer, with perforated pipes embedded in the #57 stone. Geotextile must be placed on the sides of the #57 stone.
  - A minimum of one clean-out is required for basins and curb extensions, and must be shown on design plans. For other bioretention facilities, a clean-out must be provided within 10 feet of the underdrain connection to the catch basin, sewer or manhole.
  - Connect underdrains to catch basins, manholes or directly to storm sewer pipe. Connection to a catch basin is usually the most cost-effective option. When directly connected to the Combined Sewer System, place a backflow preventer valve on the underdrain connection.

- For bioretention facilities without underdrains, observation wells are required and must be shown on the design plans. The maximum spacing of observation wells is 100 feet.
- Use curb openings with depressed gutters to convey runoff to bioretention facilities adjacent to curbed roadways. Size the openings to deliver the volume of runoff to the facility that the size of the facility can handle, per DOEE requirements:

  - Use the method in the **DOEE Stormwater Management Guidebook** Appendix H.6 to convert the flow associated with the stormwater retention volume for which the BMP is being designed into peak discharge.
  - Use the method in **FHWA HEC No. 22** to size the curb opening to achieve 100 percent interception, while meeting the spread requirements of **Section 28.2.2** for the 15-year storm. Multiple curb openings can be used for each facility to deliver the required volume.

- Curb cuts across sidewalks and step-out zones require trench covers.
- Check dams in bioswales and curb extension bioretention facilities may be necessary to allow ponding depth, achieve the storage volume and/or accommodate slow velocities. Check dams will be placed in sloped facilities at intervals to maintain ponding depth and facility depth within allowable limits.
- Pre-treatment devices are required to trap coarse sediment. Applicable choices include:

  - **Bioretention in Open Areas:** Stone-filled forebay or spreader, stone diaphragm or grass filter strip.
  - **Curb Extensions:** Concrete or stone entry splash pad as depicted in **DDOT Standard Drawings**.
  - **Streetscape Bioretention Planters:** Stone splash block adjacent to curb cut, trash rack or leaf screen across curb cut.

- Overflow devices are required for online facilities, and also for offline facilities where the lowest adjacent top of curb or sidewalk is equal to or lower than the inflow point elevation. Typical overflow devices include outflow curb openings to gutter and overflow structures. Size overflow devices for online bioretention to convey the design storm specified in **Section 28.2**. Where overflow devices are in the roadway or supersede standard drainage structures, they should be sized to meet the spread requirements per **Section 28.2**. For online facilities, provide a minimum of 3 inches of freeboard from the overflow structure to the overtopping elevation.
- Side slopes of bioswales must be designed to prevent erosion based on anticipated stormwater flow rates. Jute or coir erosion control mats should be used to stabilize soils until plantings have been established.

Safety and Access

- Edges around bioretention facilities adjacent to pedestrian areas may be sloped or have a vertical drop.
  - Railings are required around bioretention with a vertical drop adjacent to sidewalks in high-volume pedestrian areas.
- The top of the railing must be 18 inches above the sidewalk, with vertical and/or horizontal member spacing that meets ADA detection requirements for visually impaired pedestrians.
  - Bioretention with vertical drop adjacent to sidewalks in low-volume pedestrian areas must be surrounded by a curb of minimum 4 inches high and 6 inches wide.
  - Bioretention with vertical drop must have a curb of minimum 4 inches high or railing between the parking step out zone and the drop.
  - Bioretention with a sloped side must have a flat (8 percent maximum slope) 6-inch minimum width buffer of different material to meet flush with the adjacent sidewalk. Bioretention with a drop from the sidewalk surface to the bioretention surface greater than 3 feet must have a flat (8 percent maximum slope) 24-inch minimum width buffer. When sides are sloped, the finished grade must be stabilized with plants, sod, seed, mulch or stone.
  - Bioretention adjacent to a designed shared-use path (bicycle facilities) must have a flat (6:1 maximum slope) 24-inch width buffer of different material to meet flush with the adjacent path. A side with a maximum 3:1 slope and maximum 5-foot drop from the sidewalk surface to the bioretention surface or 12-inch maximum vertical drop from the sidewalk surface to

the bioretention surface is allowed. If either of those conditions is exceeded, a 42-inch-high guard is required.

- Pedestrian crossings of continuous bioretention facilities adjacent to curbs are required as follows:
    - One 6-foot paved crossing between each street tree and 35-foot maximum spacing in high-volume pedestrian areas
    - One 6-foot crossing every other tree and 70-foot maximum spacing in other areas consistent with surrounding area (paved, grass or mulched)
- A parking step-out zone between 12 inches and 36 inches wide, optimally 24 inches (measured from face of curb) is required for bioretention adjacent to parking lanes. In high-volume pedestrian areas, the step-out zone must be 18 inches wide at a minimum, including roadway curb. In low-density pedestrian areas, the step-out zone may be 12 inches wide at a minimum.
- When placing and designing bioretention facilities adjacent to travel ways, check AASHTO warrants for clear zone and traffic barrier needs. Adjust design to avoid use of traffic barriers whenever possible. The curb serves as a barrier for vehicle safety on most city streets. On streets without curbs, provide a 24-inch minimum graded shoulder between the road and bioretention, with a maximum 3:1 side slope beyond the shoulder to a maximum drop of 5 feet.
- Bioretention facilities with sloped sides and a total depth of more than 5 feet require a fence at least 36 inches high enclosing the entire facility.
- Facilities with a vertical drop of more than 30 inches require a 42-inch-high railing meeting **International Building Code 1013 (Guards)**.
- Access to all bioretention areas is required for maintenance. For facilities not adjacent to the road, an access road may be needed. For facilities on high-speed roads, ensure safe access via a shoulder or designated area. The overflow structure inside the bioretention area must be accessible to maintenance crews.

Limitations

- The bottom of bioretention facilities must be at least 2 feet above the seasonally high water table.
- Bioretention with infiltration is not allowed in hot spots as defined by DOEE.

28.8.4.4. Utility Clearances at GI Facilities

Utilities are allowed to be collocated in GI facilities subject to acceptance by the utility owner. Individual projects should be coordinated with the utility owners for specific requirements. Current guidelines for clearances of utilities are as follows:

Communications/Power

- Communication and electric lines in concrete conduits may run through GI facilities.
- Communication and electric lines not in concrete conduits will have 6-inch minimum vertical clearance and 2-foot minimum horizontal clearance.
- Utility poles may be located in permeable pavement facilities, but may not be located within bioretention unless additional stabilization is provided for the pole.
- Manholes may be located in permeable pavement facilities, but may not be located within bioretention.

Gas

- For gas lines within 6 to 24 inches of GI facilities, the Contractor must install a protective shield around the pipe. The shield must be made of fiberglass-reinforced plastic or other approved insulating material, in either a 12-inch by 12-inch flat tie plate or clip-on configuration. The shield must be placed over the gas pipe and secured in place.
- For gas lines that are less than 6 inches from the GI facility or within the GI facility, the Contractor must install a combination of a protective shield and sleeve. The protective sleeve must consist of either a gray PVC semi-circular sleeve, which comes in 60-inch lengths, or a larger plastic pipe. This protective sleeve must be installed over the gas pipe so that the protective sleeve extends at least 9 inches on either side of the area in conflict. The shield must meet requirements described above.
- Maintain a minimum of 12 inches of separation from underdrains to a gas facility.
- For excavations within 2 feet of gas facilities, the Contractor must install sheeting and shoring protection to protect pipe during construction if directed by the DDOT Engineer.
- A 4-foot minimum clearance is required between the top of gas facilities and the finished road surface grade.
- A 3-foot minimum cover is required over gas facilities in open drainage or road ditches.

Water and Sewer

- Reference DC Water Green Infrastructure Utility Protection Guidelines.
- A minimum of 12 inches of cover is required between the bottom of GI facilities and a water main, sewer main or sewer lateral.
- When less than 5 feet of vertical clearance is provided between the bottom of a GI facility and a sanitary sewer main, an impermeable liner must be used at the bottom of the GI facility to a horizontal distance at least 3 feet beyond the sewer main.
- Water service laterals may run through GI facilities.
- Concrete collars must be provided around surface structures within GI facilities (clean-outs, valve boxes, etc.). The top of collar must be above ponding depth in bioretention.

Street Lights

- Street light conduits and poles can run through GI facilities.
- The Designer must ensure that installation of shrubs or plants does not block access to openings of the transformer base. Access to transformer bases can face either the roadway or the sidewalk.

Fire Hydrants

- On the sidewalk side, a 3-foot minimum clearance must be provided around hydrants.
- On the street side, a 10-foot clearance must be provided in each direction longitudinally along the street, and 4 feet into the street to create a 4-foot by 20-foot access area. This access area may be paved with permeable pavement.

28.9. Soil Erosion and Sediment Control during Construction

During the design process, the Designer should take due diligence to minimize soil erosion and control sediment from roadway construction sites. The construction of roadway and transportation facilities tends to accelerate erosion and sedimentation, which can result in significant impacts to the environment and progress of work.

Projects that disturb more than 50 square feet of soil must have a Soil Erosion and Sediment Control (SESC) plan prepared and submitted it to DOEE to obtain an SESC permit. The SESC plans and practices must be in accordance with the current **DOEE Soil Erosion and Sediment Control Handbook**.

When a project's disturbed area is 1 acre or more, a Notice of Intent (NOI) is required for Storm Water Discharges Associated with Construction Activity under the National Pollutant Discharge Elimination System (NPDES) Environmental Protection Agency (EPA) Construction General Permit. The NOI is a U.S. EPA, NPDES form titled "Notice of Intent (NOI) for Storm Water Discharges Associated with Construction Activity Under a NPDES General Permit" and is submitted electronically through the EPA E-NOI website.

All Erosion and Sediment Control measures should be in accordance with the current **DOEE Soil Erosion and Sediment Control Handbook**.

29 Bicycle Facilities and Shared-Use Paths

29.1. General

The District has made a commitment to building a citywide network of on-street bicycle lanes, signed routes and other bicycle facilities to accommodate the rapidly growing number of cyclists. These efforts have been successful in making streets safer for all users: drivers, pedestrians, transit riders and cyclists. As bicycling becomes more accessible and visible, the City continues to see a dramatic increase in the number of bicyclists. Peak hour cycling has increased by more than 200 percent citywide, and bicycle commute trips by District residents have risen from just roughly 1 percent in 2000 to more than 4 percent in 2012.

The District's priority of expanding the bicycle network requires consideration of different types of facilities to provide safe and comfortable accommodation for all levels of bicyclists.

When designing improvements, refer to the **DC Bicycle Master Plan**, **moveDC**, the **DDOT Bicycle Facility Design Guide** and the National Association of City Transportation Officials (NACTO) **Urban Bikeway Design Guide**, and also confer with the DDOT Bicycle Program office.

The proper placement and design of bike and pedestrian facilities are important elements of all projects. The Project Manager should include bicycle and pedestrian facility options on new construction and reconstruction projects. These facilities are an integral part of the roadway environment. All streets and bridges must be designed without any impediment to bicycles and pedestrians and have wheelchair/bicycle ramps; curb inlets on streets and scuppers on bridges must have safety grates. For Resurfacing, Restoration and Rehabilitation type projects, the design of pedestrian and bicycle facilities should be considered where warranted and cost effective.

Bicycle and pedestrian facilities, including sidewalks, crosswalks, over/underpasses, traffic control features, curb cuts and access ramps for persons with disabilities, should adhere to the latest design standards and Americans with Disabilities Act requirements. Curb cuts and other provisions for persons with disabilities are required on all Federal Aid projects involving provisions for curbs or sidewalks. Exceptions to Americans with Disabilities Act standards require federal variance approval. The need to provide traffic control for bicycles and pedestrians should be included in the Traffic Control Plan. See the latest version of **Manual on Uniform Traffic Control Devices (MUTCD)** and the **D.C. Temporary Traffic Control Manual** for more information.

According to the Code of Federal Regulations, Title 23, Highways, the safe accommodation of pedestrians and bicyclists should be given full consideration during the development and construction of

Federal Aid highway projects. The special needs of the elderly and persons with disabilities must be considered on all Federal Aid projects.

Where current or anticipated pedestrian and/or bicycle traffic presents a potential conflict with motor vehicle traffic, every effort must be made to minimize the conflicts. Where rumble strips or speed humps are proposed, they should be properly designed so as not to have any adverse effects to bicycles.

Replaced and rehabilitated bridge decks should be reconstructed to accommodate bicyclists where they are permitted and when the cost is reasonable. The Project Manager is responsible for evaluating bicycle and pedestrian facilities in the design of any new construction and reconstruction work.

Pedestrian and bicyclist movements are less predictable than motorist movements. The Designer should consider this to ensure the safety of all modes wherever the interaction of these different modes of transportation occurs. The project scoping document should discuss the applicability of providing bicycle and pedestrian facilities based on design data. For new or reconstruction projects, the Project Manager should document design decisions and variances for bicycle and pedestrian facilities.

This chapter sets forth the minimum criteria to be used in the design of all bike lanes and other bicycle facilities, as well as shared-use paths, within the District's rights-of-way and easements.

29.2. Regulations and Guidelines

The guidelines below should be used when developing bicycle facilities and shared-use paths:

- American Association of State Highway and Transportation Officials (AASHTO), Guide for the Development of Bicycle Facilities
- AASHTO, Policy on Geometric Design of Highways and Streets
- AASHTO, Guide for the Planning, Design, and Operation of Pedestrian Facilities
- American Traffic Safety Services Association (ATSSA)
- Institute of Transportation Engineers (ITE)
- Manual on Uniform Traffic Control Devices (MUTCD) Part 9
- NACTO, Urban Bikeway Design Guide
- NACTO, Urban Street Design Guide
- District of Columbia Municipal Regulations (DCMR) Title 18: "Vehicles and Traffic" and other applicable District regulations and statutes
- DDOT, Bicycle Facility Design Guide
- DDOT, Pedestrian Design Guide

- DC Bicycle Master Plan
- moveDC
- US Access Board, Outdoor Developed Areas, May 2014
- US Access Board, Public Rights-of-Way Accessibility Guidelines – Shared Use Paths

While designers should consider all of the above references, the final design considerations will be made in consultation with the DDOT Bicycle Program Manager.

29.3. Common Bicycle Facilities

The District's Bicycle Program is committed to providing safe and convenient bicycle access throughout the City. DDOT has created a network of citywide bicycle facilities that help create complete streets that are safe and enjoyable for all users. Increased separation of bicycle facilities from motor vehicle traffic and pedestrian access routes typically results in higher levels of user comfort and appeals to wider skill levels of bicyclists. Common bike facilities in the District include the following:

- **Shared Roadways.** Streets and roads where bicyclists share the travel lanes with motor vehicles and may share the roadway with pedestrians without the need for special bicycle accommodations; provides minimal separation.
- **Signed Shared Roadways and Neighborhood Bikeways.** Roadways that use signs to show that the roadway is a preferred route for bicycle use; provides moderate separation.
- **Shared Lane Markings.** Streets too narrow for conventional bike lanes that use pavement markings; intended to alert motorists to share the road with bicyclists; provides minimal separation.
- **Bike Lane.** A portion of a roadway designated by pavement markings for the use of bicyclists. Bike lane configurations include conventional, contra-flow, and left-side. Bike lanes may be distinguished using color, lane markings, signage, and intersection treatments. The minimum width for a bicycle lane is 5 feet from the edge of pavement; provides moderate separation.
- **Buffered Bicycle Lane.** Traditional bike lane separated by a painted buffer or parking lane that creates a buffer between the bike lane and the vehicle travel lanes; provides good separation.
- **Protected Bicycle Lane (Cycle Track).** An exclusive bike facility that is physically separated from motor traffic and is distinct from the sidewalk for the exclusive use of bicycles that provides and extra sense of security for both cyclists and drivers. May be one-way or two-way, at street level or sidewalk level; provides high separation.
- **Shared-Use Pathways/Multi-Use Trails.** A high-quality walking and bicycling experience in an environment that facilitates separation from traffic; provides high separation.

- **Climbing Lane.** Same as a bike lane except there is a bike lane on the uphill side of the road and a shared lane on the downhill side.
- **Contra-flow Bike Lane.** Same as a bike lane except there is a bike lane going in the opposite direction of travel for the rest of the roadway.

Table 29-1 offers guidance as to what types of treatments are recommended depending on street classification, volume and speed.

Table 29-1 | Bicycle Facility Contextual Guidance (Source: NACTO)

Street Class	Desired Average Annual Daily Traffic	Posted Travel Speed (mph)	Desired Facility Type
Local	0–2,000	15–20	Neighborhood Bikeway
Local	2,000–8,000	15–25	Shared Lane Marking
Collector Arterial	4,000–15,000	20–30	Bike Lane
Collector Arterial	4,000–25,000	25–40	Buffered Bike Lane
Collector Arterial	9,000–25,000	30–50	Protected Bike Lane/Cycle Track
Arterial Freeway	6,000–30,000+	45–60	Shared-Use Path

29.3.1. Shared Roadways

Most bicycle travel takes place on the roadway system. Bicycles are permitted on all roadways in the District of Columbia, as shared roadways, except for full-access controlled facilities, such as interstates and divided expressways. Enhancing safety and capacity for bicycle traffic can be achieved through low-cost measures such as:

- Paved shoulders (at least 4 feet)
- A wide outside traffic lane if no shoulders exist (12 feet to 14 feet)
- Bicycle-safe drainage grates
- At-grade manhole covers
- A smooth, clean riding surface
- Bicycle-sensitive loop and microwave traffic signal detectors

29.3.2. Bike Routes

Certain streets are designated in the **DC Bicycle Master Plan** as on-street bicycle routes and are marked with bicycle route signs. Refer to the **Bicycle Facility Design Guide** for sign design and placement, and the **Bicycle Master Plan** to determine existing or proposed bicycle routes.

29.3.3. Bicycle Lanes

Common bike lane configurations include conventional, contra-flow, and left-side. Conventional bicycle lanes must be placed to the right of travel lanes. Bicycle lanes on one-way streets must be on the right side of the street unless otherwise specified by DDOT. Contra-flow bike lanes are bicycle lanes designed to allow bicyclists to ride in the opposite direction of motor vehicle traffic. Left-side bike lanes are conventional bike lanes placed on the left side of one-way streets or two-way, median-divided streets.

The minimum width of a bike lane is 5 feet from the edge of pavement. The minimum desired width for protected bicycle lanes (cycle tracks) is 5 feet. In areas with high bicyclist volumes or uphill sections, the minimum desired width is 7 feet to allow bicyclists to pass each other. Variations from these recommendations should be approved by DDOT.

Special attention should be paid where bicycle lanes interact with streetcar tracks and facilities. Specific elements that should be taken under consideration for design are:

- Streetcar lanes relative to bike lanes: inside lane or outside lane for streetcar
- Skewed angle between bike lanes and streetcar tracks must be near perpendicular (no less than 60 degrees) to minimize interaction between the bike wheel and track flangeway, and reduce slippage on wet rails
- Necessity to avoid track switches and tight-radius curves
- Interaction between bike lanes and station platforms and bulb-outs
- Potential to provide a grade-separated cycle track
- Bicycle-safe track drains and grates, manholes and other utility covers
- Bike lanes and pedestrian access routes

29.3.4. Signage and Striping

All designated bike lanes must be striped (using white thermoplastic on asphalt and high-contrast tape on concrete) and include bicycle symbol pavement markings, as required by **MUTCD** and **Chapter 44** of this manual**.** Some of the basic requirements are as follows:

- DDOT-approved bike lane symbol is a 6-foot arrow + 6-foot space + 8-foot image of a biker with helmet facing the center of roadway. In constrained areas, such as two-way, 8-wide cycle tracks, smaller bike symbols and arrows may be used.
- DDOT has approved “Bike Route Guide” and “Bike Route Destination” Signs (D11-1 and D1-1a). Their uses and designs are shown in the **DDOT Bicycle Facility Design Guide**.

- All dimensions and line pattern of bike signage and striping must be consistent with DDOT marking and signing regulations (**Chapter 44** of this manual).

29.3.5. Bicycle Lane Buffers and Separations

Buffered or protected bike lanes provide separation between bicyclists and the adjacent motor vehicle travel lane and/or parking lane. The following are common ways to create a physically separated bicycle lane:

- Striped buffer and delineator posts – Recommended 3-foot additional width (2-foot minimum). Typically these treatments are combined.
- Turtle bumps – Minimum 1.5-foot additional width
- Large bumps – Minimum 1.5-foot additional width
- Oblong low bumps – Minimum 1.5-foot additional width
- Parking stops – Minimum 6-inch additional width (typically combined with a striped buffer)
- Linear barriers – Recommended 6-inch additional width
- Parked cars – Recommended 11 feet for parking + buffer
- Jersey barriers – Recommended 2-foot additional width
- Planters – Recommended 3-foot additional width
- Ridged bollards – Recommended 2 foot additional width
- Cast-in-place curb – Recommended 12-inch additional width
- 12-inch precast curb – Recommended 1.5-foot additional width
- Raised bikeway – No additional width. Raised bikeways must be vertically separated from the street at an intermediate or sidewalk level.

29.3.6. Bicycle Lanes at Intersections

Designs for intersections with bicycle facilities should reduce conflict between bicyclists and vehicles by increasing the level of visibility, denoting a clear right-of-way, and facilitating eye contact and awareness of competing modes of transportation. Intersection design should take into consideration anticipated bicyclist, pedestrian, and vehicular movements. Intersection treatments may include the following:

- **Bike Boxes.** Designated at the heads of traffic lanes at signalized intersections. Provide bicyclists a safe and visible refuge as well as a way to get ahead of queuing traffic during the red signal phase; typically 10 to 16 feet deep.
- **Intersection Crossing Markings.** Crossing markings that indicate the intended path of bicyclists through the intersection.

- **Two-Stage Turn Queue Boxes.** Offer a safe way to make left turns at multi-lane signalized intersections from a right side cycle track or bike lane, or right turns from a left side cycle track or bike lane; may be used to orient bicyclists properly for safe crossings.
- **Median Refuge Island/Median Cut-Through.** Protected space in the center of a street to facilitate bicycle and pedestrian crossings; minimum width of 6 feet (10 feet desirable). See **Chapter 31** for more information.
- **Through Bike Lanes**. At the intersections where a separate right turn lane exists and is striped, the bicycle lane must transition and be placed between the through-lane and the right turn lane (see **DDOT Standard Drawings**). The desired width of a dotted bike transition lane and through bike lane is 6 feet with a minimum width of 4 feet.
- **Combined Bike Lane/Turn Lane.** Lane markings indicate a suggested bike lane or shared lane within a dedicated vehicle turn lane. This treatment includes signage advising of the proper position within the lane for vehicles and bicycles.
- **Cycle Track Intersection Approach.** Should be designed to reduce turn conflicts for bicyclists and/or to provide connections to intersecting bicycle facility types. The intersection must have some type of bicycle facility to receive cycle track users, including a conventional bike lane, bike box or combined bike lane/turn lane.
- **Bicycle Signals.** At intersections with high turn volumes, separate phases for through-bicycle movements and vehicular turns can be designed to use bicycle signals. Where bicycle traffic is heavy and there is an advantage to separating bicycle and motor vehicle movements, bicycle signal heads should be considered.

29.3.7. Bicycle Facility Obstructions

To the maximum extent practical, manholes, utility poles, air grates, sign poles or other obstructions should not be located in bike lanes or paths.

Bicycle-safe stormwater grates must be used as described in **DDOT Bicycle Facility Design Guide.** Bicycle-safe stormwater grates should allow bicycle travel from all accessible directions. Stormwater grates should have sufficiently narrow openings and appropriately spaced transverse bars to ensure that no foreseeable width and diameter of bicycle tire can drop down into openings to an unsafe extent.

29.3.8. Actuation Loop

At intersections that are not pre-timed, bicycle detection/actuation must be provided. There are many technologies available, including magnetic loop detection, microwave and video detection, among others. (See **DDOT Bicycle Facility Design Guide** and **NACTO Urban Bikeway Design Guide** for details.)

The choice of what technology to use must be coordinated with the DDOT Transportation Operations Administration.

29.4. Off-Street Shared-Use Path Design Requirements

29.4.1. Shared-Use Path Design and Location

- A shared-use path is defined as a path physically separated from the roadway for use by cyclists, pedestrians and other non-motorized users.
- A shared-use path must have a 10-foot minimum width of traveled way. Wider trails may be necessary where high user volumes are expected.
- Where possible, shared-use paths should be located at least 5 feet from the roadway.

29.4.2. Site Distance and Clearance: Trees, Vegetation and Other Obstacles

The Designer must ensure sufficient stopping and intersection sight distance at all path intersections and curves, particularly, where steep grades are proposed at path/roadway intersections. Obstructions to the visibility of motorists or path users should be removed, or the path should be aligned around the obstruction to maximize visibility. All curves with restricted sight distances should be painted with a centerline to separate traffic.

Sight distance requirements must conform with the **AASHTO Guide for the Development of Bicycle Facilities** and **Chapter 30** of this manual. Additional considerations include:

- **Preserving Trees.** Where possible, bike paths should be routed to minimize the loss of trees and disruption of natural environmental conditions.
- **Distance from a Path Edge.** A minimum of 2 feet is required between the path edge and any vertical obstructions such as trees, utility poles, signs, fences or other obstacles. Greater separation may be required by the District where side slope grades exceed 4 percent.
- **Overhead Clearance.** All bike paths must have a minimum of 10 feet of vertical clearance above the path.

29.4.3. Grade

Refer to the **AASHTO, Guide for Development of Bicycle Facilities**.

29.4.4. Design Speed

Refer to the **AASHTO, Guide for Development of Bicycle Facilities**.

29.4.5. Cross Slope

The maximum allowable cross slope is 2 percent.

29.4.6. Drainage

Proper drainage is important to ensure the longevity and safety of a path. An open system using swales, ditches and sheet flow combined with on-site detention ponds is preferred. Designers should consider the following:

- **Requirements and Standards.** All bike path designs must satisfy the storm drainage requirements of the DC Department of Energy & Environment and DC Water. See **Chapter 28** for DDOT stormwater requirements.
- **Ditch Placement.** Where a path is cut into a hillside, a ditch should be placed along the path to prevent excessive sheet flow across it.
- **Pavement.** Consider using permeable paving within the bike lane or bike path to improve stormwater management.

29.4.7. Safety Considerations

- **Consideration of Pedestrians.** The safety of pedestrians is a prime consideration in the path design.
- **Clearance Between a Path and the Street.** A path should be constructed at least 5 feet from a street curb. Where vehicular traffic speeds and volumes are high or where 5 feet is not achievable, a safety barrier should be considered.
- **Signs for Hazards and Regulatory Messages.** Signs should be posted, and they should follow the standard signing and pavement markings as shown in **MUTCD.**
- **Curb Ramps.** Standard curb ramps are to be provided at all path curb crossings to allow continuity of path use. Curb ramp width should be equal to the width of the path. The path surface must slope to the pavement at a maximum slope of 12H:1V.
- **Painted Centerline on Curves.** All curves with restricted sight distances should be painted with a centerline to separate traffic.
- **Traffic Control.** A vehicular stop condition should be required at intersections with low vehicular traffic and high path use.

29.4.8. Shared-Use Paths on Bridges

- All paths that cross water courses require either a bridge or a fair weather crossing wherever possible.

- Railings, fences and barriers must be placed in accordance with **Chapter 36** of this document.
- Barriers should not impede stormwater runoff. Smooth rub rails should be attached to the barriers at a handlebar height of 3.5 feet to avoid contact with vertical members.

29.4.9. Shared-Use Paths on Underpasses

The minimum vertical clearance is 10 feet from surface path to the underside of a bridge; 12 feet if equestrian accommodation is required.

All path underpasses must have lighting in accordance with **Chapter 43** of this manual**.**

29.5. Bicycle Parking

29.5.1. Bicycle Rack Design

- The preferred bicycle rack style is the "Inverted U."
- The rack must:
    - Be able to support the bicycle frame in at least two places, allowing the frame and wheel to be locked using a U-lock or cable lock
    - Prevent the wheel of the bicycle from tipping over
    - Not damage the bicycle
    - Be durable and securely anchored
    - Allow front-in or back-in parking
- Other rack styles placed in public space must be approved by the DDOT Bicycle Program Manager. See the **DDOT Bicycle Facility Design Guide** and **DDOT Standard Drawings** for additional information on bicycle rack design.

29.5.2. Capital Bikeshare Stations

- Capital Bikeshare Stations include a pedestrian wayfinding map that indicates locations of nearby Bikeshare Stations, transit connections, landmarks, etc.
- Stations are composed of 4 to 15 plates (40 to 150 feet long) with 15 to 59 docks. Each modular plate is 3 feet deep and 10 feet long (without bikes).
- Stations are located in curb lanes of roadways, on sidewalks, in plazas, or on publicly accessible private property.
- Accommodating a station and bikes requires a space at least 8 feet wide with no utilities (such as manholes) under the plates.

- The space should receive at least 3 hours of direct sunlight per day for solar power.

29.5.3. Off-Street Bicycle Parking

Bicycle parking is required in most new buildings.

Bicycle parking must conform to the guidelines established in DCMR Title 11, Chapter 21 and DCMR Title 18, Chapter 12. Each Inverted U rack provided will count as two bicycle parking spaces.

29.5.4. Placement of Bike Racks in Public Space

Bicycle parking should be considered during roadway reconstruction projects. Refer to the **DDOT Standard Drawings** for more details on bicycle rack placement.

30 Roadways

30.1. General

The District of Columbia roadway network provides access to the arterial and collector street network, and local streets within the established grid system. Although the design criteria in this manual are typically minimums or maximums, the Designer is responsible for exceeding these standards where good engineering practice dictates. All materials and workmanship must conform to these standards and to the current **DDOT Standard Specifications for Highways and Structures**.

Urban design, multimodal sensitivity and green infrastructure considerations should be included as a part of the design effort. Additional guidelines pertaining to roadway projects in the District include those listed in **Section 30.2**.

All private roadways connecting to DDOT-maintained public roads must be constructed to DDOT's standards if the roadways are to be dedicated to the District. This requires coordination with, and approval from, the DDOT Public Space Regulations Administration.

Follow these design guidelines to maintain consistency on existing streets and provide the best possible geometrics for new development. Where existing conditions differ from the criteria laid forth in this chapter, the Designer should consider matching existing conditions. **Chapter 12** of this manual provides more information on the design exception process and how to submit a nonstandard design for review.

30.2. Regulations and Guidelines

References used for this chapter are:

- American Association of State Highway Officials (AASHTO), A Policy on Geometric Design of Highways and Streets
- AASHTO, Guide to the Development of Bicycle Facilities
- AASHTO, Roadside Design Guide
- DC Department of Energy & Environment Stormwater Management Rule and Guidebook
- DDOT Public Realm Design Manual
- DDOT Context-Sensitive Design Guidelines
- DDOT Green Infrastructure Standards
- DDOT Right-of-Way Policy and Procedures Manual
- Institute of Transportation Engineers (ITE), Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities

- National Association of City Transportation Officials (NACTO), Urban Street Design Guidelines
- NACTO, Urban Bikeway Design Guide
- Smart Growth America, Bicycle & Pedestrian Guidelines
- Smart Growth America Complete Streets Policy
- Sustainable DC Plan
- Transportation Research Board (TRB), Highway Capacity Manual
- U.S. Department of Transportation Federal Highway Administration (FHWA), Highway Functional Classification Concepts, Criteria and Procedures

30.3. Americans with Disabilities Act (ADA) Requirements

All designs for roadways must conform to the most current **ADA Standards and Public Right-of-Way Guidelines**. Refer to **Chapter 31** for additional guidance.

30.4. Design Controls and Flexibility

Design controls are physical and operational characteristics that guide the selection of criteria in the design of roadways. Some design controls, such as terrain, climate and certain driver-performance characteristics, are fixed, but most controls can be influenced in some way through design and are determined by the Designer.

AASHTO's **A Policy on Geometric Design of Highways and Streets** and its supplemental publication, **A Guide for Achieving Flexibility in Highway Design**, identify location as a design control and establish different design criteria for various settings. AASHTO recognizes the influence context has on driver characteristics and performance. AASHTO defines the environment as "the totality of humankind's surroundings: social, physical, natural and synthetic" and states that full consideration to environmental factors should be used in the selection of design controls. Thus, flexibility in design is appropriate. Where flexibility to deviate from the criteria of this chapter is sought, the Designer must first obtain approval from DDOT.

AASHTO guidance identifies as the primary factors in determining highway design criteria: functional classification; the design speed and the speed at which the facilities operate; the mix and characteristics of the users, including transit vehicles, pedestrians and bicyclists; and the constraints of the surrounding context.

The **NACTO Urban Street Design Guide** also provides guidance regarding the influence of design on drivers, bicyclists and pedestrians, and the impact this has on the surrounding areas.

30.4.1. Functional Classification

Each roadway is classified into a sub-system based on the way it is used. Central to the highway classification process is an understanding that travel rarely involves movement along a single roadway. Rather, each trip or sub-trip initiates at a land use, proceeds through a sequence of streets, roads and highways, and terminates at a second land use.

The highway classification process is required by federal law. Each state must assign roadways into different functional classes in accordance with standards and procedures established by the FHWA.

30.4.1.1. Functional Highway Systems in Urbanized Areas

DDOT has adopted a "Functional Street Classification Plan" based on traffic volumes, land use, and expected growth. The five functional highway systems identified are:

- **Freeways/Parkways.** Carry high traffic volume. Directional travel lanes are usually separated by some type of physical barrier, and access and egress points are limited to on- and off-ramp locations, or to a very limited number of at-grade intersections.
- **Principal Arterials.** Carry moderate to high traffic volume. These serve major centers of metropolitan areas and provide a high degree of mobility. Abutting land uses can be accessed directly by driveways to specific parcels and at-grade intersections with other roadways.
- **Minor Arterials.** Carry moderate traffic volume. These provide service for trips of moderate length. They interconnect and augment the higher arterial system, provide intra-community continuity, and may carry local bus routes in an urban area.
- **Collector Streets.** Carry low to moderate vehicular movement, low to heavy pedestrian movement, moderate to heavy bicycle movement, and low to moderate transit movement. Collector streets are located in neighborhoods, but are consistent with the principles of the functional classifications. The streets are tree-lined, with established cross section distributions for sidewalks and tree spaces.
- **Local Streets.** Carry low traffic volume. These provide direct access to adjacent uses and interconnect with the other portions of the functional system.

Each classification has design criteria for maintaining and protecting the primary purpose of the roadway. All roadway classifications, except for local, are federally funded. For more information on functional classifications, refer to the current edition of U.S. Department of Transportation FHWA manual, **Highway Functional Classification Concepts, Criteria and Procedures**.

30.4.2. Design Speed

DDOT recommends using a posted speed and a design speed. These terms are defined as follows:

- **Posted speed** is the speed at which vehicles should operate on a thoroughfare in a specific context, consistent with the level of multimodal activity generated by adjacent land uses, to provide both mobility for motor vehicles and a safe environment for pedestrians and bicyclists.
- **Design speed** is the speed that governs certain geometric features of the thoroughfare, primarily horizontal curvature, superelevation and sight distance. Design speed is typically higher than the posted speed limit. DDOT recommends that the design speed be 5 mph over the posted speed.

The minimum design speed is the posted speed limit. If the speed limit is not posted, then the minimum design speed is 25 mph. The street grid system and spacing of traffic control devices influence normal vehicular speeds. Sections of the roadway in which the design speed may not be attained, such as around curves or through hazardous locations, may be posted with appropriate warning signs and speed plates to indicate the maximum recommended speed in accordance with the current FHWA **Manual on Uniform Traffic Control Devices (MUTCD)**. Designers may also consider reducing posted speed limits in accordance with the current **NACTO Urban Street Design Guide**.

30.4.3. Desired Design Speeds for New Streets

New streets/highways should be designed for a minimum speed as listed in Table 30-1:

Table 30-1 | Minimum Design Speeds by Functional Classification

DESCRIPTION	MINIMUM DESIGN SPEED (mph)
Local streets	25
Collector streets	25
Minor arterials	30
Principal arterials	35
Freeways/parkways	50

Where practical, the desired design speed for new freeways and interstate systems is 70 mph. When it is not practical to attain the desired speed in urban areas, the interstate highway or freeway design speed must not be less than 50 mph.

Design speeds must be selected in minimum increments of 5 mph. While it may be necessary to vary the design speed along certain highway sections, a uniform design speed should be maintained wherever possible. Where a change in design speed is necessary, the maximum change should not exceed 10 mph.

For roadways where it is not possible or feasible to maintain a 5 mph design speed over the posted speed limit, the Designer must maintain the most appropriate design speed given the context of the roadway, but it must never be less than the posted speed limit.

30.4.4. Traffic Volume

For planning and design purposes, traffic demand is generally expressed in terms of the hourly volume expected for the *design year*. The design year is typically 25 years after the anticipated date of construction for new construction and reconstruction, and 10 years after the anticipated date of construction for resurfacing, restoration or rehabilitation projects. For more information on the 25 year outlook, refer to the **moveDC Action Plan.**

30.4.5. Highway Capacity

To determine the capacity for a particular highway design, refer to the most recent edition of TRB's **Highway Capacity Manual** for guidance.

30.5. Basic Geometric Design Elements

Geometric roadway design pertains to the visible features of roadways. It may be defined as how the street is tailored to the terrain and surroundings, the controls of the land use, and the type and level of traffic anticipated.

This section covers the geometric design elements to be considered in certain locations and the design of the various types of streets. Included are criteria and guidelines on sight distances, horizontal and vertical alignment, and other features common to several types of roads and highways (Table 30-2). These design guidelines apply to the existing street system cross sections, neighborhood environmental restraints, reconstruction, widenings and other improvements. How to provide the best possible geometric designs for new developments and their proposed street systems is also discussed.

In applying these criteria and guidelines, it is important to follow the basic principle that consistency in design standards is of primary importance on any section of road. The street should offer no surprises to the user in terms of geometrics. Problem locations are generally where minimum design standards were introduced on a section of highway where otherwise higher standards should have been applied. The ideal highway design is one with uniformly high standards applied consistently along a section of roadway.

Table 30-2 | Geometric Design Elements

Geometric Design Elements	New or Reconstruction Projects
Desirable cross slope for driving lanes*	2.0%
Maximum degree of horizontal centerline curve	5°
Maximum superelevation	6%
Maximum cross slope rollover	8%
Minimum horizontal clearance from face of curb to obstructions	2.0’
Maximum percent grade	8% (new development)
Typical structural capacity**	HL-93 HS**
Vertical clearance**	14’-6” (roadways) 23’-6” (rail)

* For a normal crown section, the parking lane, which may be used as a through lane at times if it is wide enough, may have a cross slope of 1.0 to 3.0 percent (with engineering justification) in order to meet grades and elevations; on local streets, the parking lane may have a maximum cross slope of 4.0 percent.
** See **Chapter 14** for more information.

The geometry of the roadways must allow for the easy operation, maneuvering, turning, parking, standing and emergency stopping of all types of running vehicles, including emergency vehicles, as well as other modes of transportation. The Designer should determine whether bus or truck operations are involved, and if so, ensure the roadway geometry is such that buses and trucks can make the necessary turns.

All roadway design should take into account the Smart Growth America “Complete Streets” considerations.

For additional information and criteria relative to geometric design elements, refer to the **AASHTO, A Policy on Geometric Design of Highways and Streets.**

30.5.1. Sight Distances

Sight distance is the continuous length along a roadway for which an object of specified height is visible to the driver. For the safe and efficient operation of a vehicle on a highway, drivers traveling at or near the design speed should be given sufficient sight distance to allow them to avoid striking an unexpected object or to stop before reaching a stationary object in their path.

The criteria for measuring sight distance are dependent on the type of vehicle, the height of the driver's eye above the pavement surface, the specified object height above the pavement surface, and the height of sight obstructions within the line of sight.

For calculating both stopping and passing sight distances for passenger cars, the height of the driver's eye above the pavement surface is assumed to be 3.5 feet. For stopping sight distance calculations, the height of the object is assumed to be 2.0 feet above the pavement surface. For passing sight distance calculations, the height of object is assumed to be 3.5 feet above the pavement surface. These values will change based on the type of vehicle the roadway is being designed for. Stopping and passing sight distance are calculated according to the current **AASHTO, A Policy on Geometric Design of Highways and Streets**.

On tangents, the obstruction that limits the driver's sight distance is the road surface at some point on a crest vertical curve. On horizontal curves, the obstruction that limits the driver's sight distance may be the road surface at some point on a crest vertical curve, or it may be some physical feature outside of the traveled way, such as a longitudinal barrier, a bridge-approach fill slope, a tree, foliage, or the back-slope of a cut section.

Where an object restricts sight distance, the minimum radius of curvature is determined by the stopping sight distance at all property lines, except in the sight-distance easements that may be required to preserve the needed sight distance. The position of the driver's eye and the object sighted is assumed to be 6 feet from the inner edge of pavement, with the sight distance being measured along this arc. The sight distance must never be less than the stopping sight distance. This includes visibility at intersections and driveways, as well as around curves and roadside encroachments. Accordingly, all highway construction plans should be checked in both the vertical and horizontal planes for sight distance obstructions. Table 30-3 shows the standards for passing and stopping sight distance as they relate to design speed. See **Chapter 32** of this manual for more information.

Table 30-3 | Sight Distance for Design

	SIGHT DISTANCE IN FEET	
Design Speed (mph)	**Stopping Minimum**	**Passing Minimum***
25	155	900
30	200	1100
35	250	1315
40	305	1500
45	360	1650
50	425	1800
55	495	1950
60	570	2100
70	730	2500

*Not applicable to multi-lane highways

The passing sight distance for upgrades should be greater than the minimum. The stopping sight distances shown in Table 30-3, should be increased when sustained downgrades are steeper than 3 percent. Increases in the stopping sight distances on downgrades are discussed in the current **AASHTO, A Policy on Geometric Design of Highways and Streets.**

On arterials and collectors, the corner sight distance must allow vehicles to enter traffic and accelerate to the average running speed. All sight distance triangles must be shown on the street plan/profile plans. All sight distances must be within the public right-of-way (ROW) or a sight distance easement. If the line of sight crosses onto private property, a “Sight Distance Easement” must be indicated on the plat to meet the required sight distance. DDOT must obtain from the property owner the required easement or ROW to be dedicated to the District. In any event, DDOT should work with the property owner to establish an unobstructed sight distance triangle.

Any object within the sight triangle more than 2.0 feet above the flow-line elevation of the adjacent street constitutes a sight obstruction and must be removed or lowered. Such objects include, but are not limited to, berms, buildings, parked vehicles on private property, cut slopes, hedges, trees, bushes, utility cabinets and tall plantings. Parked vehicles in permitted locations within the DDOT ROW are not considered an obstruction for design purposes, since vehicles parked in a DDOT ROW are under the control of the District. However, the District may limit parking to enhance visibility. The sight distance must be measured to the centerline of the closest through-lane in both directions. No permanent object should ever encroach into the line of sight of any part of the sight distance triangle. Street trees required by the District are an exception to this requirement and are permitted if pruned up to 8 feet.

30.6. Horizontal Alignment

When designing horizontal curves, it is necessary to establish the proper relationships among design speed, curvature, and superelevation. Horizontal alignment must afford at least the minimum stopping sight distance for the design speed at all points on the roadway.

The major considerations in horizontal alignment design are safety, grade, type of facility, design speed, topography, available ROW and construction cost. In design, safety is always considered, either directly or indirectly. Topography largely controls both curve radius and design speed. The design speed, in turn, controls sight distance, but sight distance must be considered concurrently with topography because it often demands a larger radius than the design speed. All these factors must be balanced to produce an alignment that is safe, economical, in harmony with the natural contour of the land, and at the same time, adequate for the design classification of the roadway or highway.

To avoid the appearance of inconsistent distribution, the horizontal alignment should be coordinated carefully with the profile design.

30.6.1. Curvature

Changes in direction along a highway are accomplished by simple curves or compound curves. Excessive curvature or poor combinations of curvature generates accidents, limits capacity, causes economic losses in time and operating costs, and detracts from a pleasing appearance. Broken-back curves should be avoided. Street curvature must meet the minimum specifications in the current **AASHTO, A Policy on Geometric Design of Highways and Streets.**

A horizontal curve is not necessary for curves that have a central deflection angle of 10 minutes or less. For small deflection angles, horizontal curve lengths must be adjusted to avoid the appearance of "kink" in order to maintain driver comfort. For a central angle of 1 degree and a design speed of 30 mph, the minimum length of a curve should be 20 feet. See Table 30-4 through Table 30-6 for more information.

Table 30-4 | Minimum Lengths of Curves

Design Speed (mph)	Minimum Length of Curve (ft)
30	100
35	150
40	200
45	250
50	300
55	350
60	400
65	450
70	500

Table 30-5 | Curve Length Adjustment Factor

Central Deflection Angle	Adjustment Factor Applied to Table 30-4
5°	1.00
4°	0.80
3°	0.60
2°	0.40
1°	0.20

Table 30-6 | Minimum Horizontal Tangent Specifications

Design Criteria	Local Street	Collector Street	Minor Arterial	Principal Arterial
Minimum Reverse Curve Tangent	50 ft	75 ft	100 ft	200 ft
Minimum Intersection Approach Tangent	100 ft	150 ft	200 ft	300 ft

Note: See discussion below on superelevation for minimum tangent lengths on freeways.

30.6.2. Superelevation for Arterials, Collectors and Local Streets

Horizontal curves on streets with design speeds of 45 mph or less are often not superelevated. While normal crowned streets can have an adverse effect on left-turning vehicles, the amount of friction needed to sustain a vehicle's path along a flat curve is minimal.

Other factors that make superelevation on low-speed urban streets less practical include wider pavement sections, the necessity of meeting nearby property grades, proper drainage design requirements, the need to connect to intersecting cross streets, and the desire to encourage low speed operations. Existing cross slopes on low-speed urban streets may therefore remain unless there is an unacceptable accident history due to the nature of the curve.

Lower-speed (45 mph or less) urban streets can use a 4 percent or 6 percent maximum superelevation rate. On low-speed urban streets, AASHTO Superelevation Method 2 should be applied. This allows the friction factor to reach its maximum value prior to any superelevation of the road, since superelevation is rarely called for on low-speed urban streets.

For superelevation values for low-speed urban streets, see Table 30-7 and **AASHTO, A Policy on Geometric Design of Highways and Streets.**

Table 30-7 | Minimum Radii for Design Superelevation Rates, Low-Speed Urban Streets

	Vd **= 25 mph**	***Vd*** **= 30 mph**	***Vd*** **= 35 mph**	***Vd*** **= 40 mph**	***Vd*** **= 45 mph**
e (%)	***R*** **(ft)**	***R*** **(ft)**	***R*** **(ft)**	***R*** **(ft)**	***R*** **(ft)**
-4.0	219	375	583	889	1227
-3.0	208	353	544	821	1125
-2.8	206	349	537	808	1107
-2.4	200	337	517	773	1055
–2.0	198	333	510	762	1039
–1.5	194	324	495	736	1000
0	181	300	454	667	900

e (%)	*Vd* = 25 mph *R* (ft)	*Vd* = 30 mph *R* (ft)	*Vd* = 35 mph *R* (ft)	*Vd* = 40 mph *R* (ft)	*Vd* = 45 mph *R* (ft)
1.5	170	279	419	610	818
2	167	273	408	593	794
2.4	164	268	400	580	776
2.8	161	263	393	567	758
3.0	160	261	289	561	750
4.0	154	250	371	533	711

Vd **= design speed;** ***e*** **= superelevation;** ***R*** **= radius**

Source: AASHTO, A Policy on Geometric Design of Highways and Streets

30.6.3. Superelevation for Freeways and Parkways

Superelevation is predicated on design speed, and all freeways and parkways must be superelevated according to their speeds.

A 6 percent e_{max} superelevation rate should be used on urban freeways. A 4 percent e_{max} superelevation rate may be used on high-speed (greater than 45 mph) urban highways to minimize conflicts with adjacent development and intersecting streets.

With open roadway conditions, AASHTO Superelevation Method 5 should be applied to provide complete counteraction of the vehicles' centrifugal force. This affords drivers a significant amount of side friction at or near the design speed.

For superelevation values for urban freeways, see Table 30-8, Table 30-9 and **AASHTO, A Policy on Geometric Design of Highways and Streets.**

Table 30-8 | Minimum Radii for Design Superelevation Rates, Design Speeds and e_{max} = 4%

e (%)	V_d = 25 mph *R* (ft)	V_d = 30 mph *R* (ft)	V_d = 35 mph *R* (ft)	V_d = 40 mph *R* (ft)	V_d = 45 mph *R* (ft)	V_d = 50 mph *R* (ft)	V_d = 55 mph *R* (ft)	V_d = 60 mph *R* (ft)
NC	2050	2830	3730	4770	5930	7220	8650	10,300
RC	1340	1880	2490	3220	4040	4940	5950	7080
2.2	1110	1580	2120	2760	3480	4280	5180	6190
2.4	838	1270	1760	2340	2980	3690	4500	5410
2.6	650	1000	1420	1930	2490	3130	3870	4700
2.8	524	817	1170	1620	2100	2660	3310	4060
3.0	433	681	982	1370	1800	2290	2860	3530
3.2	363	576	835	1180	1550	1980	2490	3090
3.4	307	490	714	1010	1340	1720	2170	2700

e (%)	Vd = 25 mph R (ft)	Vd = 30 mph R (ft)	Vd = 35 mph R (ft)	Vd = 40 mph R (ft)	Vd = 45 mph R (ft)	Vd = 50 mph R (ft)	Vd = 55 mph R (ft)	Vd = 60 mph R (ft)
3.6	259	416	610	865	1150	1480	1880	2350
3.8	215	348	512	730	970	1260	1600	2010
4.0	154	250	371	533	711	926	1190	1500

***Vd* = design speed; *e* = superelevation; *R* = radius**

Source: **AASHTO, A Policy on Geometric Design of Highways and Streets**

Table 30-9 | Minimum Radii for Design Superelevation Rates, Design Speeds and e_{max} = 6%

e (%)	Vd = 25 mph R (ft)	Vd = 30 mph R (ft)	Vd = 35 mph R (ft)	Vd = 40 mph R (ft)	Vd = 45 mph R (ft)	Vd = 50 mph R (ft)	Vd = 55 mph R (ft)	Vd = 60 mph R (ft)	Vd = 65 mph R (ft)	Vd = 70 mph R (ft)
NC	2290	3130	4100	5230	6480	7870	9410	11,100	12,600	14,100
RC	1630	2240	2950	3770	4680	5700	6820	8060	9130	10,300
2.2	1450	2000	2630	3370	4190	5100	6110	7230	8200	9240
2.4	1300	1790	2360	3030	3770	4600	5520	6540	7430	8380
2.6	1170	1610	2130	2740	3420	4170	5020	5950	6770	7660
2.8	1050	1460	1930	2490	3110	3800	4580	5440	6200	7030
3.0	944	1320	1760	2270	2840	3480	4200	4990	5710	6490
3.2	850	1200	1600	2080	2600	3200	3860	4600	5280	6010
3.4	761	1080	1460	1900	2390	2940	3560	4250	4890	5580
3.6	673	972	1320	1740	2190	2710	3290	3940	4540	5210
3.8	583	864	1190	1590	2010	2490	3040	3650	4230	4860
4.0	511	766	1070	1440	1840	2300	2810	3390	3950	4550
4.2	452	684	960	1310	1680	2110	2590	3140	3680	4270
4.4	402	615	868	1190	1540	1940	2400	2920	3440	4010
4.6	360	555	788	1090	1410	1780	2210	2710	3220	3770
4.8	324	502	718	995	1300	1640	2050	2510	3000	3550
5.0	292	456	654	911	1190	1510	1890	2330	2800	3330
5.2	264	413	595	833	1090	1390	1750	2160	2610	3120
5.4	237	373	540	759	995	1280	1610	1990	2420	2910
5.6	212	335	487	687	903	1160	1470	1830	2230	2700
5.8	186	296	431	611	806	1040	1320	1650	2020	2460
6.0	144	231	340	485	643	833	1060	1330	1660	2040

***Vd* = design speed; *e* = superelevation; *R* = radius**

Source: **AASHTO, A Policy on Geometric Design of Highways and Streets**

The minimum superelevation to be used is 1.5 percent on flat radius curves. The superelevation should be increased by 0.5 percent in each successive pair of lanes on the low side of the superelevation when more than two lanes are superelevated in the same direction.

30.6.4. Superelevation Transitions

The superelevation transition generally consists of the superelevation runoff, which is the length of roadway needed to accomplish the change in cross slope from a normal crown section to a fully superelevated section or vice versa. Defining or establishing superelevation runoff must be in accordance with the current **AASHTO, A Policy on Geometric Design of Highways and Streets.**

30.7. Vertical Alignment

The profile line is a reference delineation by which the elevation of the pavement and other features of the highway are established. It is controlled mainly by topography, type of highway, horizontal alignment, safety, sight distance, construction costs, multimodal transportation availability, drainage and appearance. The performance of heavy vehicles on a grade must also be considered. All portions of the profile line must meet sight distance requirements for the design speed of the road.

In flat terrain, the elevation of the profile line is often controlled by drainage considerations. In rolling terrain, some undulation in the profile line is often advantageous, both from the standpoint of truck operation and construction economy. This should be done with appearance in mind (i.e., a profile on a tangent alignment exhibiting a series of humps visible for some distance ahead should be avoided whenever possible). In rolling terrain, however, the profile is usually closely dependent on physical controls. When considering alternative profiles, economics should be compared.

30.7.1. Position with Respect to Cross Section

The profile line should generally coincide with the axis of rotation for superelevation. Its relation to the cross section should be as follows:

- Undivided highways: The profile line should coincide with the highway centerline.
- Ramps and freeway-to-freeway connections: The profile line may be positioned at either edge of pavement, or at the centerline of a ramp if multi-lane.
- Divided highways: The profile line may be positioned at either the centerline of the median or at the median edge of pavement. The former case is appropriate for paved medians 30 feet wide or less. The latter case is appropriate when:
    - The median edges of pavement of the two roadways are at equal elevation

- The two roadways are at different elevations

- Local streets: The profile line should be at the roadway centerline.

30.7.2. Permissible Roadway Grades

The minimum allowable grade for roadways or alleys is 0.5 percent, as this will facilitate drainage. The minimum allowable grade for cul-de-sacs is 1.0 percent.

Maximum grades are controlled by the functional class of the road type, terrain type, vehicle type, and design speed. Maximum grade controls for each functional class of highway and street are further presented in **AASHTO, A Policy on Geometric Design of Highway and Streets.**

The maximum allowable grades and minimum K values for any roadway is shown in Table 30-10.

Table 30-10 | Maximum Allowable Grades

Description	Min. Design Speed (mph)	Max. Grade (%)	Min. K Value Crest	Min. K Value Sag
Local Street	25	8	7	17
Collector Street	25	8	19	37
Minor Arterial	30	7	29	49
Principal Arterial	35	6	44	64
Freeway	50	5	151	136

Longer curves are desired wherever practical, but K values in excess of 167 should generally be avoided. When K values over 167 are used, special attention should be paid to drainage.

NOTE: The maximum grade may be modified on a case-by-case basis in areas where steep hills and grades are the norm and the permissible grades cannot be attained.

30.7.3. Permissible Intersection Grades for New Streets Only

See **Chapter 32** in this manual for permissible intersection grades for new streets.

30.7.4. Vertical Curves

Vertical curves should be designed to provide adequate sight distance, safety, comfortable driving, good drainage, and pleasing appearance. Vertical curves must be designed in accordance with the **AASHTO, A Policy on Geometric Design of Highways and Streets**.

Vertical curves are not required where an algebraic difference in grade is less than 0.35 percent. Vertical curves that have a level point and flat sections near their crest or sag should be evaluated for drainage.

Curves with K values of 167 or greater should be checked for drainage. All vertical curves must be labeled in the profile with the station and elevation of the point of vertical intersection (PVI), the length of vertical curve (L), the K value, and the middle ordinate (m).

30.7.4.1. Street Lights on Vertical Curves

Where street lighting is present and adequate, the design criterion for headlight sight distance is not applicable.

30.8. Combination of Horizontal and Vertical Alignment

To avoid the possibility of introducing serious hazards, horizontal and vertical alignment must be coordinated. Particular care must be exercised to maintain proper sight distance. Where grade line and horizontal alignment will permit, it is desirable to superimpose vertical curves on horizontal curves. This reduces the number of sight distance restrictions and makes changes in the profile less apparent (particularly in rolling terrain). Care should be taken, however, not to introduce a sharp horizontal curve near a pronounced crest or grade sag (this is particularly hazardous at night).

In cases where sharp horizontal curvature is located on steep grades, it is good design practice to flatten the grade slightly throughout the length of the curve. Horizontal curvature and profile grade should meet standard grades at highway intersections.

On divided highways, variation in the width of medians, and separate profiles and horizontal alignments, should be considered to achieve the design and operational advantages of one-way roadways.

NOTE: Where noise receptors are present, alignment changes should be evaluated in accordance with the requirements of the **DDOT Environmental Manual,** Highway Noise Policy and Regulations.

30.9. Lane Transitions

Design standards for transitions between roadways of different widths should be consistent with the design standards of the superior roadway. Transitions should be made on a tangent section whenever possible and should avoid locations with horizontal and vertical sight distance restrictions. Whenever feasible, the entire transition should be visible to the driver of a vehicle approaching the narrower section. The design should be such that at-grade intersections within the transition are avoided.

Table 30-11 shows the minimum required taper lengths based on the design speed of the roadway. In all cases, a taper length longer than the minimum should be provided where possible. A reduced speed limit should be posted at angle shifts as deemed necessary.

Table 30-11 | Lane Taper Lengths

TYPE OF TAPER	MINIMUM TAPER LENGTHS
Merging Taper	At Least L
Shifting Taper	At Least 0.5L
Shoulder Taper	At Least 0.33L

Notes:
For design speeds greater than 40 mph: L = V x W
For design speed equal to or less than 40 mph: L = (V^2 x W)/60
Where:
V = Design Speed (mph)
W = Lane Width Reduction (feet)
L = Taper Length (feet)

30.10. Major Cross Section Elements

The major cross section elements considered in the design of streets and highways are the pavement section, cross slopes, lane widths, shoulder widths, parking lane widths, roadside treatment, bike lanes, curbs, sidewalks, public parking, driveways and medians. Also included are curb walks, which are narrow strips of sidewalk along the back of curbs that provide space to step out of a vehicle parked adjacent to a furnished zone. For more information on public parking see **Chapter 31** of this manual.

NOTE: For additional information and criteria relative to major cross section items, refer to the **AASHTO, A Policy on Geometric Design of Highways and Streets**.

30.10.1. Standard Roadway Element Widths for New Streets

Minimum requirements for new street construction depend on roadway functional classification as listed in Table 30-12 through Table 30-14, and an example for arterial streets is shown on Figure 30-1. Additionally, every effort should be made to upgrade the existing streets to bring them to current DDOT standards as much as practical.

Table 30-12 | Freeway/Parkways Cross Section Minimum Widths (feet)

Street Operation Type	Median	Inside Shoulder	Vehicular Travel Lanes	Outside Shoulder	Roadway Width	Total Right-of-Way
Two-Way	2.5	4-8*	12	10	90.5	Varies

*For freeways with 6 or more travel lanes, the inside shoulder should be a minimum of 10 feet.

Table 30-13 | Collector and Arterial/Commercial Streets Cross Section Minimum Widths (feet)

	Roadway				Public Space					
Street Operation Type	Vehicular Travel Lanes	Bike Lanes	Parking Lane	Roadway Width (Curb to Curb)	Curb & Gutter	Curb Walk	Furnishing Zone/ Tree Space	Sidewalk	Public Parking	Total Right-of-Way
Two-Way, Parking Both Sides	10		8	36						
Two-Way, Parking One Side	10	0 or 5	8	28	1.67	1	4	8 or 10	Varies	90
Two-Way, No Parking	11		0	22						

Table 30-14 | Local/Residential Street Cross Section Minimum Widths (feet)

	Roadway				Public Space				
Street Operation Type	Vehicular Travel Lanes	Bike Lanes*	Parking Lane	Roadway Width (Curb to Curb)	Curb & Gutter	Furnishing Zone/ Tree Space	Sidewalk	Public Parking	Total Right-of-Way**
Two-Way Parking Both Sides	10		7	34					
Two-Way Parking One Side	10		7	27					75
Two-Way No Parking	10	0 or 5	0	20	1.67	4	6 or 8	Varies	
One-Way Parking Both Sides	11		7	25					55
One-Way Parking One Side	11		7	18					

Notes:

1) The above values are minimums for new streets; where existing conditions differ from these values, DDOT may allow the Designer to match existing conditions. Additionally, where average daily traffic is low, local street lane widths of 9' may be considered.
2) The roadway and lane widths listed are measured from curb to curb and include the gutter.
3) Maximum lane width is 12', except on roadways where bicycle accommodations are provided, where up to 13' with shared lane markings are allowable.
4) When buses are present in a curbside lane, an 11' minimum lane width should be used.
5) Additional through-lane minimum width should typically be 10'. (Total minimum width for two lanes is thus 20-21', and for three lanes 30-31'.)
6) Additional turning lane minimum width is 9' (10' preferred) for local/residential roadways and collector/arterial/commercial roadways.
7) Sidewalk widths are based on adjacent land use. See **Chapter 31** for more information on public space widths.

*If bike lanes are present, the minimum width is 5'. With no bike lanes, the minimum roadway widths are as shown. However, where bike lane(s) are present, travel lane widths 1' narrower than shown are acceptable.

** Total ROW width of 55' is limited to one-block-long streets only. Where streets extend farther, 75' of ROW is required.

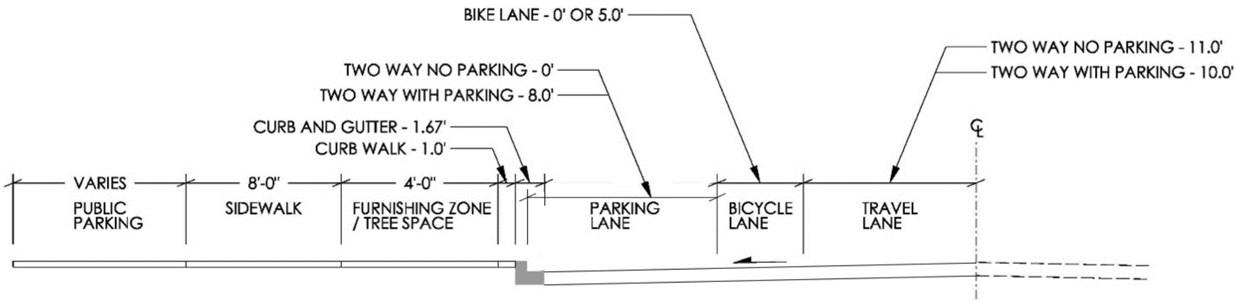


Figure 30-1 | Example Standard Roadway Element Width Typical Section for New Arterial Streets

30.11. Lane Widths

On freeways, the predominant lane width is 12 feet. Lane widths on arterials, collectors and local streets are typically between 10 and 11 feet, inclusive of the gutter, and are based on the following:

- **Design Speed.** Lanes 10 feet wide may be considered on streets with design speeds of 40 mph or less. Use the wider end of the range (11 to 12 feet) at design speeds greater than 40 mph.
- **Design Vehicle.** Vehicles such as transit buses and large tractor-trailers require wider lanes, particularly in combination with higher design speeds if they frequently use the thoroughfare. Consider wider lanes only if appropriate for the frequency of the design vehicle.
- **Right-of-Way.** Balance the provision of the required design elements of the thoroughfare with the available right-of-way. This balance can mean reducing the width of all elements or eliminating lower-priority elements.
- **Width of Adjacent Bicycle and Parking Lanes.** The width of adjacent bicycle and parking lanes influences the selection of lane width. If the adjacent bicycle or parking lane is narrower than recommended, first consider widening the bicycle lane. If a design vehicle or design speed justifies it, provide a wider travel lane to better separate lanes. Where bike lanes are provided on multi-lane streets, the outside lane width should be 1 foot wider than the adjacent through-lane width.
- All lane widths must be measured from the center of the pavement markings.

30.11.1. Number of Lanes

- **Existing Street.** Confirm appropriate number of lanes. If the existing number is appropriate, make no changes. Otherwise, treat as a proposed street. This may necessitate lane reductions or road use changes.

- **Proposed Street.** The number of lanes should be determined by procedures outlined in the TRB **Highway Capacity Manual**. A traffic impact analysis should also be conducted for the appropriate year if requested. Refer to **AASHTO, A Policy on Geometric Design of Highway and Streets** and **Chapter 38** of this manual for additional guidelines.

30.12.Curbs and Gutters

Curbs serve the following purposes: drainage control, pavement edge delineation, ROW reduction, aesthetics preservation/enhancement, pedestrian walkway delineation, maintenance operations reduction, and as an aid to orderly roadside development. Curbless streets may be considered in select locations, and only with DDOT approval.

All city streets on the Federal Aid system and in historic areas will be constructed with granite curbs and brick gutters, or replaced with in-kind materials, or with brick in special situations or when there is evidence of bricks in the city blocks. Similarly the local streets (locally funded) outside the historic districts will be considered for granite curbs and brick gutters on a case-by-case basis. Asphalt curbs will be constructed only for temporary construction or repairs.

The District's standard curbs are 7-inch-high concrete or granite for city streets, 9-inch-high granite curbs for bridge structures, and 4-inch-high mountable curbs for special situations. Each may be designed as a separate unit, jointly with the pavement, or with a 1-foot-wide gutter to form a combination curb and gutter section.

Curbs are not allowed to be constructed on freeways, parkways and interstate highways. Where positive protection is required, such as on long, narrow medians or adjacent to bridge substructures, suitable barrier or guiderail should be provided.

See **Chapter 31** of this manual for more information.

30.13.Medians

Medians generally fall into one of three categories: depressed, raised and flush. Depressed medians are preferred where highly efficient drainage and snow removal is required. Flush medians have application on urban arterials where left turn movements are common. Raised medians are often used where the regulation of left turn movements is desirable and aesthetics are imperative.

The minimum width of raised medians should be no less than 4 feet as measured from the edge of pavement of the travel lane, with a maximum width as appropriate for their specific corridor. Medians may be designed for collector and local streets if approved by the DDOT Project Manager.

Medians that are 5 feet or less in width should be paved where there is high risk and cost in maintaining landscaping.

Nose areas must be paved back to a point 5 feet from the tip of the nose.

When a median is provided for pedestrian refuge, it should be raised rather than flush or depressed. Medians intended for pedestrian refuge should be a minimum of 6 feet wide from back-of-curb to back-of-curb (8 feet is recommended). At intersections, medians provide the best refuge for pedestrians when the median nose extends beyond the crosswalk. An accessible route through the median is required for pedestrians, either through the use of curb ramps or a cut-through. Medians and pedestrian refuge islands should be encouraged in places where they may help improve the safety of pedestrians crossing the street. They are particularly helpful on multi-lane streets with high traffic volumes and/or high speeds. Other requirements for medians include:

- Medians must not obstruct any of the design vehicles' turning movements. All medians must be evaluated by vehicle tracking templates to ensure no turning movements are obstructed.
- Any landscaped medians must include drainage facilities to handle sprinklers with trickle irrigation. Outfall curbs and gutters should be used.
- Medians and their contents (light pole pedestals, signage, etc.) must be placed such that the required sight distance in the intersection is not obstructed.

Detectable warning surfaces (truncated domes) are to be used for the sight impaired to detect the boundary between the sidewalk/median cut-through and the street. These surfaces must be placed in any median cut-through that is a minimum of 6 feet long from back-of-curb to back-of-curb. Detectable warning surfaces should not be placed in a median cut-through less than 6 feet long, as it gives a pedestrian a false sense of safety. A 2-foot strip must be used for the entire width of each cut-through entrance. The minimum median cut-through width is 6 feet, and its maximum should be narrow enough to prevent a passenger vehicle from U-turning in it.

At the point where the curb of the median cut-through meets the curb of the roadway, the corner should be rounded to prevent a sharp edge that could damage a tire if hit.

30.13.1. Turn Lane and Access

When designing medians, the need for turn lanes and accesses must be evaluated. For the minimum turn lanes requirements, refer to **Chapter 32** of this manual.

30.13.2. Drainage

Depressed medians must be provided with drainage facilities to handle runoff and nuisance flows. Please see **Chapter 28** for details. Raised medians that drain onto a roadway surface must be accounted for in roadway drainage calculations. In a typical crown section, all median gutters should be reverse-pitched (have a spill gutter), directing drainage away from the median.

30.13.3. Noses

- Use vehicle-tracking templates to determine the position of the median nose so that vehicles do not track onto the median.
- The minimum radius for nose curbs is 2 feet.
- Vertical curb transitions from full height to flush with pavement (nose downs) are encouraged.

30.13.4. Paving

All non-landscaped areas of medians on collector roads must be paved with stamped concrete, colored concrete, exposed aggregate concrete or permeable pavement in accordance with landscape standards of the District. On local streets with channelizing islands or medians, the median may be paved with plain concrete as directed. Raised medians must be constructed of the same materials as required in the Downtown Streetscape Regulations or other historic districts and arterial streets as shown in other sections of this manual.

30.13.5. Transitions

The changes in median alignment as they transition into turn lanes must have a minimum radius of 50 feet. A change of direction should be accomplished using curved radii. Angled points are discouraged.

30.13.6. Objects

No permanent structures, including light poles, fire hydrants, trees, etc., are allowed to be placed less than 2.0 feet from the face of curb or in any location that would obstruct sight distance except for structures approved in this manual. If a median streetlight is placed within 5 feet of the travel lane and the median is not raised, the light must be a breakaway model, except for lights placed on a barrier-type wall.

30.14. Roadway/Rail/Streetcar At-Grade Crossings

All roadway/rail crossings should be coordinated with the railroad to provide consistent surface and traffic control. The geometric design of the railroad-highway at-grade crossing should be created concurrently with the determination of the type of warning devices to be used. Details of the warning devices to be used are discussed in the **MUTCD**. Factors to be considered include vehicular speeds and volumes, train speeds and volumes, sight distance, crossing skew, number of tracks, highway approach grade, presence of pedestrians and bicyclists, and emergency services. For more information, refer to:

- **Existing Street. AASHTO, American Railway Engineering and Maintenance-of-Way Association (AREMA)** and **MUTCD,** except that gates may not be required for all approaches. Conduct a Safety Analysis including an Operation and Safety Report on all resurfacing, restoration and rehabilitation projects.
- **Proposed Street. AASHTO, Chapter VI, AREMA** and **MUTCD,** except that gates may not be required for all approaches. Design speed is the maximum safe speed that can be maintained over a specific section of highway when conditions are favorable.

To properly accommodate bicyclists, at-grade roadway/rail crossings should be at right angles to the rails. If the crossing is less than 45 degrees, an additional paved shoulder should be provided to permit the bicyclist to cross the track at a safer angle. Refer to the **AASHTO Guide for the Development of Bicycle Facilities** for additional information.

Streetcar tracks and crossings should be coordinated with roadway plans for track alignment and vehicle clearance, and additional pavement at the crossing should have a smooth surface to permit bicyclists to cross the track. Refer to the **DC Streetcar Design Criteria** for additional information.

31 Sidewalks, Public Parking, Alleys and Curb Cuts

31.1. General

All facilities must be designed in accordance with the most current Americans with Disabilities Act (ADA) standards and guidance, the requirements of this manual and all other DDOT requirements. This chapter sets forth the minimum criteria to be used in the design of all sidewalks, curb ramps and other pedestrian and ADA facilities within rights-of-way (ROWs), and other public easements.

31.1.1. Regulations and Guidelines

This chapter is based on criteria from the following references:

- American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets
- AASHTO, Guide for the Planning, Design, and Operation of Pedestrian Facilities
- DDOT, Downtown Streetscape Regulations
- DDOT, Public Realm Design Manual
- Federal Highway Administration (FHWA), Accessible Sidewalks and Street Crossings
- National Association of City Transportation Officials (NACTO), Urban Street Design Guide
- U.S. Access Board, Americans with Disabilities Act Accessibility Guidelines (ADAAG)
- U.S. Access Board, Public Rights-of-Way Accessibility Guidelines (PROWAG)
- U.S. Department of Justice, ADA Standards for Accessible Design (2010)

31.1.2. Designated Street Distribution

DDOT maintains a historic "Designated Street Distribution Card" for each street in the District of Columbia, which allocates the ROW for each roadway, sidewalk and public parking area (a landscaped "park-like" area between the sidewalk and property line). The Designated Street Distribution Card contains width information for each street, and whenever any changes or improvements are made within the public space area of a street, the designated widths must be maintained as a minimum. These designated street widths may vary from block to block. Whenever any changes to the distribution are made in a street ROW, a written justification is required stating what part of the street's ROW is being changed and the reason for this change. DDOT requires all affecting agencies within the District of Columbia to document the reasons for any proposed change of a street's ROW, and these changes are subject to approval by the DDOT Director.

31.2. Sidewalks

Sidewalks are a critical element of the District's transportation network. They provide a dedicated safe and accessible environment for pedestrians and persons with disabilities. General criteria for sidewalk are laid forth in this section.

All sidewalks must be constructed with a minimum depth of 4 inches of concrete. Alleys and driveway entrances must be constructed with a minimum depth of 7 inches of concrete. Commercial and heavy truck traffic entrances must be constructed with a minimum depth of 8 inches of concrete. The scoring pattern, texture and color of the sidewalk paving should continue across the alley or driveway entrance.

All public sidewalks must comply with the requirements of the most current accessibility standards and guidelines, which include requirements for sidewalk widths, grades, locations, markings, surface treatments and curb ramps.

If the District of Columbia Department of Consumer and Regulatory Affairs allows a builder to extend the building projection into the ROW of a street, that issue must be addressed during public space permitting to ensure that pedestrian accessibility and safety, as well as traffic safety, is not compromised, and sidewalk minimum widths must still be met.

31.2.1. Layout and Design Criteria

31.2.1.1. Sidewalk Widths

The aforementioned Designated Street Distribution Card identifies the "sidewalk" dimension for each street. It is important to note that this dimension includes the furnishing/tree-planting area, which is typically 4 to 6 feet wide, as shown in Table 31-1. The Designated Street Distribution "parking" dimension is the minimum width of public parking that must be provided, and is discussed further in **Section 31.3**. DDOT may require additional sidewalk area to ensure a sufficient pedestrian clear path. Minimum sidewalk widths are defined by a block-long clear pedestrian pathway free of any above-grade obstruction. Pedestrian clear path requirements are determined by the land use adjacent to the sidewalk.

- The minimum sidewalk width is 6 feet for low- and moderate-density residential areas, 8 feet for high-density residential or light commercial areas, and 10 feet for the Central Business District (CBD) and commercial areas in the vicinity of the CBD. See Table 31-1 for details.

Table 31-1 | Minimum Sidewalk Widths

	Curb Walk*	Tree/Furnishing Zone***	Sidewalk Unobstructed Clear Width (min)	Public Parking/ Café Zone	Total Minimum Sidewalk Width
Low- to Moderate-Density Residential**	None	4-6 feet	6 feet	Varies	10 feet
High-Density Residential	1 foot	4–8 feet	8 feet	Varies	13 feet
Central DC and Commercial Areas****	1–2 feet	4–10 feet	10 feet	Varies	16 feet

NOTE: All widths depend on sidewalk space within the ROW Designated Street Distribution Cards; for all projects, refer to streetscape standards for historic zones and the DDOT Green Infrastructure Standards.

***Curb walks must be provided where permitted by DDOT and if accessible parking spaces are provided in accordance with the proportions set forth in the Federal PROWAG.**

****Single-family detached houses and row houses.**

*****Reference soil volume minimums and identify utility locations when establishing this zone.**

******Curb walk and tree furnishing zones must total at least 6 feet.**

- If there is no designated sidewalk width in the Designated Street Distribution, the minimum 10-foot designated sidewalk width must be used.
- All Central Business District streets must have a total minimum sidewalk width of 16 feet, which includes a 6-foot furnishing zone and 10 feet of unobstructed sidewalk, unless additional requirements are set forth by DDOT. Where no furnishing zone is provided, the width of the sidewalk should be 16 feet, especially where there is no shoulder, as the width deters truck overhangs or side view mirrors from hitting pedestrians.
- Every effort should be made to remove obstacles to achieve the minimum sidewalk clear width, but where utility poles, sign supports, fire hydrants, tree boxes or other obstacles exist within the sidewalk that cannot be moved, the minimum unobstructed width of sidewalk at a pinch point must be at least 4 feet to allow wheelchair passage.
- Utility vaults, grates, or other utility elements must not be placed within the clear pedestrian width. When the utility vault is proposed to be located in the public space between the sidewalk and the property line, it may be located in this area when the following conditions are fulfilled:

  (1) The utility vault is incorporated into the landscape design;

  (2) The utility vault does not interfere with the planting of required trees; and

(3) The utility vault cover is solid and filled with a material the same as, or compatible with, the adjoining sidewalk.

- A sidewalk constructed to serve as a shared bicycle facility is considered a multi-use trail and must be at least 10 feet wide. The facility must meet the most recent ADA compliance standards (also see **AASHTO Guide for the Development of Bicycle Facilities**).
- Minimum sidewalk width at and adjacent to bus stops is 8 feet (see **Chapter 34**).
- DDOT may require additional sidewalk width in certain areas based on current and future pedestrian volumes and if bus shelters are to be provided. The final sidewalk width must be determined through a pedestrian demand study and available ROW.
- Minimum setback for sidewalk obstructions/furnishings (streetlights, signs on posts, bicycle racks, etc.) is 18 inches from the back of curb, but ideally 24 inches is preferred. Sidewalk obstructions/furnishings should not encroach on the sidewalk's clear travel path. For more information on setbacks and sidewalk obstructions/furnishings, refer to **AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities**.
- *If the existing sidewalk width is less than 60 inches, "passing pads" measuring 60 inches by 60 inches must be constructed at least every 200 feet to allow disabled persons to pass one another. Crossing driveways and alleys are not considered "passing pads."*
- *Where the surrounding sidewalk is reconstructed, existing concrete on manhole covers must be removed and replaced flush with the sidewalk surface.*

31.2.1.2. Sidewalk: Both Sides of Street

The **District of Columbia Law 18-227 "Priority Sidewalk Assurance Act of 2010"** requires DDOT to:

"…construct a sidewalk on at least one (1) side of every street or roadway where pedestrians are legally permitted in the District of Columbia. For road segments that lack sidewalks on both sides of the street, DDOT's policy is that a sidewalk will be installed (except in limited circumstances) when a roadway reconstruction project, a curb and gutter installation project, or a curb and gutter replacement project is planned for that road segment. Where such construction is not planned, DDOT's policy is that priority be given to the installation of sidewalks that provide access to schools, parks and recreational facilities, transit stops, locations where substantial pedestrian safety risks exist and roadway segments for which residents petitioned to have new sidewalks installed."

31.2.1.3. Slope

- **Cross Slope.** Maintain 2 percent (maximum) sidewalk cross slope toward the roadway. Cross slopes exceeding 2 percent do not meet ADA requirements and are not acceptable.

- **Longitudinal Slope.** Longitudinal slope must not exceed 5 percent, except to match the adjacent roadway grade. Where longitudinal grades exceed 5 percent, refer to **ADAAG 2010**.

31.2.1.4. Horizontal and Vertical Curves

Horizontal and vertical curves on all sidewalks must follow the roadway design criteria. For shared use path criteria, see **Chapter 29** for more information.

31.2.1.5. Vertical Clearance

Sidewalk vertical clearance must be 10 feet. The minimum vertical clearance distance to the bottom of a street sign or other feature in the sidewalk must be no less than 8 feet.

31.2.1.6. Sidewalk Cafés Located Within Public Space

- The minimum distance between the curb of the street and the edge line of the sidewalk café boundary should meet the minimum sidewalk widths noted in Table 31-1.
- Accessibility implies adequate dimensioning of café aisles (3 feet between tables), turning spaces, spaces for routes leading to ramps and doorways, and compliant paths of travel to toilet facilities and to payment transactions (as applicable).
- If the cafés are not accessible when planned and operated within the public space, permits will automatically be denied.
- Chain and/or rope barriers can be hazardous to pedestrians in the sidewalk areas. These barriers are difficult to see, especially when lower than 32 inches high and at night. Discretion should be used when designing and placing barriers in the sidewalk, and a means should be devised to increase their detection.
- The bases of the poles and/or posts for chain/rope barriers must not protrude into the clear sidewalk area. They must be located within the boundaries of the sidewalk café.
- Any umbrellas, awnings or canopies employed must comply with DDOT's minimum 8-foot vertical clearance requirement, and must be contained within the boundaries of the café and not project into the sidewalk clear space.
- A least 5 percent of the total café tables (or a minimum of one) must comply with the most current ADA compliance standards.

31.2.1.7. Protruding Objects

Objects protruding into sidewalks can cause many challenges to a person with a disability. These objects may be utility poles, mailboxes, signal poles, signal boxes, signs, etc. A protruding object (control box, sign, etc.) that is mounted to a fixed structure must be mounted in the following manner:

- Objects mounted between 27 and 80 inches above the ground cannot extend more than 4 inches from the fixed structure into the sidewalk.
- Objects mounted either below 27 inches or above 80 inches may not extend more than 12 inches from the fixed structure into the sidewalk.

At the same time, the Designer must provide a minimum 4-foot corridor for pedestrian passage.

31.3. Public Parking

The public parking zone is intended to provide a landscaped and “park-like” area between the sidewalk and adjacent property. The use of this area is regulated via the public space permitting process managed by the DDOT Public Space Regulation Administration, with regulations generally found in District of Columbia Municipal Regulations (DCMR) Title 24. Most streets in the District feature public parking. The Designated Street Distribution identifies the public parking dimension for each street. This dimension is the minimum width of public parking that must be provided. Additional public parking width may be approved by DDOT.Access

It is the policy of DDOT that vehicular access to private property for uses such as parking or a loading dock should be from an existing alley. DDOT may approve one of the following options, in order of preference, for vehicular access to private property:

- Widening an existing alley onto private property to an appropriate width for vehicular access
- Where no alley exists, installing a new public alley of an appropriate width for vehicular access
- Where no alley exists, installing a new private alley of an appropriate width for vehicular access
- Constructing a shared driveway that provides vehicular access from a street to the side or rear of two or more properties or buildings
- Constructing a new driveway and curb cut that provides vehicular access from a street to a single property or building, as a last resort when the above more preferred vehicular access options are infeasible or inappropriate

31.4. Alleys

Alleys provide accessibility and service to individual land parcels. They are characterized by a narrow ROW and generally range in width from 8 to 30 feet. Alleys may be designed to include parking and green infrastructure as described in **Chapter 45** and **Chapter 28** of this manual, respectively.

Alleys should be aligned parallel to or concentric with the street property lines and should be situated in such a manner that both ends are connected either to streets or to other alleys. All alleys should have grades established to meet as closely as possible the existing grades of the abutting land parcels. The longitudinal grade should not be less than 0.3 percent.

Alley cross sections will be V-shaped with transverse slopes leading 2 to 9 inches above and toward a center V gutter that directs runoff to a catch basin, either in the alley itself or to the connecting street gutter system. The transverse slope or “dish” may be modified to meet existing features or conditions and to provide proper drainage. See DDOT’s **Standard Drawings** for details.

31.4.1. DDOT Requirements for Alleys:

- When entering and exiting any private or public space alley, all traffic must head-in and head-out from any District street. Vehicles are not allowed to back into a public alley from a District street.
- Private and public alleys must allow safe vehicular exit via a minimum 15-foot sight-distance from the edge line of the alley on a 45 degree angle from the property line to the back edge line of the sidewalk. If no sidewalk exists, then use the curb line of the street. No over-height fencing or vegetation over 42 inches in height at maturity is allowed within this area, excluding city trees.
- Curb radii for alleys must be 10 feet.
- All alleys must be flush with the grade of the sidewalk at the sidewalk crossing area. No step-down curbs or ramps are allowed at alley entrances.

31.5. Curb Cuts

- While curb cuts can be necessary to provide vehicular access to private property, DDOT aims to minimize their presence for the following reasons: A curb cut creates an additional conflict point between vehicles, pedestrians and bicycles
- A curb cut removes on-street parking spaces
- A curb cut detracts from the site aesthetically and removes trees and landscaped pervious areas

Therefore, the number and impact of curb cuts and driveways on public space should be minimized to improve pedestrian circulation and safety by:

- Restricting the number of curb cuts at all properties, regardless of land use. The maximum number of curb cuts, including those intended for circular driveways, must be no more than two for a property abutting one street, and no more than three for a property abutting two or more streets (see DCMR Title 24, Subsection 605.9). Despite these limits, DDOT policy is that, absent a compelling need, there should be no more than one curb cut per building.

- Consolidating curb cuts for different uses, such as loading and parking garage entrances.
- Providing curb cuts only where leading to multiple vehicular parking spots, since a curb cut typically removes at least one on-street vehicular parking space.
- Limiting the number of curb cuts for multi-phased developments and adjacent developments through shared curb cuts, potentially requiring easements.
- Locating the curb cut on the street with the lower volume of vehicular traffic when a property fronts on two or more streets and when consistent with area planning and historic preservation objectives.
- Prohibiting backing movements through public space due to safety concerns. Turning movements must be accommodated on private property to ensure head-in/head-out vehicle movements through public space as established in this manual.
- Choosing a driveway design that is as narrow as practical and meets the standards established in this manual.
- Establishing appropriate distances between curb cuts and other disruptions to the sidewalk; see **Section 31.5.5** for minimum setbacks for driveways.
- Providing adequate line-of-sight setbacks behind sidewalks at parking garage exits.
- Using driveway paving materials that continue the paving color and texture of the adjoining sidewalk across the driveway as an indication to drivers that they are crossing a pedestrian pathway.
- Maintaining a continuous canopy of street trees.
- Maintaining a pedestrian clear path width across the driveway or alley that is no less than the minimum required width for the sidewalk as specified in this manual.
- Complying with the ADA sidewalk slope requirements, as specified in this manual, for the full width and length of the pedestrian clear path crossing the driveway or alley.
- Complying with the sidewalk surface requirements set forth in the ADA standards for the full width and length of the pedestrian clear path crossing the driveway or alley.

31.5.1. Curb Cut Requirements

- A new curb cut or driveway is not permitted from any property with alley access, potential access through an improved alley, alley widened onto private property or with potential access to an expanded alley network on private property, unless the applicant provides documentation demonstrating that alley access is not possible due to topography, or that alley access would conflict with existing land uses and is not supported by guidelines in the current **DC Comprehensive Plan** and those outlined in **Section 31.4**.

- Driveway entrances should be constructed perpendicular to the curb line of the street through the entire public space area to the property line.
- All driveways must be flush with the grade of the sidewalk when crossing the entire sidewalk area. No step-down curbs or ramps are permitted.
- The grade of any driveway within a public space must not exceed 16 percent, and the algebraic difference of the driveway grade with the counter slope must not be greater than 20 percent.
- A curb cut and/or respective portion of the driveway, including the flare or radius at the curb cut, must be within the public space abutting the same lot with the building or structure it is intended to serve.
- Sight-distance for safely exiting driveways and parking garages must be a minimum of 15 feet from the edge line of the driveway on a 45-degree angle from the property line or building line at the garage exit, as applicable, to the back edge line of the sidewalk. No over-height fencing or vegetation over 42 inches in height at maturity is allowed in this area, excluding city trees.
- Signalized driveways must be designed to meet all intersection guidelines.
- All driveway entrances must be constructed of poured concrete in accordance with the **DDOT Standard Specifications for Highways and Structures**.
- Driveway paving materials must continue the paving color and texture of the adjoining sidewalk across the driveway as an indication to drivers that they are crossing a pedestrian pathway.
- Driveways and parking pads must be constructed so that the parking of a motor vehicle thereon does not cause any portion of the vehicle to intrude in part or whole over any portion of the public space.
- When changes are made at a property due to redevelopment or new businesses, all existing driveways must be restored with new curb and gutter, tree space and sidewalk to current DDOT standards.
- Any existing curb cut proposed for new use must be applied for as a new curb cut and driveway at the DDOT Public Space Permit Office, and the above requirements must be met.

31.5.2. Commercial Curb Cut Requirements

- Driveway entrances must be constructed with 6-foot-radius curb returns at the street in accordance with the “Type A” driveway entrance specified in the **DDOT Standard Specifications for Highways and Structures**.
- Driveways accessing a street must be a minimum of 10 feet wide from edge line to edge line for one-way circulation of motor vehicles, but must not exceed 12 feet wide.

- Driveways accessing a street must be a minimum of 18 feet wide from edge line to edge line for two-way circulation of motor vehicles, but must not exceed 24 feet for two-way circulation when unusually heavy vehicular traffic is anticipated. Narrower driveways matching residential width standards may be considered for small commercial projects.
- Where unavoidable, driveways that must be more than 24 feet wide to accommodate large, heavy and frequent vehicles must have a minimum 6-foot-wide pedestrian safety island. This pedestrian island must be paved as an 8-inch-thick sidewalk that matches the material used for the existing or proposed adjacent sidewalk. The pedestrian island must have minimum 3-foot-radius curb returns at the street. This 6-foot-wide island must be designed to prohibit vehicles from crossing within the public space area and may be landscaped.
- Two driveways accessing a single property must be at least 12 feet apart. (This does not apply to a single driveway with ingress/egress separated by a 6-foot-wide pedestrian island.)
- Driveways for loading docks with entrances on the roadway must be a minimum of 12 feet wide from edge line to edge line, but must not exceed 24 feet wide, regardless of the number of loading bays.
- All motor vehicles accessing a loading dock driveway from a roadway must both enter and exit the driveway entrance in a forward direction to avoid vehicles backing into the public space.
- All turning and backing movements associated with accessing a loading dock from a driveway entrance on a street must take place on private property.
- All parking and standing associated with the use of a loading dock must be on private property, and no portion of a standing or parked motor vehicle is allowed to intrude in part or whole over any portion of the public space.
- Driveways within the Downtown Streetscape area and other areas designated by DCMR Title 11, Hotel-Residential Incentive Overlay District, must be constructed at a right angle (90 degrees) to the curb line of the roadway through the entire public space area to the property line, and must have 6-foot-radius curb returns at the roadway. Driveway edge lines must be located a minimum of 8 feet from any interior property line.

31.5.3. Residential Curb Cut Requirements

- A residential curb cut is defined as typically having a “Type D” driveway entrance with 6-foot-radius curb returns that are used to access single-family residences, flats and duplexes, but not condominiums or apartment buildings.

- Off-street parking accessed by a curb cut and driveway must measure a minimum of 9 feet wide by 19 feet long and must not cause any portion of the vehicle to intrude into any portion of the public space.
- Driveways from any roadway at a single-family residence must have a minimum width of 9 feet measured edge line to edge line within the public space, but must not exceed 12 feet wide.
- Driveway entrances must be flared (Type D) or have a maximum radius of 6 feet at the roadway in accordance with the **DDOT Standard Specifications for Highways and Structures**. The type of entrance constructed depends on the standard for the specific neighborhood.
- When two adjacent dwellings are being constructed or permitted at the same time, and where alley access is not available or feasible, a curb cut and driveway shared by the two adjacent dwellings is required, provided no more than 7 feet of the driveway width is located on one side of the shared lot line extended.
- Any driveway entrance or exit on an alley must be at least 30 feet away from a roadway as measured from the driveway edge line to the intersection of the alley edge line and roadway curb line extended.

31.5.4. Circular Driveway Requirements

- Circular driveways are allowed in accordance with DCMR Title 24, Subsection 607.4, and when written documentation is provided to the DDOT Public Space Permit Office to substantiate a compelling need for one-way circulation of motor vehicles for drop-off and pick-up, and other options are not viable.
- Circular driveways within public space must not be used for stacking parked vehicles, as these driveways are intended to give passengers closer access to a building entrance for drop-off and pick-up. A clear drive width for the entrance and exit must be maintained for the entire length of the driveway in the public space.
- A circular driveway entrance or exit on any roadway must be at least 60 feet away from a roadway intersection as measured from the intersection of the driveway edge line and the roadway curb lines extended to the intersection of the roadway curb lines extended.
- The 6-foot curb radius for a circular driveway entrance must not be located less than 8 feet from an interior lot line extended.
- There are two types of circular driveways. One is designed on a 60-degree angle with the street curb, and the other is a “U” shaped designed on a 90-degree angle with street curb. See drawing details for the layouts of these driveways.

31.5.5. Minimum Setbacks for Driveways

- The minimum acceptable distance between the edge line of an intersection and the edge line of an adjacent driveway or alley is 60 feet as measured along the roadway curb between the near edge lines of the driveway or alley.
- The minimum acceptable distance between the edge line of a driveway and the edge line of an adjacent driveway or alley is 24 feet, as measured along the roadway curb between the near edge lines of the driveway or alley. However, where a tree is located between driveways and/or alleys, the minimum acceptable distances shown on Figure 31-1 apply.
- A driveway must be at least 8 feet from the adjacent property line extended onto public space as measured from the edge line of the driveway closest to the adjacent property line extended. Adjacent driveways that access two different properties must be no less than 24 feet from edge line to edge line.
- Adjacent driveways that are 24 feet wide or narrower and that access a single property may be located 12 feet apart provided the driveway entrances have 6-foot-radius curb returns that are flush with the sidewalk.
- The minimum distance between the edge line of a driveway or alley and the near side of an adjacent existing or proposed street tree must be no less than the following:
    - 10 feet for driveways having a Type B, C or D driveway entrance as specified on the current **DDOT Standard Drawings** and typically used at residential dwellings.
    - 12 feet for driveways having a Type A driveway entrance, typically with 6-foot curb returns as specified on the current **DDOT Standard Drawings** and typically used to support commercial traffic or higher volumes of traffic.
    - 16 feet for alley entrances typically having 10-foot curb returns as specified on the **DDOT Standard Drawings** for Type A or Brick Paving alley entrances.
    - 16 feet for any driveway or alley entrance when the existing tree is 37 inches in circumference or greater at breast height.

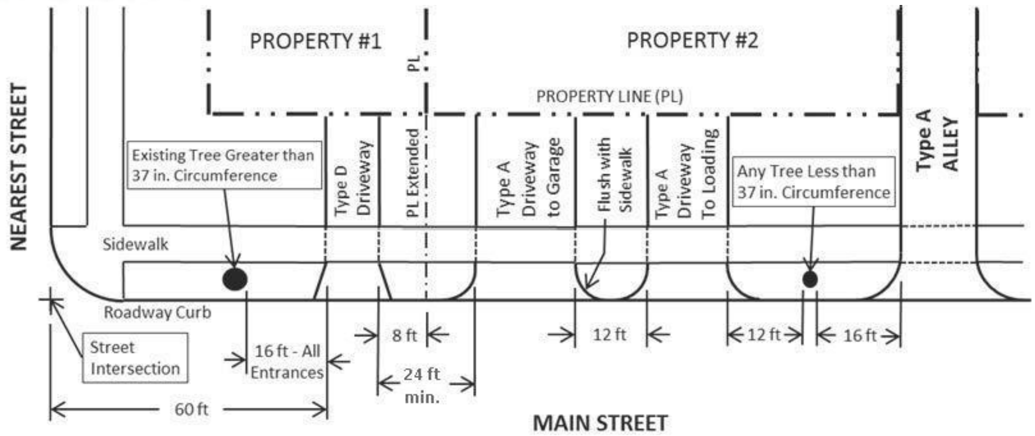


Figure 31-1 | Minimum Setback Distances

31.6. Curb Ramps

Curb ramps are critical to providing access between the sidewalk and the street for people who use wheelchairs. Curb ramps are most commonly found at intersections, but they may also be used at other locations such as on-street parking, loading zones, bus stops and midblock crossings.

Curb ramps are categorized by their structural design and how they are positioned relative to the sidewalk or street. The structure of a curb ramp is determined by how the components, such as ramps and flares, are assembled. The type of curb ramp and the installation site will determine its accessibility and safety for pedestrians with and without disabilities. Curb ramp types are summarized in Table 31-2.

Table 31-2 | Curb Ramp Types

RAMP TYPE	ADVANTAGES TO PEDESTRIANS	DISADVANTAGE TO PEDESTRIANS
Perpendicular Figure 31-2	• Ramp aligned with crosswalk • Straight path of travel on tight radius • Two ramps per corner	• May not provide a straight path of travel on larger radius corners
Parallel Figure 31-3	• Requires minimal right-of-way • Has an area aligning with the crossing • Allows ramps to be extended to reduce ramp grade • Has edges on the side of the ramp that are clearly defined for pedestrians with vision impairment	• Pedestrians need to negotiate two or more ramp grades (difficult for wheel chair users) • Improper design can result in the accumulation of water or debris on the landing at the bottom of the ramp
Combination (Parallel & Perpendicular) Figure 31-4	• Does not require turning or maneuvering on the ramp • Ramp is aligned perpendicular to the crosswalk • Level maneuvering area at the top and bottom of the ramps	• Visually impaired pedestrians need to negotiate sidewalk ramps

RAMP TYPE	ADVANTAGES TO PEDESTRIANS	DISADVANTAGE TO PEDESTRIANS
Blended Transitions Figure 31-5	• Eliminates the need for a curb ramp	• Pedestrians with cognitive impairments may have the illusion that the sidewalk and street are unified pedestrian space • Improper design can allow large vehicles to travel onto the sidewalk to make tight turns which puts the pedestrian at risk • More difficult to detect the boundary between the sidewalk and the street for persons with vision impairments • Service dogs may not distinguish the boundary between the sidewalk and the street and continue walking • The design may encourage motorist to turn faster by traveling onto the sidewalk

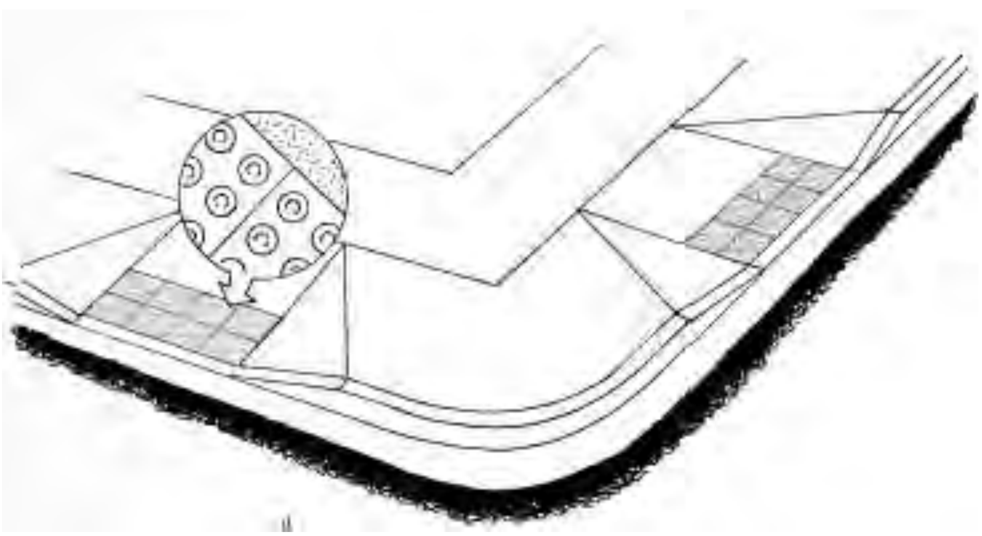


Figure 31-2 | Perpendicular Curb Ramp

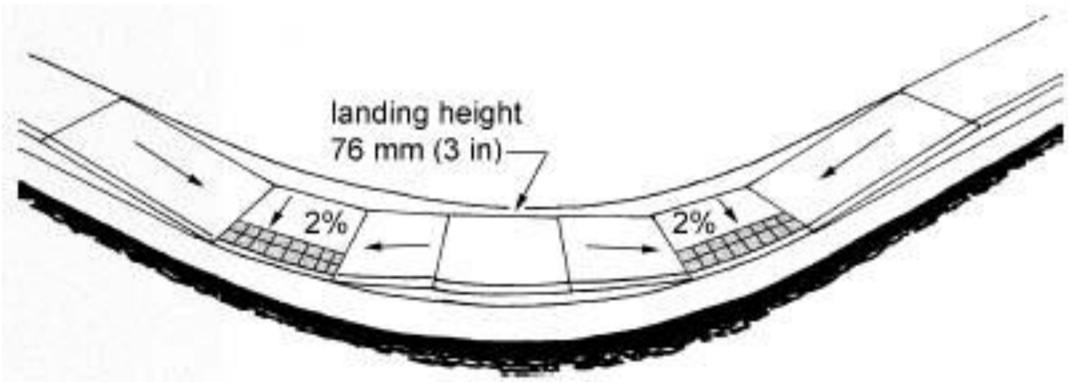


Figure 31-3 | Parallel Curb Ramp

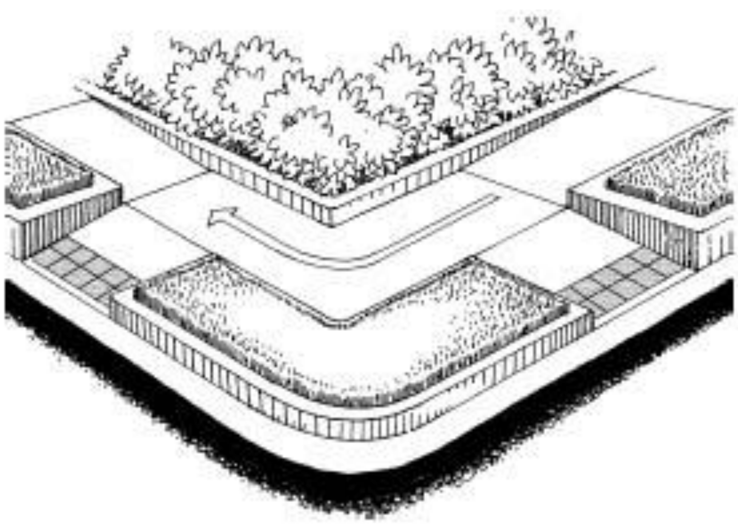


Figure 31-4 | Combination Curb Ramp

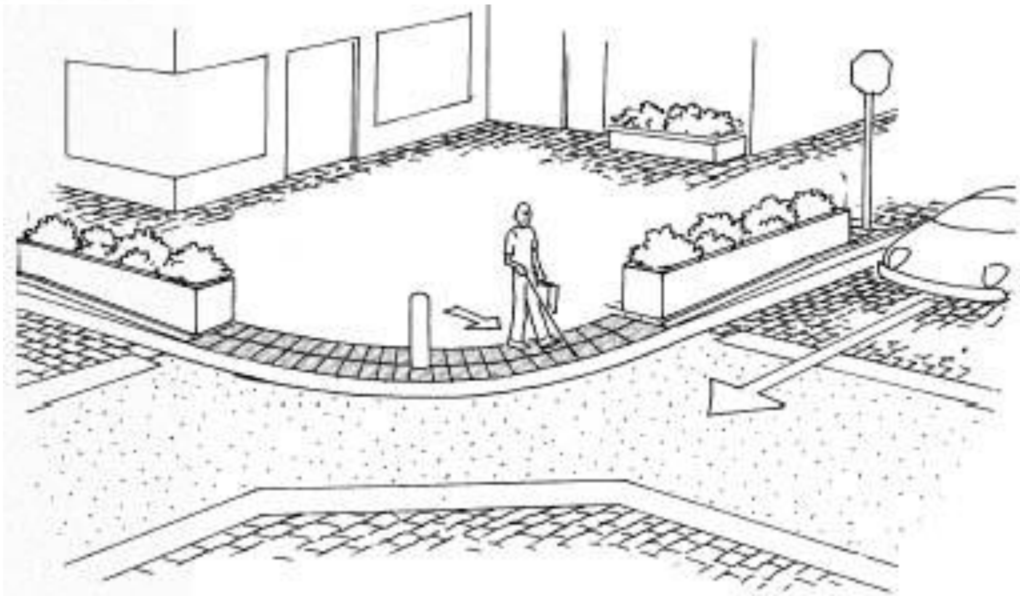


Figure 31-5 | Blended Transitions Curb Ramp

31.6.1. Curb Ramp Specifications

There are a variety of curb ramp designs, and designers can work with the various features to maximize access. Most curb ramps adhere to the following:

- A maximum curb ramp slope of 8.33 percent is permitted by ADAAG. The slope may not be negative (sloped down from the roadway)
- The ramp cross slope may not exceed 2 percent
- The ramp width must be a minimum of 4 feet
- The algebraic difference in grade between the gutter slope and the pedestrian ramp must be no more than 13.33 percent
- Curb ramp alignment must be perpendicular to the curb face, with a straight line of travel
- Transition points between adjacent curb ramp surfaces must be flush
- Sidewalk approach widths should be a minimum of 4 feet
- Landings at the top and bottom of the curb ramp should be minimum 4 feet by 4 feet in dimension, and the cross slope should not exceed 2 percent
- Ramp construction must prevent ponding at the ramp gutter line
- Where there are two curb ramps at the corner of an intersection, the curb height between them may be reduced from 7 inches to 3 inches if needed

Additional information on curbs and gutters may be found in **Chapter 30**.

31.6.2. Pedestrian Crossings

A pedestrian crossing is defined as any location where a pedestrian leaves the sidewalk and enters a roadway, typically at an intersection or mid-block. Selecting the appropriate crossing treatment to enhance safety depends on several factors, including the number of lanes to cross and the traffic volumes of the roadway.

For crossings at roadways with traffic volumes less than 1500 vehicles per day (vpd), a parallel crosswalk and/or W11-2 assembly is the most appropriate treatment. For crossings at roadways with traffic volumes greater than 1500 vpd, use Table 31-3 to determine the appropriate treatment.

Table 31-3 | Crossing Treatment Selection

Roadway Configuration	1500–9000 vpd	9000–12,000 vpd	12,000–15,000 vpd	>15,000 vpd
2 Lanes [1]	A	A	A or B	B or C
2 Lanes with Channelized Turn Lanes [1]	A	A	B	B or C
2 Lanes One Way	B	B	C	C
4 Lanes w/Raised Median [2]	B	B	C	C
3 Lanes No Median [3]	B	B	C	C
5 Lanes w/Raised Median [3]	B	B	C	C
6 Lanes w/Raised Median [4]	B	B	C	D
4 Lanes No Median [4]	B	B or C	C	D
5 Lanes No Median [3]	B	B or C	D	D
6 Lanes No Median [4]	B	B or C	D	D

Notes:
1. This assumes a two-way road with 1 lane in each direction at the crossing location
2. The road may be one-way or two-way with unbalanced lanes at the crossing location
3. The road may be one-way or two-way at the crossing location
4. The relationship of traffic volume, number of lanes, and speed for "C" treatments require additional evaluation to determine their effectiveness, as these features are relatively new devices
5. Lane configurations should be determined at peak hour vehicular volume conditions

Crossing Treatment Types:
Treatment A – High-Visibility Crosswalk and Side of Street Pedestrian Law Sign
Treatment B – In-Street Stop for Pedestrians Sign and/or Traffic Calming (See **Chapter 40**). Advance Stop Sign should be used for all Multi-Lane Crossings.
Treatment C – Activated Pedestrian Device (Rapid Flash Beacon, Flashing Beacon, In-Roadway Lights)
Treatment D – Signal (Pedestrian Hybrid, Full Signal) or Grade Separation

Design of a safe and accessible pedestrian crossing requires several considerations, including information (signs, accessible pedestrians/traffic signals and markings), required turning radius, adequate curb ramps, visible crosswalks, and adequate crossing times, traffic light phasing and sight distances. Curb ramps on both sides of the street are required for a safe and accessible pedestrian crossing. Furthermore, curb extensions increase the visibility of pedestrians, create safer and shorter crossings for pedestrians and provide connectivity to sidewalks. See **Chapter 32** of this manual for more information on crossings.

Medians and islands offer a needed refuge for pedestrians to cross travel ways safely. The most common pedestrian crossings for DC are:

- Painted crosswalks
- Raised crosswalks
- Ramped medians
- Cut-through medians
- Corner islands with cut-through
- Ramped corner islands

Raised and painted crosswalks must have a minimum width of 10 feet for local streets and 15 feet for commercial areas; however, consideration for higher pedestrian volumes at intersections may warrant wider crosswalks. Crosswalks should have a maximum cross slope of 2 percent.

Ramped medians should have a curb ramp at either end of the median. Curb ramps should not be offset to avoid mobility issues for wheelchair users, but should run continuously to ensure adequate access. The minimum landing of a ramped median should be 6 feet by 4 feet. Detectable, 2-foot-wide warning pavers must be installed on both ends of the median. See Figure 31-6.

Corner islands with cut-throughs must be a minimum width of 4 feet and include 2-foot-wide, detectable warning pavers. See Ramped corner islands must have a minimum landing width of 4 feet, and 5 feet is preferred. Detectable warning pavers should be installed at the island/street interface. See Figure 31-8.

For additional information on median design, refer to **Chapter 30**. For information on island guidelines, refer to **Chapter 33**.

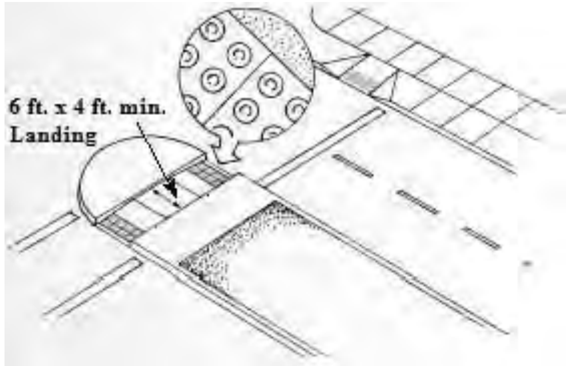
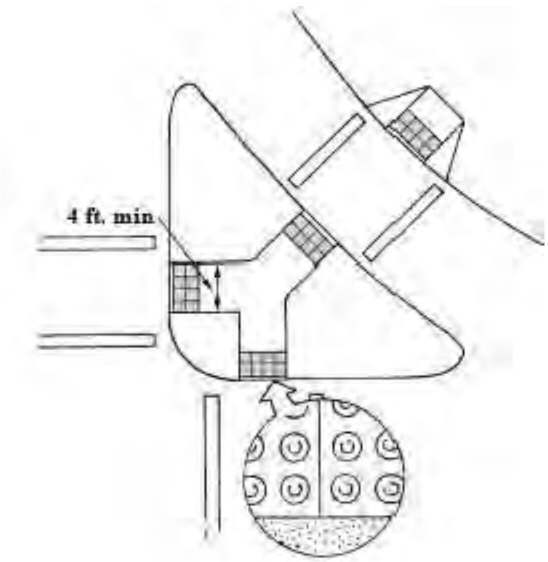


Figure 31-6 | Warning Pavers on Ramped Median



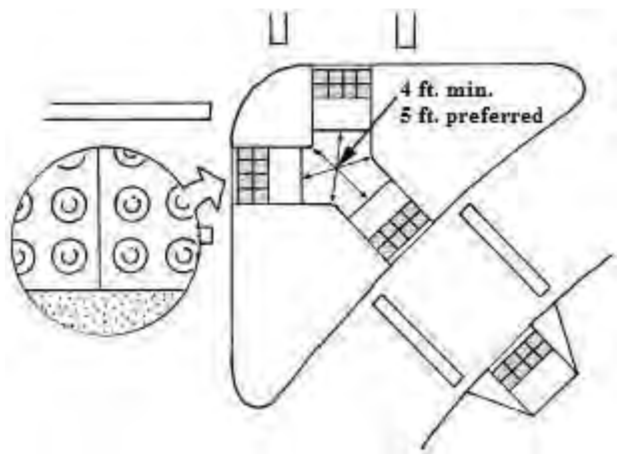


Figure 31-7 | Warning Pavers on Corner Island **Figure 31-8 | Warning Pavers on Corner Island**

Adapted from: FHWA Accessible Sidewalks and Street Crossings Guide

31.7. Historic Districts

For the districts listed below, the standards should consist of brick sidewalks, granite or stone curbs, Washington globe lights, and concrete ADA ramps. The concrete for the ADA ramps does not need to be tinted to match the brick. For the alleys in the two blocks bounded by 9th, 10th, M and O Streets (Blagden Alley & Naylor Court), and in Foggy Bottom, the Designer should take particular care to preserve or replace in-kind the block and brick alley paving. Ideally, all alleys in these districts that are brick or asphalt block should be repaired or replaced in-kind rather than paved over. Where bluestone curbing exists (typically in Georgetown and Capitol Hill), care should be taken to preserve and reuse the bluestone wherever possible (refer to the **Downtown Streetscape Regulations** for construction in the Central Washington area). If not well maintained, sidewalks with brick-on-sand type of design may be hazardous to visually impaired and blind persons, who can trip, lose their balance and fall if the bricks become loose. Most non-mechanical wheelchair users do not like dislodged bricks either, as the bricks can become obstacles for them to maneuver around. See **Section 31.7.1** for more details on new and existing sidewalks in historic districts. When a community wants to modify the standard design in a historic area, approval must be requested from the DC State Historic Preservation Office (SHPO).

The DC Historic Landmark and Historic District Protection Act requires DC government agencies to take into account the effects of their undertakings on properties listed in or eligible for listing in the District of Columbia Inventory of Historic Sites, and to consult with and afford the DC SHPO a reasonable opportunity to comment. These requirements are to be fulfilled before an agency authorizes the expenditure of funds for design or construction, or seeks the permit, license or approval for a DC undertaking.

District government agencies are required to get a building permit before starting work on a government construction project. For work on a historic property or in a historic area, getting a permit also involves making sure that proposed changes are compatible with protected historic and architectural characteristics. This is done through a design review process managed by the SHPO and Historic Preservation Review Board.

DC historic areas consist of the following:

- Anacostia
- Armed Forces Retirement Home
- Blagden Alley/Naylor Court
- Capitol Hill
- Cleveland Park
- Chesapeake and Ohio Canal
- Downtown
- Dupont Circle
- Federal Triangle
- Fifteenth Street Financial
- Foggy Bottom
- Fourteenth Street
- Fort McNair
- Fourteenth Street
- Foxhall Village
- Gallaudet College
- Georgetown
- George Washington University/Old West End
- Grant Road
- Kalorama Triangle
- Lafayette Square
- LeDroit Park
- Logan Circle
- Marine Barracks
- Massachusetts Avenue
- McMillan Park Reservoir
- Meridian Hill
- Mount Pleasant
- Mount Vernon Square

- Mount Vernon Triangle
- National Mall
- National Zoological Park
- Pennsylvania Avenue
- Potomac Parks
- Rock Creek Park
- Seventeenth Street
- Shaw
- Sheridan-Kalorama
- Sixteenth Street
- St. Elizabeth's Hospital
- Strivers' Section
- Takoma Park
- U Street
- Walter Reed Army Medical Center
- Washington Cathedral
- Washington Heights
- Washington Navy Yard
- Woodley Park

The Office of Planning website has maps of the historic districts at http://planning.dc.gov/page/historic-district-maps.

Construction methods and materials must follow the current **DDOT Standard Specifications for Highways and Structures,** addenda and supplements thereto when constructing or rehabilitating components of the transportation infrastructure within a historic district.

31.7.1. New and Existing Sidewalks in Historic Districts

New sidewalks in historic areas, when constructed where no sidewalk previously existed, must be:

- Brick on 4-foot-thick concrete base
- Set in a running bond pattern

Existing sidewalks must be rehabilitated to retain their materials and pattern:

- Brick on concrete must be replaced with brick on concrete.
- Brick on sand must be replaced with brick on concrete (exceptions will be considered on a case by case basis).
- Every effort will be made to reset existing bricks and to supplement existing brick from DDOT's brick stockpile. If there is insufficient brick to rebuild the sidewalk with the original bricks, then the reusable bricks must be used together in one area and the remainder of the sidewalk built with new bricks.
- Concrete sidewalk, when rebuilt, must be rebuilt with brick on a concrete base.
- Exposed aggregate concrete is the recommended material in certain historic neighborhoods, and brick is recommended in others. In historic neighborhoods where exposed aggregate is

favored, straight finished concrete with a “pebble” concrete dye is used on non-Federal Aid (i.e., local) streets.

- Various types of historic alley paving materials are used, depending on the historic district. Bluestone dyed/scored concrete patterns can be used as an alternative in commercial alleys of historic districts with the approval of DDOT.
- The brick pattern of the rehabilitated sidewalk must match the predominant pattern that was present prior to rehabilitation.
- In all cases, the color and size of new bricks must match as closely as possible to the color and size of existing bricks in the vicinity.
- Where there are no sidewalks, new sidewalks must be provided at existing bus stops from the front and rear doors of the bus to the nearest crosswalk. The minimum sidewalk width is 6 feet. ADA ramps must lead to the crosswalk and be installed on both sides of the street.

See **Section 31.2.1.1** for further requirements for sidewalk widths.

31.7.2. Historic Alleys

Historic alleys in the District of Columbia must be repaired or restored with special consideration. Alleys must be restored with the same material as originally constructed if possible. Brick alleys must be rebuilt in brick; cobblestone alleys must be rebuilt in cobblestone. Concrete, asphalt and asphalt-block alleys must also be rebuilt in-kind.

If the historic alley was constructed with materials that are no longer in use today, the alley must be reconstructed with materials that match as closely as possible to the existing in color, texture and other characteristics. Various types of paving materials can be used in historic alley reconstruction, depending on the historic district (for example, the Commission of Fine Arts has approved bluestone dyed/scored concrete patterns for use as an alternative in commercial alleys of historic districts such as Blues Alley in Georgetown and numerous alleys in Adams Morgan). The DDOT Chief Engineer will make the final determination.

District regulations require that all alleys be lit to current lighting standards. If the alley is currently lit, the only work required will be the replacement of luminaries, lamps and photocells to DDOT standards. If the alley does not meet current standards, then a new lighting system must be designed to include manholes, conduits, wiring, poles luminaries, lamps and photocells. New poles will be placed on the property line between adjoining lots where possible.

When a contractor or utility company performs work in an alley deemed historic by the District of Columbia, the DDOT Chief Engineer must be notified. Where the work involves removing rare materials that may no longer be obtained as replacement parts, the contractor or utility company may be required to carefully remove the entire special paving, perform the required work, and repave the alley as directed to avoid unsightly patch work. DDOT will delineate the square area of paving for the contractor to carefully remove and replace using materials that match the original in color, size and texture as closely as possible.

31.7.3. Other Special Districts

For the following districts, the standards consist of concrete sidewalks, stone curbs with brick gutter, Washington globe lights, and concrete ADA-compliant pedestrian ramps:

- Dupont Circle
- Sheridan-Kalorama
- Massachusetts Avenue
- Sixteenth Street

For the following districts, the standards consist of concrete sidewalks; concrete, granite or stone curbs and gutters; Washington globe lights; and concrete ADA-compliant pedestrian ramps:

- Mount Pleasant
- Cleveland Park
- Woodley Park
- Takoma Park

In Mount Pleasant, asphalt pavers in alleys should be retained rather than replaced or paved over.

31.7.4. Bluestone Curbing

Bluestone curbing, regardless of location, must be reset and reused wherever possible. If existing bluestone cannot be reused for sound engineering reasons, the stone must be salvaged and returned to the DDOT Street Maintenance facility. In historic districts, bluestone that cannot be reused must be replaced with granite.

32 Intersections

32.1. General

An intersection is the common area where two or more roadways join or cross, where speed and direction may change and conflicts may occur. Intersections must be designed to provide for the safety of motorists, pedestrians and bicyclists. By their nature, intersections are conflict locations where vehicles, pedestrians and bicycles all cross paths. Each crossing is a conflict point. Intersections should be designed to make the movements for modes of transportation intuitive and safe.

32.1.1. Guidelines and Regulations

This chapter is based on criteria from the following documents:

- American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets
- AASHTO, Guide for the Planning, Design, and Operation of Pedestrian Facilities
- Institute of Transportation Engineers (ITE) Traffic Engineering Handbook
- ITE Context-Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities
- National Association of City Transportation Officials (NACTO) Urban Bikeway Design and Urban Street Design Guide
- NACTO Urban Street Design Guide
- Federal Highway Administration (FHWA) Roundabout Design Guide (FHWA-RD-00-067)
- National Cooperative Highway Research Program (NCHRP) Report 279, Intersection Channelization Design Guide
- NCHRP Report 572, Roundabouts in the United States
- NCHRP Report 672, Roundabouts: An Informational Guide

32.1.2. Intersection Design Criteria

- **Physical area of an intersection (intersection proper).** This area is defined by a line connecting the center of corner curbs (points of intersection extensions). This area is shared by traffic traveling in different directions.
- **Functional area of intersection.** This area includes all queue storage areas, auxiliary lanes, and perception and reaction lengths.
- Intersection design covers the entire functional area of an intersection.

32.2. Basic Intersection Design

The basic design of intersections must have the following objectives:

- Minimize points of conflict
- Simplify areas of conflict
- Limit conflict frequency
- Limit conflict severity
- Facilitate safe and efficient flow of multi-modal traffic
- Reduce impacts on surrounding intersections
- Reduce pedestrian exposure
- Accommodate future land use

32.3. Lane Alignment

All lanes must be aligned through an intersection and should not shift more than 2 feet; any shift must have engineering justification. If lanes must shift through an intersection, channelizing pavement markings should be provided to assist drivers. Refer to **Chapter 44** for more information.

32.4. Angle of Intersection

Crossing roadways should intersect at 90 degrees whenever possible. If 90 degrees is not feasible, it is highly desirable to have crossing roadways intersect between 80 and 90 degrees. New intersection designs must never intersect at less than 70 degrees, unless it is a historic angled street, and then precedence should be given to the historic roadway angle.

32.5. Horizontal Alignment and Vertical Profile

- **Horizontal.** For intersections on which a major roadway curves and a minor roadway is located tangent to that curve, it is highly desirable to realign the minor roadway as close to 90 degrees as possible.
- **Vertical.** The street profile grade must not exceed 4 percent on the approach to the intersection, as measured along the centerline of the street. The profile grade within the intersection streets must not exceed 3 percent. For new construction, crosswalk cross slopes must not exceed 2 percent. In areas of hilly terrain and steep grades where it may not be possible to attain a 4 percent approach to the intersection and a 3 percent grade within the intersection, the design may be modified to provide the best design attainable.

- **Prevailing street grade.** The grade of the street with the higher classification must prevail at intersections. The lesser street must adapt to the grade of the major street. Grading of adjacent property and driveways must adapt to the street grades.

32.6. Exclusive Left Lane Turns

Exclusive left turn lanes may be provided on arterial roadways wherever left turns are approved. The Designer must determine whether an exclusive left turn lane is warranted at designated locations. At intersections with pedestrian activity, left turn lanes should be limited to a single left turn lane. The designer needs to consider the safety benefits of adding turn lanes while minimizing pedestrian crossing distance. The following criteria, based on **NCHRP Report 279 – Intersection Channelization Design Guide**, must be followed:

- **Warrants for Signalized Intersections.** A separate left turn lane may be required if one of the following criteria is met:
    - The left turn design volume is at least 20 percent of total approach volume, or
    - The left turn design volume exceeds 100 vehicles per hour (vph) in peak periods, or
    - The level of service criterion is not satisfied without a separate left turn lane.
- **Warrants for Un-signalized Intersections.** Left turn lanes may be required at approaches to intersections in which the combination of through, left, and opposing volumes exceeds the above-mentioned warrants.
- **Design Criteria.** Left turn lanes must be designed to provide the following functions:
    - A means for safe deceleration outside the high-speed through lane
    - A storage length long enough for left turning vehicles so that signal phasing can be optimized and intersection delay minimized
    - Separate movements at un-signalized intersections to reduce left turn impacts on other flows
    - The design elements are the approach taper, bay taper, lengths of lanes, width of lanes and departure taper
- Warrants for Left Turn Lanes on Two-Lane Highways:
    - Advancing volumes, opposing volumes (vph), speed and percent left turns are used to determine whether a left turn storage lane is warranted on two-lane highways.

The warrants from **AASHTO, A Policy on Geometric Design of Highways and Streets** should be used to determine required storage lengths for left turn storage lanes on two-lane highways (see Table 32-1, Figure 32-1 and the Exhibits at the end of this chapter).

Table 32-1 | Warrants for Left Turn Lanes

VPH OPPOSING VOLUME	ADVANCING VOLUME			
	5% LEFT TURNS	10% LEFT TURNS	20% LEFT TURNS	30% LEFT TURNS
40 MPH DESIGN SPEED				
800	330	240	180	160
600	410	305	225	200
400	510	380	275	245
200	640	470	350	305
100	720	515	390	340
50 MPH DESIGN SPEED				
800	280	210	165	135
600	350	280	195	170
400	430	320	240	210
200	550	400	300	270
100	615	445	335	295
60 MPH DESIGN SPEED				
800	230	170	125	115
600	290	210	160	140
400	365	270	200	175
200	450	330	250	215
100	505	370	275	240

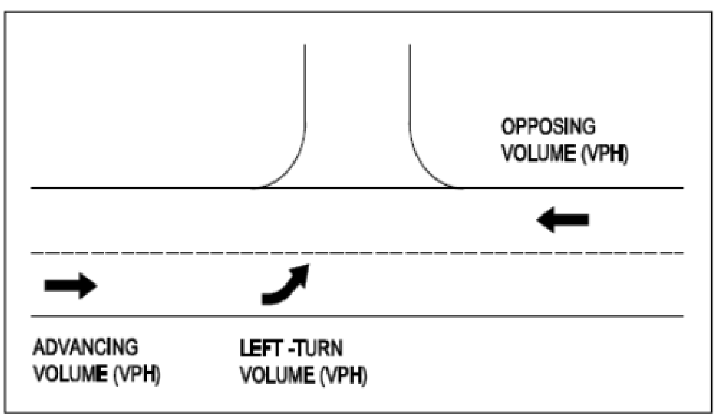


Figure 32-1 | Warrants for Left Turn Lanes

Image from *Access Management Design Standards for Entrances and Intersections* courtesy of Virginia Department of Transportation

32.7. Exclusive and Channelized Right Turn Lanes

In urban contexts, high-speed channelized right turns are often inappropriate because they create conflicts with pedestrians. Under some circumstances, providing channelized right turn lanes on one or more approaches at a signalized intersection can be beneficial.

The general principles and considerations for channelized right turns include the following:

- Avoid using channelized right turn lanes where pedestrian activity is significant. If a channelized right turn lane is unavoidable, use design techniques described below to lessen the impact on pedestrians.
- Exclusive right turn lanes should be limited. A right turn volume threshold of 200 to 300 vph is an acceptable range for the provision of right turn lanes. Once it is determined that a right turn lane is necessary, a well-designed channelization island can help slow down traffic, provide pedestrian refuge and reduce conflicts between right-turning vehicles and pedestrians.
- If an urban channelized right turn lane is justified, design for low speeds (5 to 10 mph) and high pedestrian visibility.
- For signalized intersections with significant pedestrian activity, it is highly desirable to have pedestrians cross fully under signal control. This minimizes vehicle-pedestrian conflicts and adds to the comfort of pedestrians walking in the area.
- On streets with bike lanes, right turn lanes should be to the right of the bike lane unless it is a protected bike lane with its own signal phase.

32.8. Acceleration/Deceleration Lanes

On roadways with posted speeds above 35 mph, acceleration/deceleration lanes may be considered at each high-volume driveway and major intersection. The specific designs for these lanes must be in accordance with **NCHRP 279** and this chapter.

32.9. Curb Returns

A curb return is the curved portion of curb and gutter at the corner of an intersection, driveway, median, etc. The minimum allowable grade around curb returns is 0.5 percent to allow proper drainage.

Minimum curb return radii dimensions are shown in Table 32-2. Curb return radii may be increased beyond the minimum dimension, depending on the geometry of the road, the dimensions and frequency of different types of running vehicles, and roadway context.

Table 32-2 | Minimum Curb Return Radii

TYPE OF INTERSECTION	CURB RADIUS (FT)
Desired curb return radius for street intersections	15
Standard curb return radius for alleys	10
Standard curb return radius for driveways	6

AASHTO, A Policy on the Geometric Design of Highways and Streets provides the basis for roadway geometric design. The Design Policy states that where turning vehicles exist within minimum space, as at non-channelized intersections, the corner radii should be based on the minimum turning path of the selected design vehicles. The appropriate design may depend on other factors such as the type, character and location of the intersecting roads, the vehicular and pedestrian traffic volumes, the number and frequency of the larger vehicles involved in turning movements, and the effect of these larger vehicles on other traffic. For example, if turning traffic is nearly all passenger vehicles, it may not be cost-effective or pedestrian-friendly to design for large trucks. However, the design should allow the occasional large truck to turn by swinging wide and encroaching on other traffic lanes without disrupting traffic significantly.

Curb return radii should be designed to reflect the “effective” turning radius of the corner. The effective turning radius takes into account the wheel tracking of the design vehicle using the width of parking and bicycle lanes. Using the effective turning radii allows a smaller curb return radius while still accommodating larger vehicles.

Intersections should be designed as compactly as practical in urban contexts. Intersections should minimize crossing distance, crossing time, and exposure to traffic, encourage pedestrian travel and increase safety.

Use a design speed appropriate for the context. Motorists traveling at slower speeds have more time to perceive and react to conflicts at intersections.

To help select a design vehicle, identify bus routes to determine whether buses are required to turn at the intersection. Also check transit service plans for anticipated future transit routes. Map existing and potential future land uses along both streets to evaluate potential truck trips turning at the intersection.

32.10.Median Islands Separating Opposing Traffic

Medians provide the best refuge for pedestrians crossing multi-lane streets. Refer to **Chapter 31** for additional information.

32.11.Dedicated Rights-of-Way (ROWs)

Intersections must be constructed within dedicated ROWs.

- **Requirements.** All intersection ROWs must be dedicated so there is adequate space for sidewalks, curb ramps and utilities. Additional ROW area may be required to accommodate additional left or right turn lanes.
- **Roundabouts.** On all arterials and some collectors, additional ROW may be required at intersections to accommodate the potential installation of a roundabout in the future.

32.12.Intersection Sight Distance

Street intersections must be designed so that adequate sight distance is provided along all approaches. The required sight distance is determined by the design speed and grades of the street, the acceleration rate of the average driver, intersection control, driver's eye height and object height.

- **Purpose.** Sight distance is provided at intersections to allow the drivers of stopped vehicles a sufficient view of the intersecting roadway to decide when to enter or cross the intersecting roadway. If the sight distance for an entering or crossing vehicle is at least equal to the appropriate stopping sight distance for the major road, then drivers have enough sight distance to avoid collisions. In some cases, a vehicle on a major road may need to stop or slow to accommodate a maneuver by a vehicle from a minor road. Therefore, sight distances that exceed stopping distances are desirable along major roads. See **AASHTO, A Policy on Geometric Design of Highways and Streets**, for additional guidance.
- **Minimum Requirements.** All designs must incorporate the minimum safe stopping sight distance in accordance with current AASHTO guidelines. Additionally, for all arterial and collector intersections, the sight distance must allow a vehicle to enter the street and accelerate to the average running speed without interfering with the traffic flow on the arterial or collector street.
- **Landscaping and Hardscaping.** Within a 30-foot by 30-foot sight triangle (as measured from the center of the travel lane to the center of the intersecting approach travel lane) at each intersection corner, no landscaping or hardscaping will be permitted that blocks the line of sight (generally higher than 24 inches). Major roads may be required to include a 50-foot by 50-foot sight triangle.

32.13.Channelization

Channelization refers to physical or visual guides that separate vehicles into particular paths.

- Channelization is intended to:
    - Prohibit undesirable or wrong way movements
    - Define desirable vehicular paths
    - Encourage safe vehicle speeds
    - Separate points of conflict wherever possible
    - Cause traffic streams to cross at right angles and merge at relatively flat gradients
    - Facilitate high-priority traffic movements
    - Facilitate traffic control scheme
    - Remove decelerating, stopped, or slow vehicles from high-speed through-traffic streams
    - Provide safe crossings for pedestrians/bicycles
    - Provide safe refuge for pedestrians
- **Specific Channelization Requirements.** Channelization is required at locations where it is necessary for the safety of all users or to protect the operation of the major street. Examples include:
    - Raised medians in all arterials where left turns are prohibited
    - Exclusive turning lanes, with appropriate striping

32.14.Roadway Narrowing and Curb Extensions

Local, collector or arterial streets may be narrowed at intersections to provide more visibility for pedestrians when approved by DDOT. This shortens the distance necessary for pedestrians to cross the street.

Curb extensions (also called bump-outs or bulb-outs) extend the line of the curb into the traveled way, reducing the width of the street. Curb extensions are typically placed at intersections, but can be used at mid-block locations to shadow the width of a parking lane, bus stop or loading zone. Curb extensions can provide the following benefits:

- Reduce pedestrian crossing distance and exposure to traffic
- Improve driver and pedestrian sight distance and visibility at intersections
- Separate parking maneuvers from vehicles turning at the intersections
- Visually and physically narrow the traveled way, resulting in a calming effect

- Encourage and facilitate pedestrian crossing at preferred locations
- Keep vehicles from parking too close to intersections and blocking crosswalks
- Provide wider waiting areas at crosswalks and intersection bus stops
- Reduce the effective curb return radius and slow turning traffic
- Enhance ADA requirements by providing space for level landings
- Provide space for streetscape elements if extended beyond crosswalks

The following practices are recommended when designing curb extensions:

- Reduce crossing width at intersections by extending the curb line into the street by 6 or 7 feet for parallel parking and to within 1 foot of stall depth with angled parking. Specifically, the extension should be 1 to 2 feet less than the adjacent parking lane width. Also ensure that the curb extension does not extend into travel or bicycle lanes.
- Apply the appropriate curb return radius in the design of a curb extension. If necessary, use three-centered or asymmetric curb returns to accommodate design vehicles.
- Where buses stop in the travel lane, curb extensions can be used to define the location of the stop and create additional waiting area and space for shelters, benches and other pedestrian facilities.
- When possible, allow water to drain away from the curb extension. In other cases a drainage inlet may need to be installed and connected to an existing underground storm drain system. In retrofit projects, curb extensions may be constructed to allow drainage along the original flowline. Consider that this design might require additional maintenance to keep the flowline clear.
- When considering construction of curb extensions where an existing high road crown exists, reconstruction of the street might be necessary to avoid back draining the sidewalk toward abutting buildings. Slot drains along the sidewalk may provide an alternate solution.
- Sidewalks, ramps, curb extensions and crosswalks should all align with no unnecessary meandering.

32.15. Roundabouts

Roundabouts are a form of traffic control when approved by DDOT. The roundabout is a traffic control device in lieu of a multi-way stop or traffic signal. Roundabouts improve the performance of intersections that have the following characteristics:

- High number of accidents

- High delays
- More than four legs or usual geometry
- Frequent U-turns
- Frequent left turn movements

There are two types of roundabouts: Modern and Mini.

- **Modern Roundabouts.** Modern roundabouts are specially designed to the specific need on high-traffic-volume streets and used to improve traffic flow. The following are minimum requirements:
    - **Central Island Radius.** The central island radius must be determined by the Designer and approved by DDOT.
    - **Roadway Width.** The circulatory roadway width must be a minimum of 30 feet. Concrete truck aprons with a minimum width of 6 feet must be provided on the perimeter of the central island.
    - **Where Allowed.** Roundabouts may be allowed on any roadway as approved by DDOT; designs must have a documented constructed capacity that meets or exceeds the 20-year projected intersection volume.
    - **Sight Distance.** Roundabouts must meet the minimum intersection sight distance requirements mentioned in this chapter; however, landscaping in the central island of the roundabout should be used to limit sight distances to the minimum to encourage slower driving speeds within the roundabout.
    - **Design Software.** The roundabout design must be completed with the aid of computer software.
    - **Splitter Islands.** Raised splitter islands are required on all approaches, with appropriate entry and exit angles.

- **Mini Roundabouts.** Mini Roundabouts may be allowed in a neighborhood setting for traffic calming:
    - **Where Allowed.** Mini roundabouts may be used on District streets with average operating speeds of 30 mph or less.
    - **Design Basis.** The design must be in accordance with **Chapter 33** of this manual.
    - **Roadway Width.** The circular roadway must be 20 feet wide, and the approach legs must be 16 feet wide.

32.16.Concrete Pavement

Concrete paving at intersections must extend on each approach leg to the beginning points of the bay tapers. Refer to the **DDOT Standard Drawings** for the typical concrete pavement joint locations.

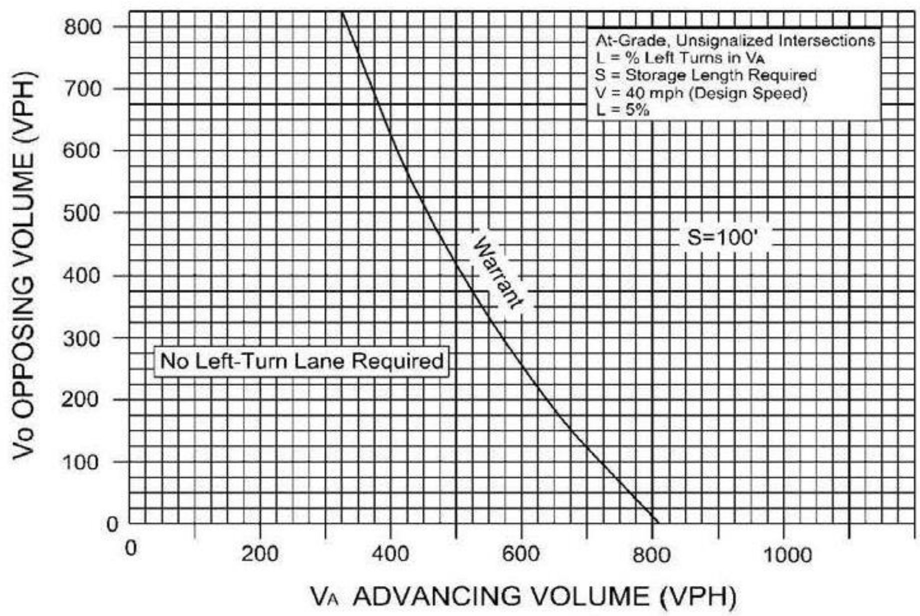
Joints for concrete pavement should include transverse expansion joints, a transverse contraction joint, a longitudinal contraction joint, and longitudinal construction joints. Span length of slabs or transverse joint spacing must be equal, with a maximum length of 20 feet.

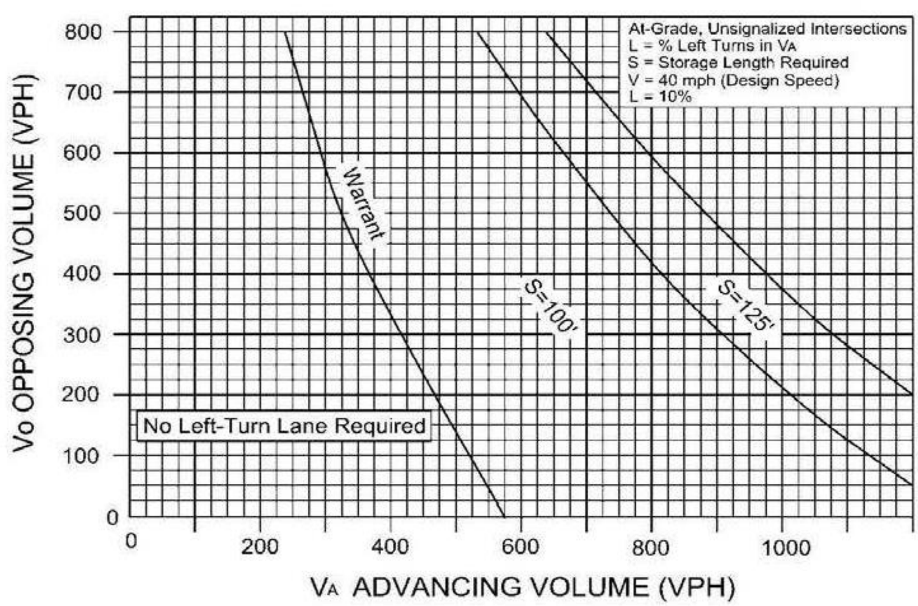
Transverse joint spacing may be changed at intersections to allow the joint to align with the Point of Tangency (P.T.) of the curb return. Joints running to the corner must be radial to the corner curve, with a minimum length of 1 foot. Transverse expansion joints must be placed at street intersection P.T.'s at a maximum spacing of 20 feet.

Exhibit 32-1: Warrants for Left Turn Lanes

Images from *Access Management Design Standards for Entrances and Intersections* courtesy of Virginia Department of Transportation

WARRANT FOR LEFT-TURN STORAGE LANES ON TWO-LANE HIGHWAY





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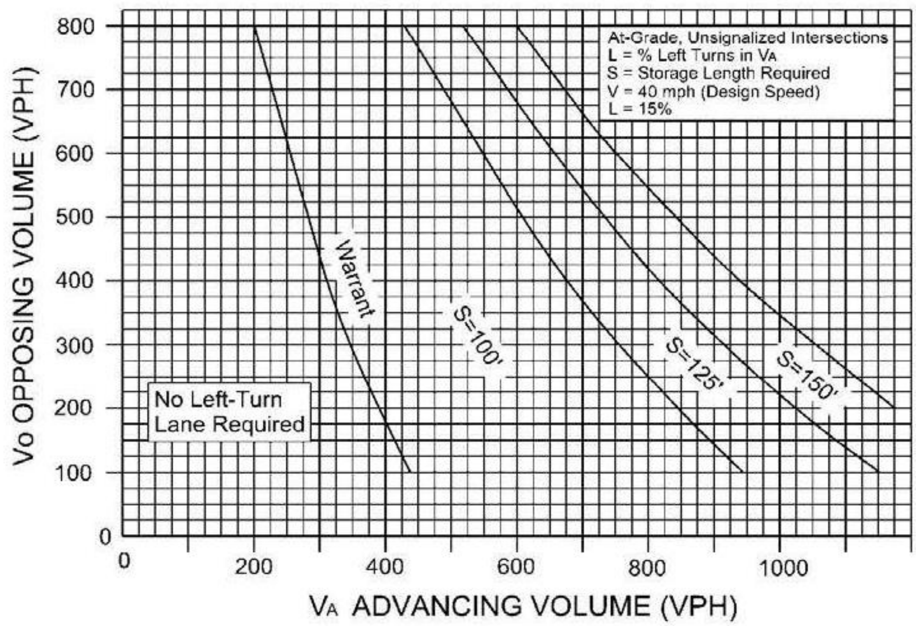

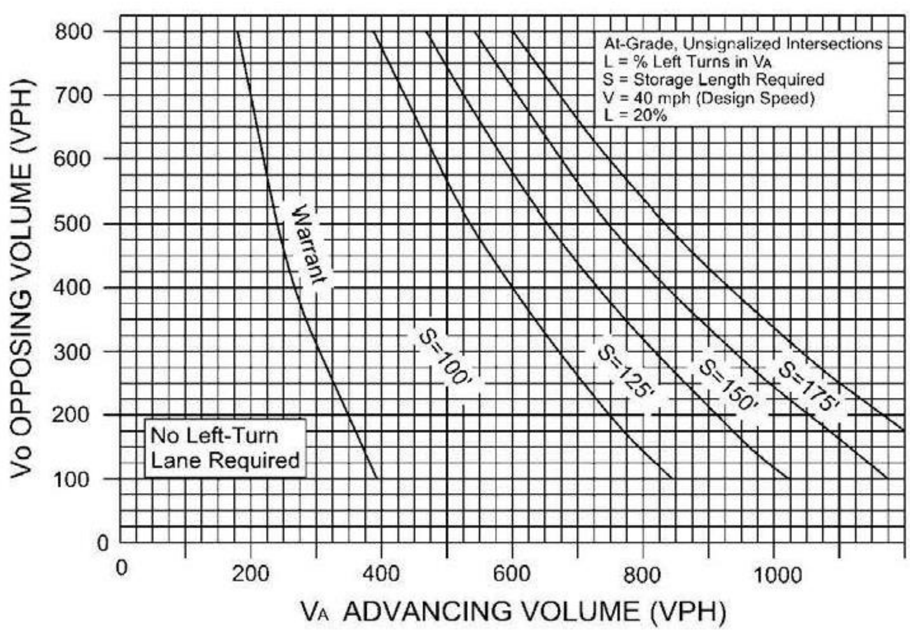

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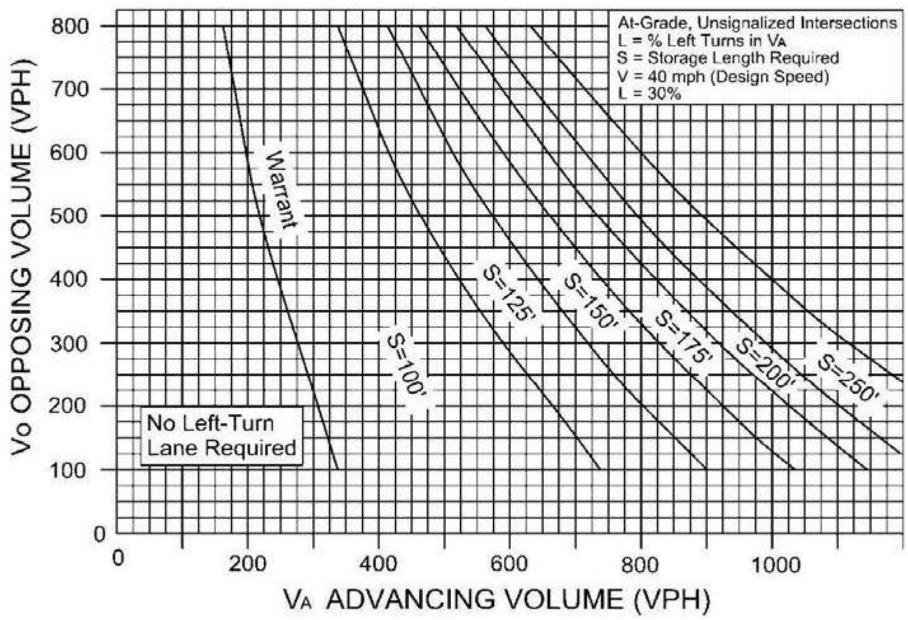

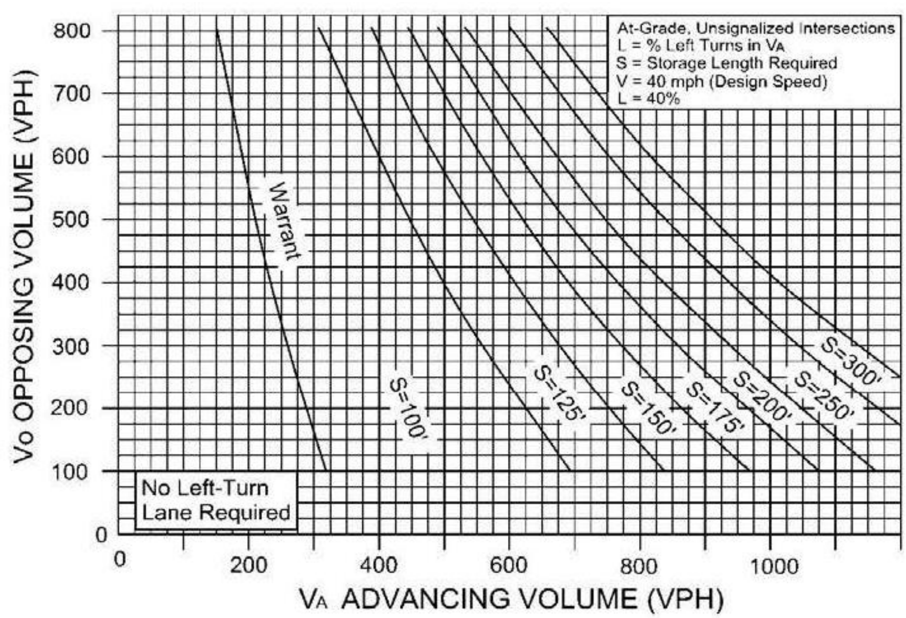

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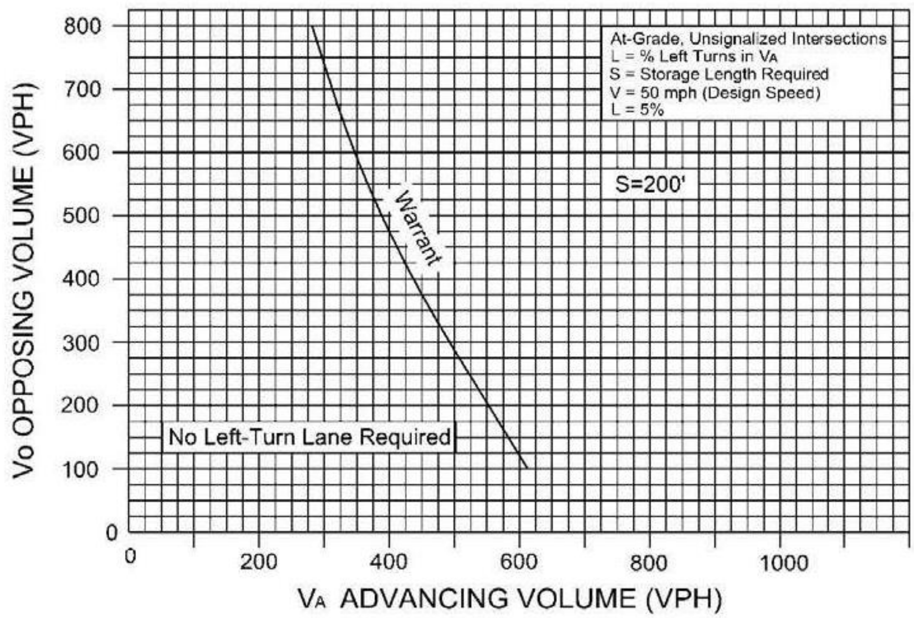

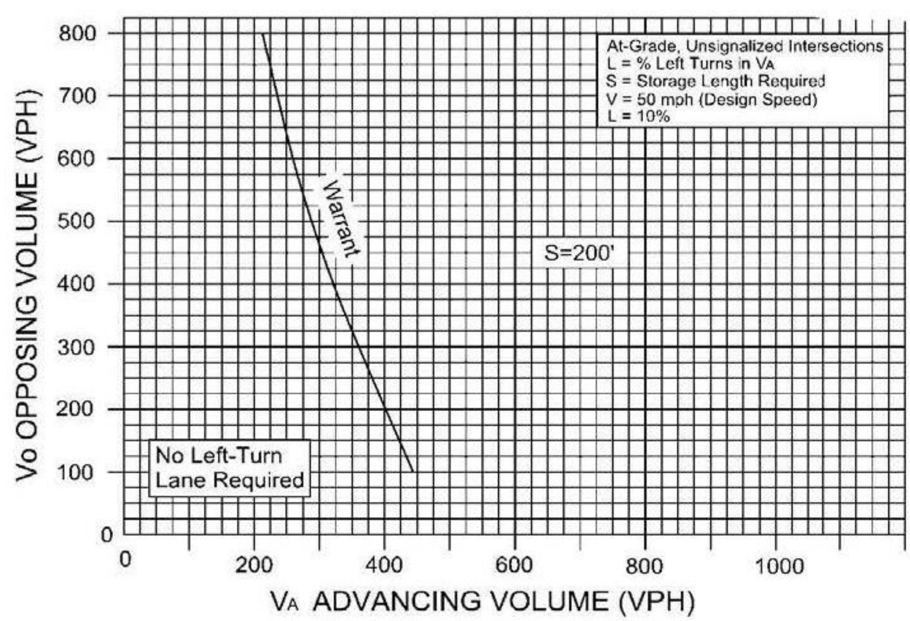

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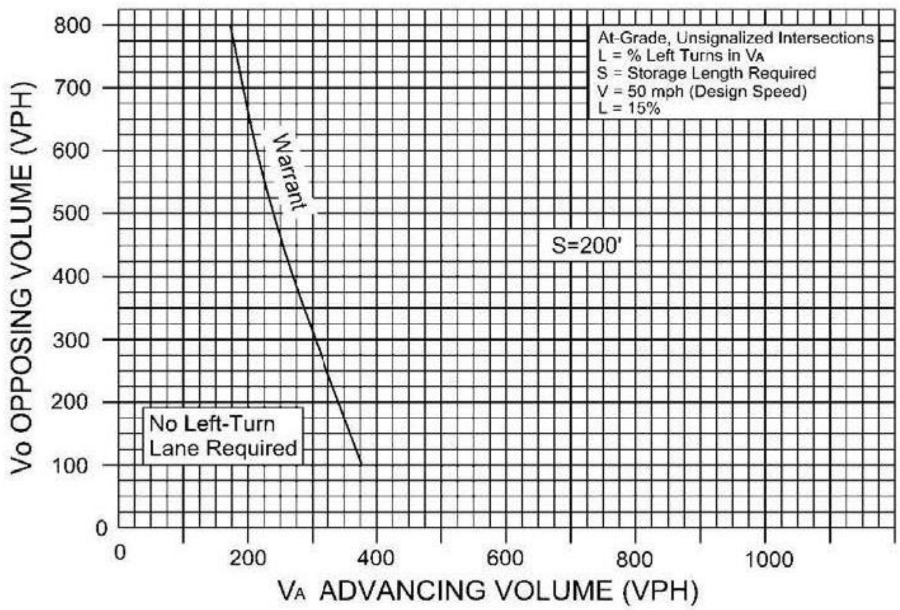

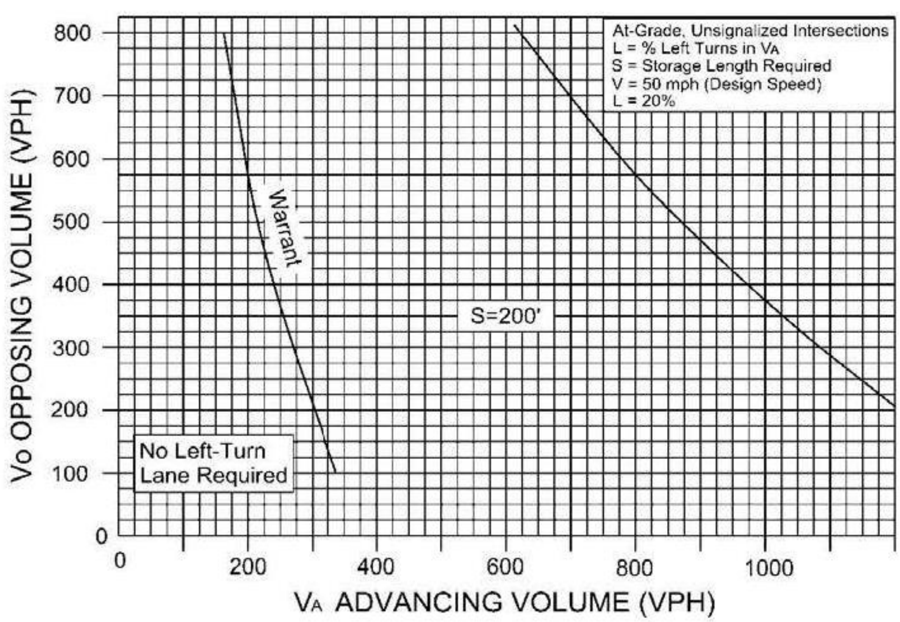

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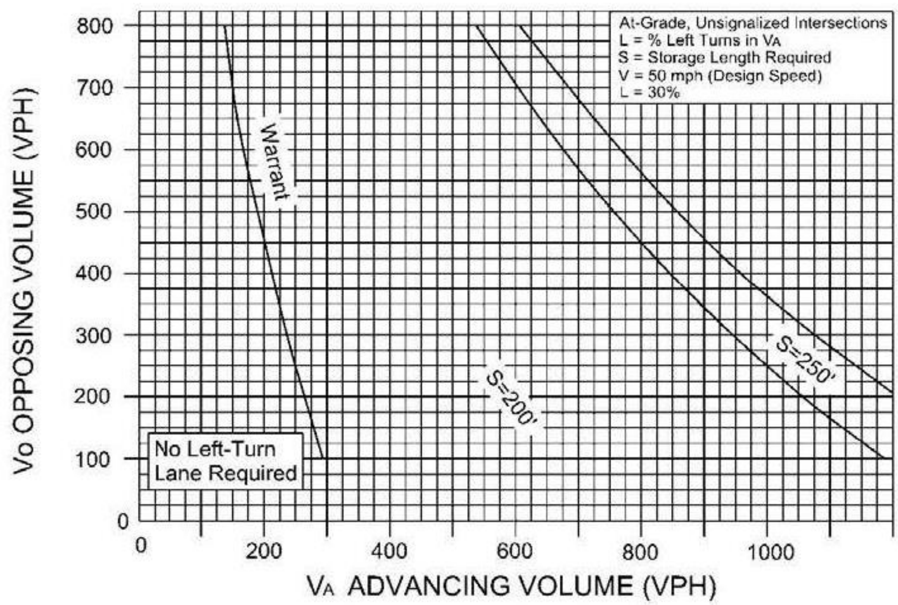

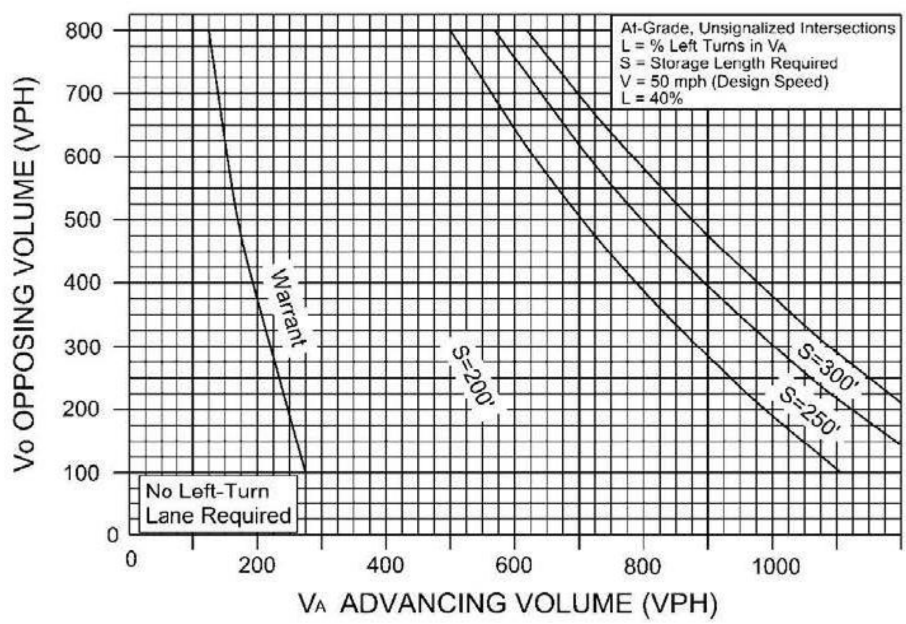

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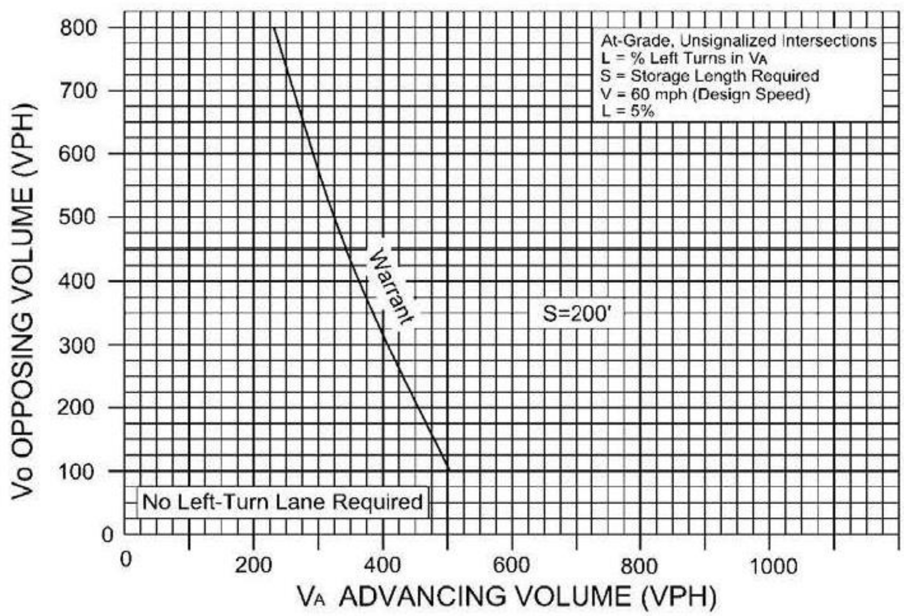

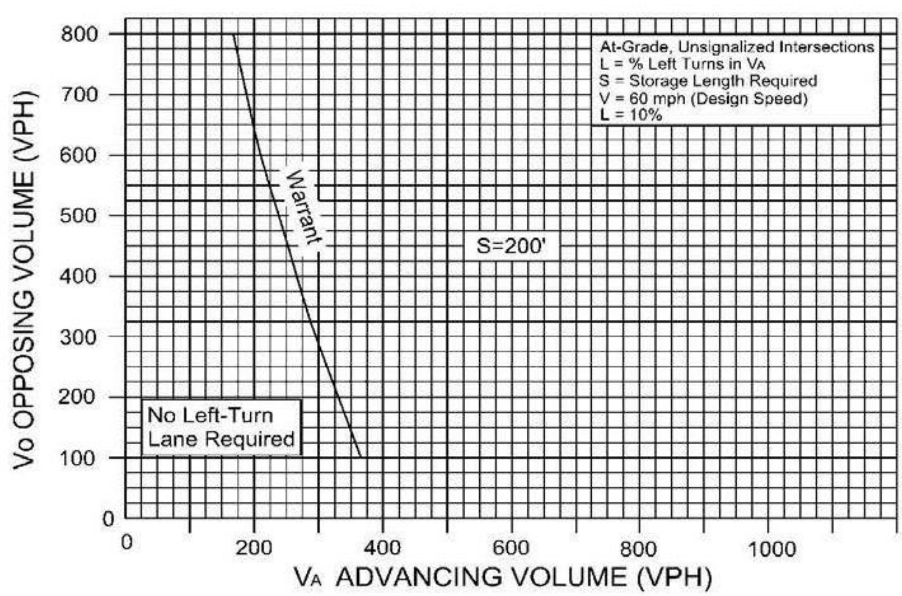

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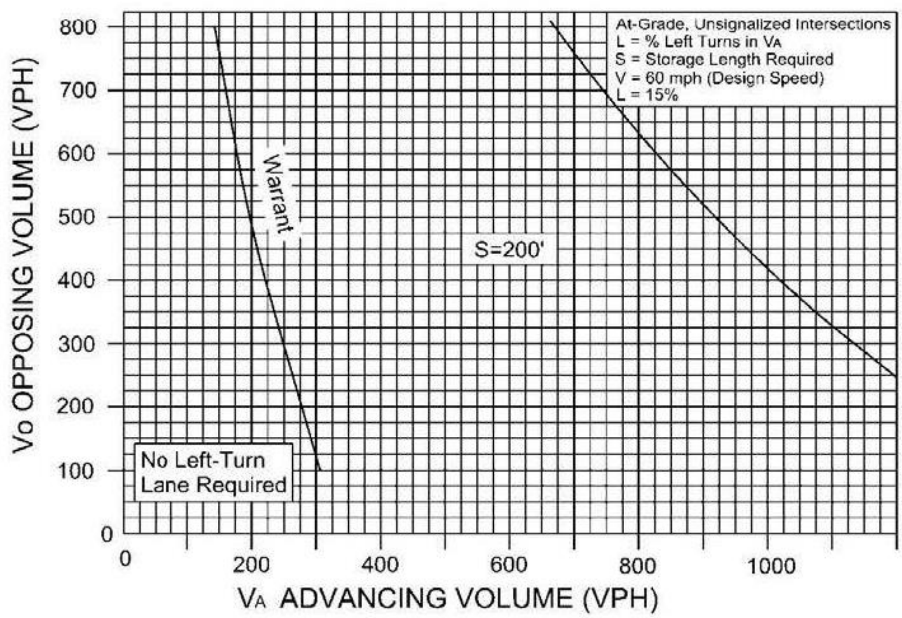

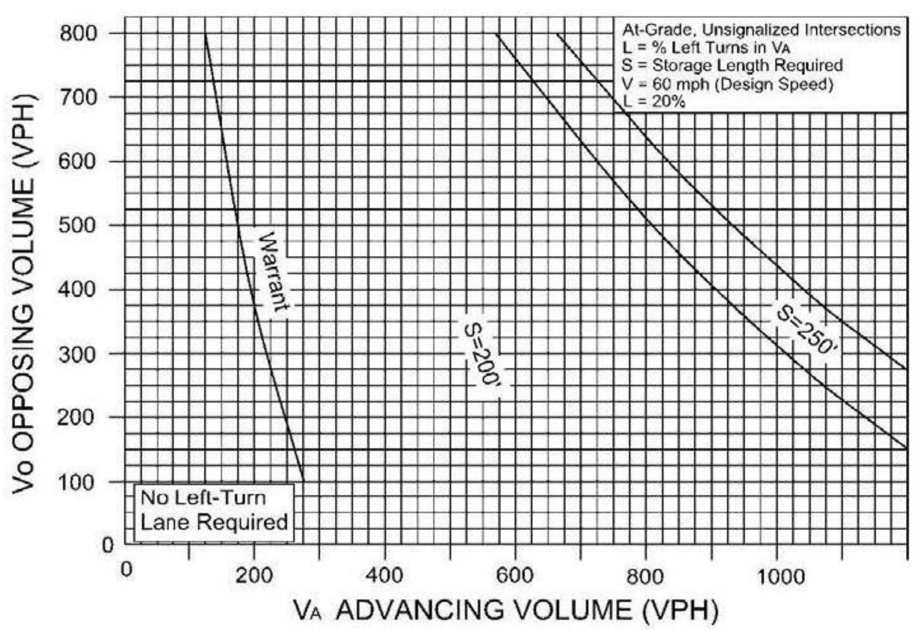

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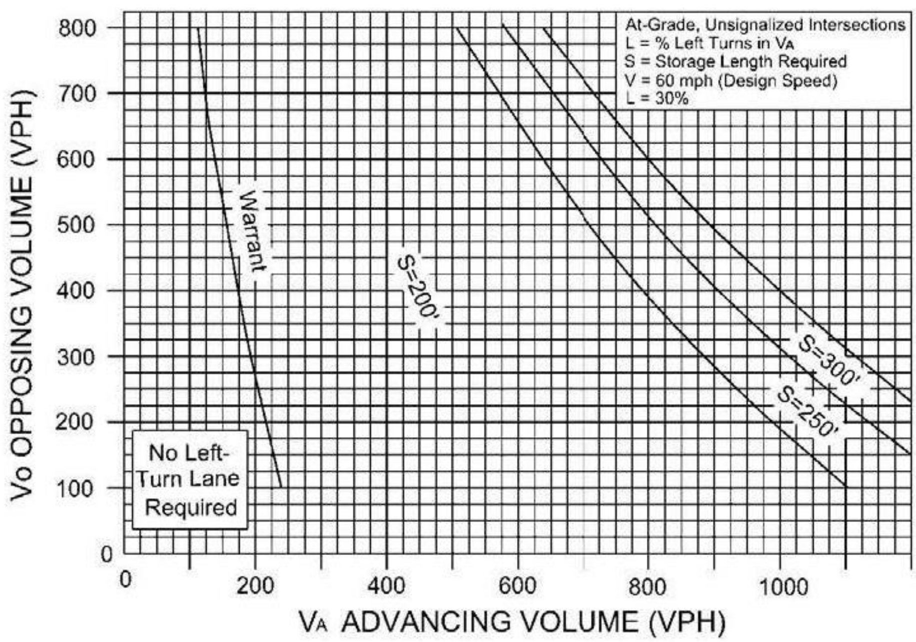
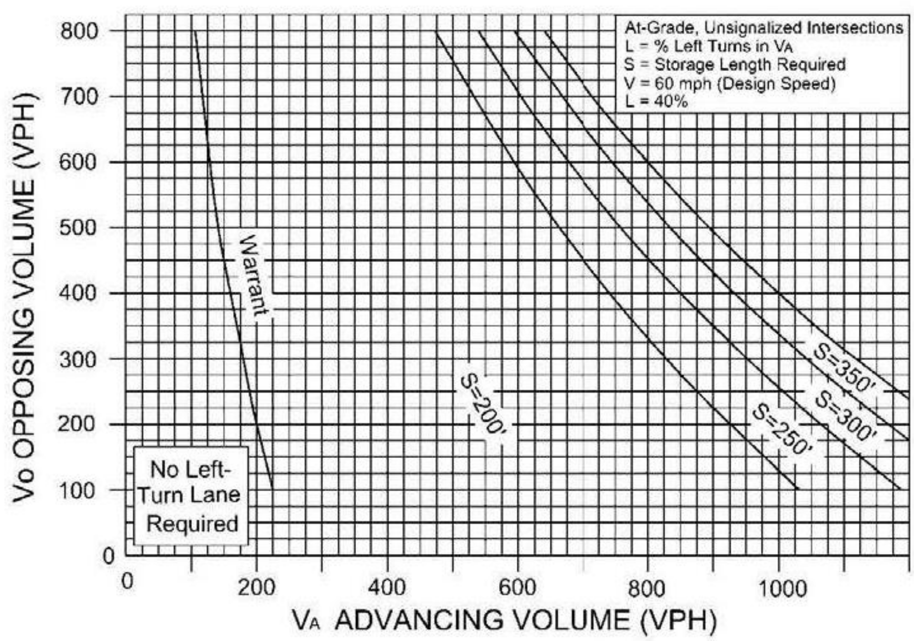




33 Interchanges

33.1. General

The capacity of arterial highways, particularly in urban areas, to handle high volumes of traffic safely and efficiently depends on their ability to accommodate crossing and turning movements at intersecting highways. The greatest efficiency, safety and capacity are attained when the intersecting through traffic lanes are on separate grades.

An interchange is a system of interconnecting roadways with one or more grade separations that allows traffic to move between two or more roadways on different levels. Interchanges increase safety and traffic capacity. Crossing conflicts are eliminated by grade separations, and turning conflicts are either eliminated or minimized, depending on the type of interchange design.

This chapter is based on criteria from the following documents:

- American Association of State Highway and Transportation Officials (AASHTO), A Policy on Geometric Design of Highways and Streets
- Manual of Uniform Traffic Control Devices (MUTCD)
- DDOT, Policy and Process for Access to the District of Columbia Interstate and Freeway System
- AASHTO, Guide for the Planning, Design, and Operation of Pedestrian Facilities
- Transportation Research Board's Highway Capacity Manual

33.2. Warrants for Interchanges

Due to the wide variety of site conditions, traffic volumes, highway types and interchange layouts, an interchange may or may not be warranted at a given location. Warrants should be based on the following items and sound engineering judgment.

- **Design Designation.** If a highway will have full control of access between selected terminals, highway grade separations or interchanges are warranted for all intersecting roadways crossing the highway. Once it has been decided to develop a route as a freeway, it should be determined whether each intersecting highway will be terminated, rerouted or provided with a grade separation or interchange. The chief concern is the continuous flow on the major road.
- **Reduction of Bottlenecks or Spot Congestion.** Insufficient capacity at the intersection of heavily traveled routes results in significant congestion on one or all approaches. The inability to carry essential capacity with an at-grade facility is a warrant for an interchange.

- **Safety Improvement.** Some intersections have a disproportionate rate of serious crashes. The potential to eliminate even a few serious crashes can often justify a grade separation structure. Serious crashes at heavily traveled intersections also warrant interchange facilities. In addition to greater safety, the operational efficiency for all traffic movements is also improved with an interchange.
- **Site Topography.** At some locations, a grade separation may be the only economically feasible design to satisfy design criteria if other provisions entail higher costs or require more land for construction.
- **Road-User Benefits.** The road-user costs due to delays at congested intersections are significant. Road-user costs such as fuel and oil consumption, wear on tires, vehicle maintenance, delays to motorists and crashes (that result from speed changes, stops and waiting), are well above those for intersections permitting uninterrupted or continuous operations. Although interchanges involve more total travel distance than direct crossings at grade, the cost of the extra travel distance is less than the costs due to stopping and delay. For any type of intersection, the ratio of annual road-user benefits to the annual capital cost of improvement may indicate an economic warrant for that improvement. The annual benefit is the cost savings to road users for the improved condition, while annual capital cost is the sum of interest and amortization of the cost of improvement. The larger the ratio, the greater the justification. Comparison of these ratios is important for determining the type and extent of improvements to be made when considering design alternatives. If used for justifying a single project or design, a ratio in excess of one is the minimum economic justification.
- **Traffic Volume.** Traffic volumes that exceed the capacity of an intersection may be the most tangible of any interchange warrant.
- **Pedestrian / Bicycle Safety.** Interchanges are often the only mode of crossing a freeway for pedestrians and bicyclists. Therefore, interchanges should be deigned with pedestrians and bicyclists in mind, with an emphasis on maximizing the safety of ramp crossings by minimizing the speed of motor vehicles entering and exiting the freeway, especially in urban areas.

The following information is required for initiating preliminary interchange design:

- Basic data. Traffic, physical and economic factors
- Preliminary design. Aerial photos (if available), topographic maps, GIS maps and preliminary sketches of plans and profiles for alternative designs
- Comparative costs. Cost estimates of alternative designs

- Selection of suitable design. Suitable from the standpoint of carrying capacity, economy and safety considerations

The following are required for initiating a final interchange design:

- A Traffic Impact Analysis (TIA) of the interchange and arterial roadway system. The TIA is to include alternate routes, congestion, effects on the existing highway system, economic analysis and local commitment to improving local roads. The TIA will include a project-level feasibility study to determine the precise location and extent of traffic impacts on the roadway system.
- Environmental studies. Environmental studies must be conducted and appropriate documentation prepared.
- Final plans. Final plans will include design approval of interchange configuration, traffic flow restrictions and controls, complete calculations, plans and profiles, traffic flow diagrams showing the design hourly volume and the design year of all anticipated traffic movements, and proposed construction plans.
- Final report:
  - The final report is to be submitted for formal approval to the DDOT Chief Engineer.
  - Upon preliminary approval by the Chief Engineer, the request will be forwarded, if necessary, to the Federal Highway Administration for approval.

33.2.1. Freeways and Interstate Highways

Interchanges must be provided on interstate highways and freeways at all intersections where access is justified. Other intersecting roads or streets must be grade separated, terminated or re-routed.

33.3. Interchange Types

Intersection and interchange design should move all traffic modes safely and efficiently through any conflict points that may arise at the crossing of highways. Two or more highways can cross in one of four ways:

- At-grade intersections
- Grade separations
- Full interchanges
- Partial interchanges

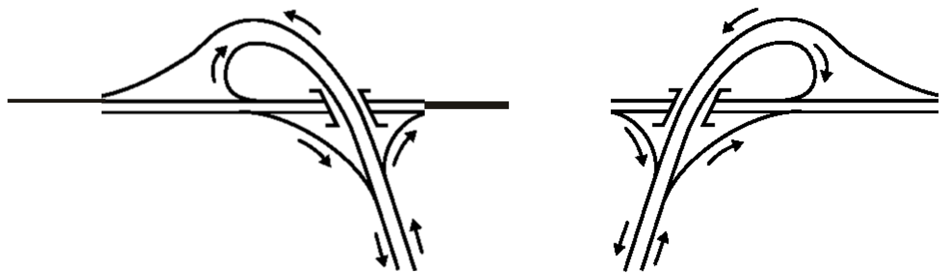
Even though interchanges are designed to fit specific conditions and controls, the pattern of interchange ramps along a freeway should follow some degree of consistency. Rearranging portions of the local street system in connection with freeway construction is often the best way to attain optimum traffic service and community development. Signage is also a major element of interchange design. Signage should be tested for each design to ensure it facilitates a smooth, safe flow of traffic. The need to simplify interchange design from the standpoint of signage and driver understanding cannot be overstated.

In general, interchanges with all ramps connecting with a single cross street are preferred. Interchange types are characterized by the basic shapes of ramps: diamond, loop, directional or variations of these. There are two major interchange designs: three-leg designs and four-leg designs:

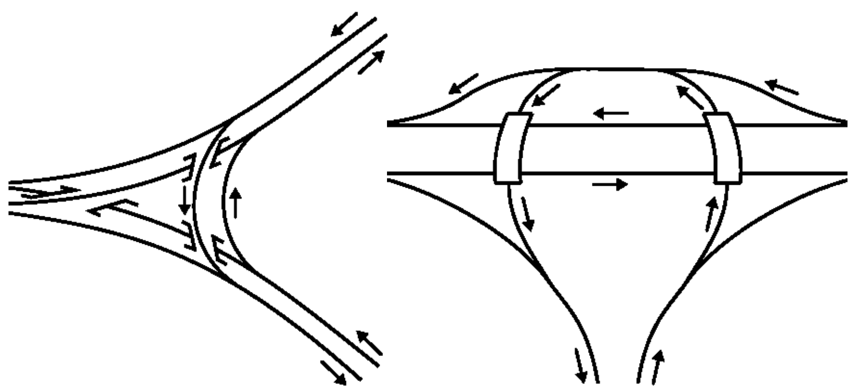
- **Three-leg designs** have three intersecting legs consisting of one or more highway grade separations and one-way roadways for all traffic movements. When two of the three intersection legs form a through road and the angle of intersection is not acute, the interchange is classified as a T interchange. When all three intersection legs have a through character or the intersection angle with the third intersection leg is small, the interchange is classified as a Y interchange. Figure 33-1 illustrates the patterns of three-leg interchanges.
- **Four-leg designs** have four intersection legs in one of seven general configurations. Figure 33-2 illustrates typical examples of the seven general configurations of four-leg interchange designs:

Ramps in one quadrant
Diamond interchanges
Single-point urban interchanges
Partial cloverleafs
Full cloverleafs
Interchange with direct connections
Interchange with semi-direct connections

Other interchange configurations include offset interchanges or a combination of two or more of the previously discussed interchanges. An offset interchange may be applicable where there are large buildings or other developments near a freeway crossing. A combination interchange design may be preferred when an analysis determines that one or two turning movements that have high volumes with respect to the other turning movements should be accommodated. Refer to **AASHTO, A Policy on Geometric Design of Highways and Streets** for detailed information on interchange types and their specific uses.



1. Three-Leg Interchanges with Single Structure



2. Three-Leg Interchanges with Multiple Structures

Figure 33-1 | Patterns of Three-Leg Interchanges

Images courtesy of PennDOT Design Manual, Part 2, Highway Design Publication 13M

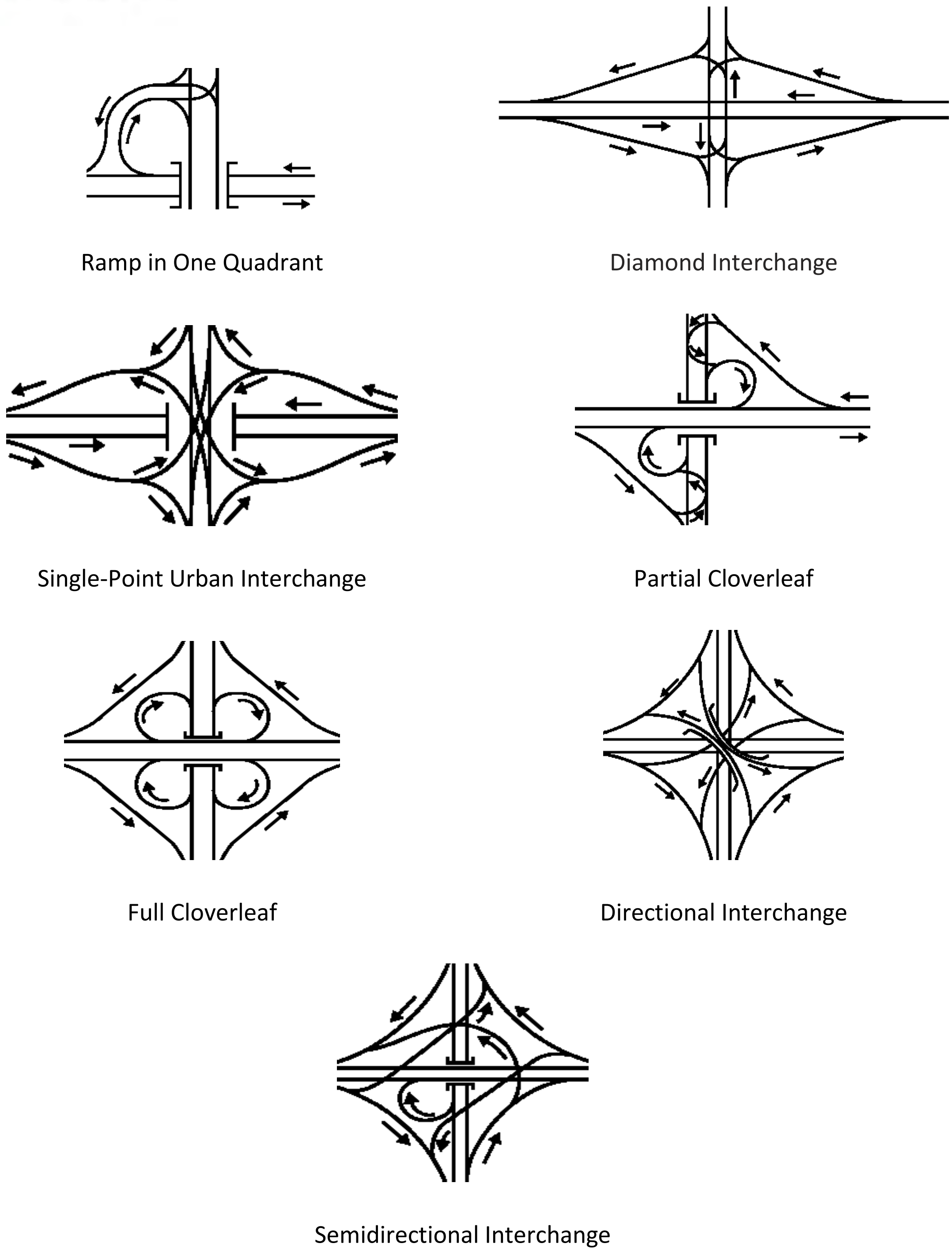


Figure 33-2 | Typical Examples of Four-Leg Interchange Designs

Images courtesy of PennDOT Design Manual, Part 2, Highway Design Publication 13M

33.3.1. Sight Distance

Sight distance along the through roadways and all ramps should be at least equal to the minimum safe stopping sight distance (preferably longer) for the applicable design speed.

33.3.2. Alignment, Profile and Cross Section

Traffic passing through an interchange must have the same degree of utility and safety as traffic on the approaching highways. The standards for design speed, alignment, profile and cross section for the main lanes through the interchange area should be the same as for the approach legs. The profile of the through highways at an interchange should be relatively flat and have high visibility. The full roadway cross section must be continued through the interchange area and adequate vertical and horizontal clearances provided at structures.

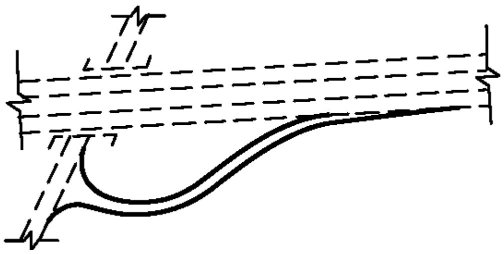
33.4. Ramps

The term “ramp” includes all types, arrangements and sizes of turning one-way roadways that connect two or more legs of an interchange. The components of a ramp are a terminal at each end, a connecting road, usually with some curvature, and a gradient. Figure 33-3 illustrates several types of ramps and their characteristic shapes, each of which can be used to create numerous shape variations for an interchange.

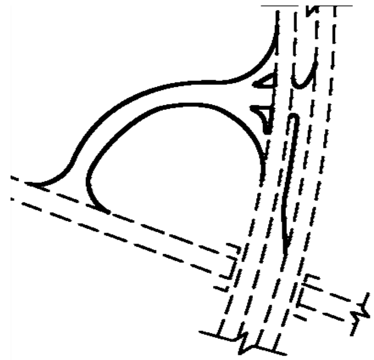
For exit ramps that intersect surface streets at right angles, an urban interchange is recommended to improve pedestrian and bicycle access, visibility and safety. Refer to the **AASHTO, Guide for the Planning, Design, and Operation of Pedestrian Facilities**, for more detailed guidelines.

The following items should be considered to determine the best type of ramp for an interchange:

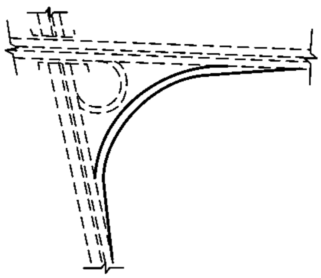
- Ramp capacity
- Design speed
- Grades
- Sight distance
- Ramp widths
- Location of ramp intersections on cross roads
- Superelevations and cross slopes
- Curvature
- Turning movement diagram



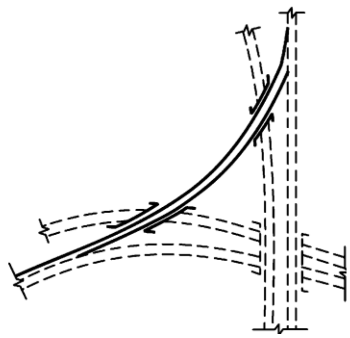
Diagonal Ramp



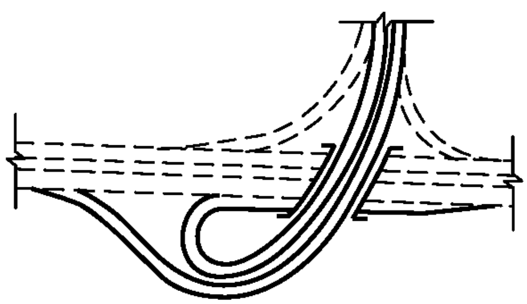
One Quadrant Ramp



Outer Connection Ramp



Directional Ramp



Loop and Semidirectional Ramp

Figure 33-3 | Types of Ramps

Images courtesy of PennDOT Design Manual, Part 2, Highway Design Publication 13M

33.4.1. Ramp Capacity

The capacity of a ramp is generally controlled by one of its terminals. Occasionally the ramp proper determines the capacity, particularly where speeds may be significantly affected by curvature, grades or truck operations. The service volumes for the ramp proper on single-lane ramps are shown in Table 33-1 below. Refer to **AASHTO, A Policy on Geometric Design of Highways and Streets** for more information.

Table 33-1 | Single-Lane Operation

DESIGN CON-DITION	T - PERCENT TRUCKS DURING PEAK HR	DESIGN SPEED V< 20 MPH 90' MIN, 125' DES.			DESIGN SPEED V<25 MPH R = 150'			DESIGN SPEED V<30-40 MPH R = 230-240'			DESIGN SPEED V<50 MPH R = 690'		
		RATE OF UPGRADE PERCENT			RATE OF UPGRADE PERCENT			RATE OF UPGRADE PERCENT			RATE OF UPGRADE PERCENT		
	0	0-2	3-4	>5	0-2	3-4	>5	0-2	3-4	>5	0-2	3-4	>5
SERVICE LEVEL B	0	800	800	800	1000	1000	1000	1100	1100	1100	1220	1220	1220
	5	760	720	700	950	900	870	1050	1000	950	1140	1090	1040
	10	720	670	610	910	830	770	1000	920	850	1090	1000	920
	20	670	570	500	830	720	620	920	780	690	1000	860	750
	30	610	500	420	770	620	530	850	690	580	920	750	630
SERVICE LEVEL C	0	1000	1000	1000	1250	1250	1250	1400	1400	1400	1500	1500	1500
	5	950	900	870	1190	1140	1090	1330	1270	1220	1420	1360	1300
	10	910	830	770	1140	1040	960	1270	1170	1080	1360	1250	1150
	20	830	720	620	1040	890	780	1170	1000	870	1250	1070	940
	30	770	620	530	960	780	660	1080	880	740	1150	940	790

Adapted from FHWA report on "Capacity Analysis for Design and Operations of Freeway Facilities", 1974

Notes: For 2 lane ramps multiply tabular values as follows: 1.7 for 20 mph or less, 1.8 for 25 mph, 1.9 for 30 to 40 mph, 2.0 for 50 mph or more. For down grade, use same values as for 0-2 percent upgrades. To approximate level of service E, multiply above values by 1.25. Minimum ramp radius on Interstate highways should not be less than 150 feet.

33.4.2. Design Speed

Ramp design speeds should approximate the low-volume running speed on the intersecting highways because it is not practical to build ramps with design speeds comparable to those on the through roadways. Recommended design speeds depend on ramp type:

- Loop ramps: 25 mph
- Semidirectional: 30 mph
- Directional: 40 mph

Ramp design speeds should not be less than 25 mph. On cloverleaf interchanges, the design speed on outer connections should be 35 mph. Refer to Table 33-2 for guide values for ramp design speeds.

Table 33-2 | Guide Values for Ramp Design Speed as Related to Highway Design Speed

		Highway Design Speed (mph)					
		30	**40**	**50**	**60**	**65**	**70**
Ramp Design Speed (mph)	Upper Range (85%)	25	35	45	50	55	60
	Middle Range (70%)	20	30	35	45	45	50
	Lower Range (50%)	15	20	25	30	30	35

33.4.3. Grades

Ramp grades should be as flat as feasible to minimize driving effort required to maneuver from one road to another. On one-way ramps, a distinction can and should be made between upgrades and downgrades. Maximum upgrades on ramps should generally be limited to the values in Table 33-3.

Table 33-3 | Upgrades on Ramps

Design Speed (mph)	Max. Upgrade Range (percent)
45 –50	3 –5
35 –40	4 –6
25 –30	5 –7
15 –25	6 –8

Ramp grades should not be less than 0.50 percent. One-way downgrades for passenger vehicles on ramps should be held to the same general maximums, but in special cases they may have a maximum grade of 8 percent. When the ramp is to be used predominately by truck traffic, upgrades should be limited to 5 percent, and one-way downgrades should be limited to 3 to 4 percent.

33.4.4. Sight Distance

The sight distance along a ramp should be at least as great as the design stopping sight distance. There should be a clear view of the entire exit terminal, including the exit nose and a section of the ramp pavement beyond the gore. Sight distance for passing is not needed. The sight distance on a freeway preceding the approach nose of an exit ramp should exceed the minimum stopping sight distance for the through traffic design speed by 25 percent or more.

No planting of vegetation that would restrict the ramp sight distance to less than the minimum for the applicable design speed is permitted.

33.4.5. Ramp Widths

Factors that influence the required width of the ramp traveled way include radii values, the presence of curbs and/or shoulders on the ramp and traffic conditions including percentage of trucks. Other factors include provision for passing a stalled vehicle and whether the ramp will function as a two-way or one-way facility. Refer to **AASHTO, A Policy on Geometric Design of Highways and Streets** for more information.

33.4.6. Location of Ramp Intersections on Cross Roads

Factors that influence the location of ramp intersections on cross roads include sight distance, costs of construction and obtaining rights-of-way, circuitous travel for left turn movements, cross road gradient at ramp intersections, storage requirements for left turn movements from the cross road, and the proximity of other intersections of lower order.

For left turn maneuvers from an off ramp at an unsignalized intersection, the length of cross road open to view should be greater than the product of the prevailing speed of vehicles on the cross road and the time required for a stopped vehicle on the ramp to safely execute a left turn.

Where design controls prevent locating the ramp terminal far enough from the structure to achieve the required sight distance, the sight distance should be obtained by flaring the end of the overcrossing structures or setting back the piers or end slopes of an undercrossing structure. Sharp curves at an off ramp terminal (at the intersection with the local street) should be avoided, even if the intent is to provide an acceleration lane for merging into the local street traffic. It is often better to provide a near-90 degree intersection with stop sign control.

Slip ramps from a freeway to a local two-way street are also undesirable because of the limited sight distance usually encountered at the merge with the local street traffic.

33.4.7. Superelevations and Cross Slopes for Interchange Ramps

Interchange ramp superelevations are governed by the same principles as their parent roadways. See **Chapter 30** for more superelevation information.

At street intersections where a slope or reduced speed condition is in effect, and under some conditions at ramp junctions, the requirement to use the full superelevation may be waived. Edge of pavement profiles should be produced at ramp junctions to ensure a smooth transition.

The cross slope on tangent sections of ramps are normally sloped one-way at 2 percent.

The maximum relative gradient (the elevation from one roadway edge relative to another) is varied with design speed to provide longer runoff lengths at higher speeds and shorter lengths at lower speeds. Refer to **AASHTO, A Policy on Geometric Design of Highways and Streets** for more information on maximum relative gradients.

With respect to the beginning and ending of a curve on the ramp proper (not including terminals), two-thirds of the full superelevation should be provided at the beginning and ending of the curve. This may be altered to adjust for flat spots or unsightly sags and humps when the geometry is inflexible. Smooth-edge pavement profiles that do not appear distorted to the driver should be provided for driver comfort.

33.4.8. Curvature

The design guidelines for turning roadways at interchanges apply directly to the design of ramp curves and depend on design speeds. Compound or spiral curve transitions are often used to obtain the desired ramp alignment to provide a comfortable transition from the design speeds of the through and turning roadways and fit the natural paths of vehicles. Caution should be exercised when using compound curvatures to prevent unexpected and abrupt speed adjustments. Refer to **AASHTO, A Policy on Geometric Design of Highways and Streets** for information on ramp curvature.

33.4.9. Turning Movement Diagram

The turning movement diagram illustrates the design traffic volume predicted for each movement within an intersection or interchange. It is used as partial confirmation for acceptable levels of service and to justify design features such as turning lanes and storage lengths.

The diagram should be included on a plan sheet showing the proposed intersection or interchange design. It provides a permanent record of the data that justified the design features of the intersection/interchange. At a minimum, it will show the design hourly volume for each movement within the intersection/interchange. The diagram may also show the current average daily traffic; it will reflect the current year or proposed construction year, and a 25-year projection of traffic movements. The traffic movement data should be no more than 2 years old.

33.5. Freeway Entrances and Exits

33.5.1. Basic Policy

All interchange entrances and exits should connect at the right of through traffic. Freeway entrances and exits should be located on tangent sections where possible for maximum sight distance and optimum traffic operation.

33.5.2. Ramp Terminals

The ramp terminal is the portion of the ramp adjacent to the through lanes and includes the speed change lanes, tapers, gore areas and merging ends. Superelevation transition should not exceed 2 percent per distance traveled in 1 second at design speed.

Also, the suggested maximum algebraic differences in cross slope rates at the crossover crown line should not exceed the values shown in Table 33-4. The design control at the crossover crown line is the algebraic difference in cross slope rates of the ramp terminal pavement and the adjacent mainline pavement. A desirable maximum algebraic difference at a crossover line is 4 to 5 percent.

Table 33-4 | Maximum Differences in Cross Slope Rates at the Crossover Crown Line

Design Speed of Exit or Entrance Curve (mph)	Maximum Algebraic Difference in Cross Slope at Crossover Line (percent)
15–20	5–8
25–30	5–6
35 and over	4–5

33.5.3. Distance Between Successive Ramp Terminals

At interchanges, there is the potential for two or more ramp terminals to be close together along the through lanes. In some interchange designs, ramps may split into two separate ramps or combine into one ramp.

To provide sufficient weaving length and adequate space for signage, a reasonable distance should be provided between successive ramp terminals. Spacing between successive outer ramp terminals is dependent on the classification of the interchanges involved, the function of the ramp pairs (entrance or exit), and weaving potential. There are five possible ramp-pair combinations:

- Entrance to Entrance (EN-EN)
- Exit to Exit (EX-EX)
- Exit to Entrance (EX-EN)
- Entrance to Exit (EN-EX)
- Turning Roadway

Minimum ramp spacing values can be found in **AASHTO, A Policy on Geometric Design Highways and Streets**. These values, along with lengths for weaving sections, should be verified with the

Transportation Research Board's **Highway Capacity Manual.** Auxiliary lanes should be used for successive noses that are less than 1500 feet apart.

For exit ramps that intersect surface streets at right angles, an urban interchange is recommended to improve pedestrian and bicycle access, as well as visibility and safety. Refer to the **AASHTO**, **Guide for the Planning, Design, and Operation of Pedestrian Facilities** for detailed guidelines.

During the early design stage, the DDOT Traffic Operation Administration should be consulted to ensure proper signs can be installed.

33.5.4. Auxiliary Lane Lengths

The **AASHTO, A Policy on Geometric Design Highways and Streets** lists the required lengths of auxiliary lanes on grade and on level.

33.5.5. Curbs

Curbs may be used on ramps, including at the ramp connection with the local street, to protect pedestrians, for channelization and to provide continuity with the local facility.

33.6. Additional Lanes

To ensure satisfactory operating conditions, additional lanes may be added. Where an entrance ramp of one interchange is closely followed by an exit ramp of another interchange, the acceleration and deceleration lanes may be joined. This should be the general practice where the weaving distance is less than 1500 feet.

Where interchanges are more widely spaced and ramp volumes are high, the need for an additional lane between the interchanges should be determined by checking the traffic volume on the lane crossing the freeway, and assessing existing operations and access control. This check should include consideration of freeway grade and volume of trucks.

33.7. Lane Reduction

Lane reduction is not permissible through an interchange. Where the reduction in traffic volumes is sufficient to warrant a decrease in the number of lanes, a preferred location for the lane drop is beyond the influence of an interchange, and preferably at least 1/2 mile from the nearest exit or entrance. Lane drops should be located on tangent alignments with a straight or sag profile so that the pavement markings in the merge area can be easily seen.

33.8. Route Continuity

Route continuity refers to the provision of a directional path along and throughout the length of a designated route. The designation pertains to a route number or name of a major highway.

Ideally, motorists on the designated route should travel smoothly and naturally in their lane without being confronted with points of decision. This means the chosen through lane should neither terminate nor exit. Therefore, each exit from the designated route or entrance to the designated route should be on the right, i.e., vehicular operation on the through route occurs to the left of all other traffic.

33.9. Weaving Sections

Vehicles entering and leaving the highway at common points results in vehicle paths crossing, creating weaving. Weaving should be avoided within an interchange or between closely spaced interchanges.

On cloverleaf intersections, the distance between loop ramp terminals should not exceed 1000 feet. Where the weaving volumes require larger separations than feasible, a collector-distributor roadway that will distribute local traffic while decreasing the mainline traffic volume should be considered.

33.10.Access Control

Access rights must be acquired along interchange ramps to their junction with the nearest existing public road. At such lane junctions, access control extends to the end of the acceleration or deceleration, excluding the taper. The access control should be extended beyond the end of the acceleration or deceleration lane taper by a minimum of 100 feet.

The interior of all ramps and loops at interchanges must also be acquired as rights-of-way. Where access is proposed at new or existing interchange locations, design waivers will be granted only after a thorough analysis has been made with respect to the cost of acquisition and impact on safety and traffic operations.

33.11.Median Barriers

Median barriers used on approaches should be carried through interchanges without interruption. Refer to **Chapter 36** for more information.

Flush or painted medians are commonly used on urban arterials; however, where used on freeways, a median barrier may be needed. The crowned type is frequently used because it eliminates the need for collecting stormwater in the median.

34 Public Transportation

The bus stop guidelines in this chapter are based on the physical design criteria that must be integrated with any plan that incorporates transit: transportation plans, land use ordinances, pedestrian plans, traffic control plans and street design guidelines. Developers and builders should consult these design guidelines for any project that interfaces with public transit.

34.1. Manuals, Guidelines and Reports

The related manuals, guidelines and reports that the Designer should use when designing transit accommodations, such as bus stops, shelters and bulbs are listed below.

- American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Street
- AASHTO Roadside Design Guide
- DDOT Bikeways Work Plan
- District Department of Energy and the Environment (DOEE) Stormwater Management Guidebook
- Federal Highway Administration Manual on Uniform Traffic Control Devices
- National Association of City Transportation Officials Urban Street Design Guidelines
- Transportation Research Board (TRB) Highway Capacity Manual (HCM)
- TRB Transit Capacity and Quality of Service Manual
- TRB Transit Cooperative Research Program (TCRP) Report 65: Evaluation of Bus Bulbs
- Washington Metropolitan Area Transit Authority (WMATA) Guidelines for the Design and Placement of Transit Stops
- WMATA Station Site and Access Planning Manual

34.2. Bus Stops and Bus Zones

34.2.1. Siting of Bus Stops

All bus stop locations in the District must be sited with the approval of DDOT. Metrobus stop locations will be determined by joint decision of the DDOT Progressive Transportation Services Administration and the WMATA Metrobus Planning, with public input from the Advisory Neighborhood Commissions. DC Circulator stop locations will be determined by DDOT and the DC Circulator operator, with public input from Advisory Neighborhood Commissions. Commuter bus stops will be sited by DDOT's Commuter Bus Planner and the commuter bus agency.

WMATA Metrobus and DC Circulator bus stops have the following minimum requirements for distance from crosswalks:

- Near side: 5 feet
- Far side:
    - Single 40-foot bus: 50 feet
    - Single 60-foot articulated bus: 70 feet
    - Every additional 40-foot bus requires an additional 50 feet from the crosswalk
    - Every additional 60-foot articulated bus requires an additional 70 feet from the crosswalk
- Mid-block: N/A

34.2.2. Bus Stop ADA Compliance

All new bus stops in the District must conform to DDOT and Americans with Disabilities Act (ADA) standards. At a minimum, all bus stops must have a 6-foot wide by 8-foot deep (from the perspective of an alighting passenger) unobstructed concrete landing pad aligned with the location where the front door of the bus will open. This area must not be obstructed by trees, poles, fire hydrants, trash cans or other street furniture. This landing pad must be constructed at a less than 2 percent slope, with connections to the sidewalk and closest intersection via accessible sidewalks and ramps.

Sidewalk and landing pad materials should be concrete and other smooth surfaces, but not slick (see **Chapter 31** of this manual for details on sidewalks and curbs). Materials such as cobblestone are not considered accessible. An accessible path a minimum of 4 feet wide must exist beyond the landing pad to connect the passenger to an accessible path around any sidewalk obstruction, such as a bus shelter.

See **Chapter 31** for more detailed information on ADA compliance beyond the bus stop.

34.2.3. Bus Zones

The length of a bus zone is dependent on the location with respect to the intersection and the type and number of buses that use that stop at the same time. These zones are identified by red and white signs that say “No Parking. No Standing. Metrobus Zone” with directional arrows showing the extent of the zone.

WMATA Metrobus and DC Circulator bus zones have the following minimum length requirements (distances are listed in the direction of travel):

- Near side:

- Single 40-foot bus: 100 feet prior to the bus stop pole
- Single 60-foot articulated bus: 120 feet prior to the bus stop pole
- Every additional 40-foot bus requires 50 feet added to the zone
- Every additional 60-foot articulated bus requires 70 feet added to the zone

- Far side (distance from crosswalk):
  - Single 40-foot bus: 95 feet
  - Single 60-foot articulated bus: 115 feet
  - Every additional 40-foot bus requires 50 feet added to the zone
  - Every additional 60-foot articulated bus requires 70 feet added to the zone

- Mid-block:
  - Single 40-foot bus: 80 feet prior to the bus stop pole and 30 feet after the pole
  - Single 60-foot articulated bus: 100 feet prior to the bus stop pole and 50 feet after the pole
  - Every additional 40-foot bus requires an additional 50 feet for the zone prior to the bus stop zone
  - Every additional 60-foot articulated bus requires an additional 70 feet for the zone prior to the bus stop zone

All design drawings for construction areas near bus zones should include the location of the bus zone signs.

34.2.4. Bus Pad Requirements

For bus pad locations, the Designer should coordinate with the DDOT Infrastructure Project Management Administration. The minimum pad width is 9 feet excluding gutter, but 10 feet is desirable. The minimum pad length is 40 feet. Mid-block pads should be 80 feet long. Block pads must be a minimum of 12-inch-thick concrete in composite roadways with 10 inches of plain Portland Cement Concrete (PCC) base. The bus pad must be 10-inch-thick reinforced concrete.

Bus pad widths vary depending on the roadway. All buses that travel along asphalt concrete roadways must have bus pads constructed of concrete. Bus pad lengths vary depending on the bus characteristics. Standard single-unit bus lengths range from 40 to 45 feet, while articulated buses are usually 60 feet long.

DDOT's Progressive Transportation Services Administration should be consulted for verification of all bus pad dimensions. Refer to the **DDOT Standard Drawings** for a typical section for a 12-inch PCC bus pad.

34.2.5. Bus Stop Relocation (Temporary)

If a bus stop needs to be temporarily relocated due to construction, the Applicant must propose a new location that can fulfill the requirements of **Sections 34.2.1** through **34.2.3**. The relevant agencies listed in **Section 34.2.1**, including DDOT, must approve of the temporary location. DDOT will determine whether the Designer is required to make any upgrades to bring the temporary stop into ADA compliance based on how long the temporary stop will be used.

After a plan for temporary stop relocation is approved by the relevant agencies, the Applicant must provide at least 30 days' notice to the transportation provider (e.g., WMATA, DC Circulator) before the temporary stop will go into effect, unless there is an emergency need to relocate sooner.

The Applicant is responsible for removing any regulatory signage, such as "No Standing. No Parking. Metrobus Zone" signs, from the permanent stop and placing them appropriately at the temporary stop, based on approved distances from the crosswalks listed in **Sections 34.2.1** through **34.2.3**. The Applicant is also responsible for placing the signs in the approved locations at the permanent stop when the temporary location is no longer needed. The transportation provider (e.g., WMATA, DC Circulator) is responsible for moving its pole and flag to the temporary stop and back to the permanent location when the temporary stop is no longer needed.

All signage for permanent and temporary stops should be marked on plans submitted through the permitting process.

If metered parking spaces need to be removed temporarily for the creation of the temporary bus stop, the Applicant will be responsible for paying for those spaces during the relocation at the behest of DDOT's Parking Group. If Residential Parking Permit spaces must be removed for the temporary bus stop, the DDOT Parking Group must be notified 30 days in advance of the relocation.

34.3. Bus Shelters

DDOT determines the placement of bus shelters.

In the event that a bus shelter is close to a construction area, the requestor should contact DDOT's Bus Shelter Coordinator at least 30 days in advance to determine what action needs to be taken to protect the shelter. Actions can include protecting a shelter with scaffolding, covering the shelter with wood, temporarily removing the shelter at the cost of the developer, or some other solution.

If a shelter needs to be relocated, it must not interfere with ADA compliance at the bus stop per **Section 34.2.2**.

34.4. Bus Bulbs

34.4.1. Introduction

Local, collector or arterial streets may be modified to implement a bus bulb, which is defined as a curb and sidewalk extension from the edge of a curb/parking lane to the edge of the adjacent travel lane. Successful bus bulb design and construction is site specific and dependent on transit, roadway and pedestrian characteristics. Bus bulbs are primarily used in areas of high bus ridership, areas that may benefit from traffic calming and areas of high pedestrian activity. Bus bulbs can improve bus travel and dwell times, vehicle travel times and intersection level of service (LOS). Bus bulbs also create opportunities for livability improvements such increased sidewalk width and Green Infrastructure facilities that provide green space and capture stormwater runoff. In addition, bus bulbs enhance DC's Complete Streets Program by increasing pedestrian safety and calming traffic. When considering bus bulb design, it is important to discuss the feasibility of implementation with DDOT and WMATA.

34.4.2. Bus Bulb Overview

Bus bulbs operate as typical bus stops where the bus remains in the travel lane to allow passengers safe and efficient boarding and alighting without the vehicle having to weave in and out of traffic. Bus bulbs provide an additional area of sidewalk where bus stop amenities can be placed without impeding pedestrian traffic. Bus bulbs can assist traffic calming efforts and reduce crosswalk length. The additional sidewalk space also allows Green Infrastructure projects to be implemented.

34.4.3. Best Practices

The **Transit Cooperative Research Program Report 65 – Evaluation of Bus Bulbs** and other guidelines provided by transit organizations across the nation indicate that many benefits can be gained when bus bulbs are implemented. The documents reported on several cities and show that bus bulbs increase pedestrian space on the sidewalk, improve boarding and alighting activities by enlarging waiting areas and reducing dwell times for boarding passengers, increase pedestrian safety by reducing crossing distance and increasing visibility, and reduce travel times for buses and vehicles. In several cities analyzed, bus bulbs included bike lanes and/or Green Infrastructure; both are options for bus bulb design, discussed in detail in this chapter.

Certain conditions are fundamental for successfully implementing bus bulbs, so certain site characteristics should be considered before deciding to install a bus bulb. Table 34-1 below highlights favorable and unfavorable site characteristics for bus bulb installation.

Table 34-1 | Favorable and Unfavorable Site Characteristics for Bus Bulbs

Favorable Site Characteristics	Unfavorable Site Characteristics
Communities that support transit	High operating speeds (> 40 mph)
Roadways with lower operating speeds (< 40 mph)	Roadways with significant traffic volumes
High levels* of bus patronage	Low transit ridership
High levels* of pedestrian activity on the sidewalk	Low pedestrian activity and bus layovers
Support of local business owners	Design complexities (drainage, high bicycle traffic)
Presence of on-street parking	24-hour curbside parking is not available
Two or more travel lanes per direction	Only one travel lane per direction
Difficult for buses to re-enter traffic	Evacuation routes
***Definition of "high levels" is variable and subject to street type, location or other site characteristics**	

34.4.4. Site Conditions

This section provides guidance to help determine if a bus bulb is appropriate for a specific project or location.

34.4.4.1. General

Site characteristics must be assessed for all locations where bus bulbs are being considered. While bus bulbs can be an appropriate option at some sites, other sites may not have the necessary space or the desirable characteristics for installation.

34.4.4.2. Roadway Lane Configurations

This section provides general guidance to help determine where bus bulbs may be appropriate based on the roadway lane configurations within a project's limits.

34.4.4.2.1. Number of Travel Lanes

A minimum of two travel lanes in the direction of bus traffic, or sufficient single-lane roadway width to be approved by DDOT and WMATA to support safe passing, is required. Bus bulbs require buses to stop within the travel lane during passenger boarding and alighting, and having two or more travel lanes allows vehicles approaching a bus from its rear to pass the bus in the adjacent travel lane while passengers load and unload.

34.4.4.2.2. On-Street Parking

Study areas with 24-hour curbside street parking are ideal for the implementation of a bus bulb. Bus bulbs must not be constructed at locations where parking lanes temporarily become travel lanes, such as where parking is prohibited during rush hours. Replacing a standard bus stop with a bus bulb allows additional parking if the length of the bulb is less than 100 feet, as a standard bus stop requires 100 feet of No Parking Zone. Impacts on other curbside facilities, such as loading and unloading zones, should be investigated during project initiation and mitigated as necessary.

34.4.4.2.3. Bike Lanes

Bicyclist safety must be considered during design of bus bulbs, specifically on roadways where bike lanes are currently provided or may be added in the future. Because each roadway is unique, and street characteristics can vary widely, cyclist needs also vary from street to street. On every street, understanding the needs of cyclists is critical to maintaining safety for cyclists, as well as pedestrians, passengers and vehicles.

The Designer must ensure that all proposed bicycle lanes are taken into consideration and the bus bulb design meets all current bike lane policies in accordance with the current **DC Bicycle Master Plan**, the latest **DDOT Proposed Bicycle Facilities Map** and the **DDOT 2015 Bikeways Work Plan**. Where bike lanes are present or proposed adjacent to a bus bulb, the Designer must also follow the guidelines in this manual and coordinate with the DDOT Active Transportation Program Manager.

For streets with existing or proposed bike lanes running parallel to the vehicle travel lane (i.e., bike lane is adjacent to the bus stop), bus bulbs must not impede the bike lanes on the street. Bike lanes must be located outside of the bus bulb, between the bus bulb and the travel lane, unless otherwise directed by DDOT or WMATA.

Other configurations of bus bulbs may be considered for streets with bike lanes. If supported by DDOT and WMATA, bus bulbs may be located between a bike lane and the travel lanes such that the bike lane separates the bulb from the sidewalk and tree space area.

For streets without existing or proposed bike lanes, the bus bulb must not extend to the full width of the parking lane to avoid creating a pinch point for cyclists. For these streets, bus bulb widths must not exceed 1 foot less than the width of the parking lane. For example, a bus bulb width must not exceed 7 feet on a street with an 8-foot parking lane.

34.4.4.2.4. Roadway Widths

The minimum width for a single lane adjacent to a bus bulb stop is 11 feet per the **WMATA Station Site and Access Planning Manual** and **Chapter 30** of this manual.

34.4.4.2.5. Evacuation Routes

The installation of bus bulbs, as well as other types of traffic modifications that involve the reduction of lane capacity or lane narrowing, may require input from the Fire Department if the bulb is on a primary response route. The Fire Department's input is also requested when the bus bulb is off the primary response routes, particularly where the change or improvement could restrict the amount of space necessary to respond to an emergency at any address.

34.4.4.2.6. Roadway Speed Limit

Per **TCRP Report 65**, bus bulbs should not be constructed at locations with speeds greater than 45 mph, and, and for safety concerns, should be considered carefully at locations with speed limits of 40 mph. In particular, there is a higher potential for rear-end crashes between vehicles and buses on high-speed roadways.

34.4.4.3. Vehicle Volumes

The vehicle volumes in a project study area must be considered during the design process. Vehicle volume is one of the main elements that influence the impacts of bus bulbs on traffic and transit operations. As a reference, Table 34-2 provides a summary of potential traffic and transit impacts of bus bulbs through the study area for a range of vehicle volumes per lane.

Table 34-2 | Bus Bulb Impact on Traffic and Transit Operations: Traffic Volumes per Lane

Hourly Vehicle Volumes per Lane	Expected Traffic & Transit Operation Impacts
< 250 vehicles	Nominal impact to bus operation Nominal impacts to vehicle travel time
250 to 450 vehicles	Bus operations can improve Nominal impacts to vehicle travel time
> 450 vehicles	Bus operations can improve Vehicle travel time can degrade

The volume, V, to capacity, C, ratio for bus approaches can also be used as a reference to understand the impacts of bus bulbs, as shown in Table 34-3.

Table 34-3 | Bus Bulb Impact on Traffic and Transit Operations: Volume to Capacity Ratio

Approach Volume to Capacity (V/C) Ratio	Expected Traffic & Transit Operation Impacts
V/C < 0.50	Nominal impact to bus operation Nominal impacts to vehicle travel time
0.50 < V/C < 0.85	Bus operations can improve Nominal impacts to vehicle travel time
V/C > 0.85	Bus operations can improve Vehicle travel time can degrade

A detailed traffic analysis should be performed to evaluate the traffic and transit operation impacts from bus bulb implementation, as discussed in **Section 34.4.4.1** in this report.

34.4.4.4. Transit Frequency

Designers must consider the total number of buses stopping at a bus bulb, which depends on the bus frequency and specific bus routes in the study area. District transit operators include:

- WMATA Metrobuses
- DC Circulator buses
- Private shuttles
- Commuter buses

Bus bulbs must accommodate the buses stopping at each location by accounting for reliability impacts and bus bunching. Based on bus bulb location considerations (in **Section 34.2.1** of this manual) and the site traffic analysis (in **Section 34.4.4.1** of this manual), bus bulbs should be constructed when impacts on traffic operations and safety will be minimized. Bus bulbs should not be installed when bus frequency is greater than 10 to 15 buses per hour; installing bus bulbs when bus frequency is very high may prevent adequate traffic flow.

Bus bulbs should be designed to accommodate all types of buses that use the stop, including articulated buses if applicable. Refer to the **WMATA Station Site and Access Planning Manual** for appropriate bus stop dimensions.

34.4.4.5. Transit Ridership

Bus bulbs are appropriate at locations with high bus patronage, as bus bulbs can improve bus operations and provide a higher quality of service for passengers. However, locations with very high bus patronage may experience long dwell times for buses while large numbers of passengers board and alight. Longer dwell times may significantly reduce roadway capacity because buses at bulbs stop in the travel lanes for boarding and alighting. Therefore, bus dwell time must be carefully considered when locating and designing bus bulbs, specifically in locations where average dwell times exceed 30 to 35 seconds. It is also worth noting that if the dwell times are long due to overcrowding at the stops, which slows down the boarding process, bus bulbs may reduce average dwell times by providing more space for bus passengers, expediting boarding and alighting, and reducing overall dwell time.

In addition to dwell times, the flow of people through the corridor should be considered. In areas of high bus patronage, bus bulbs may increase the flow of people through a corridor by decreasing bus travel times. Because one bus can carry more people than 40 smaller vehicles can, even if other vehicles are slowed by reduction in roadway capacity, the higher bus speeds the bulbs afford and the large number of people aboard each bus may increase the number of people moving through the corridor in a given time.

Bus bulbs can also improve the LOS for passengers and pedestrians by increasing the available sidewalk area per pedestrian in front of and behind the bus stop.

34.4.4.6. Pedestrian Volumes

Pedestrian volumes must be considered when designing bus bulbs. Because a bus bulb acts as an extension of sidewalk into the roadway, it increases the useable sidewalk area per pedestrian. Bus bulbs are most appropriate in districts and neighborhoods that have:

- High pedestrian activity on the sidewalk
- Restaurants or cafes with sidewalk seating
- High bus ridership

The **TRB HCM** offers guidance for quantifying pedestrian comfort on sidewalks, shown in Table 34-4. The first two columns of Table 34-4 may be used to analyze sidewalk LOS before and after bus bulb installation. The far right column of Table 34-4 can be used to assess the need for a bus bulb in relation to existing sidewalk LOS improvement (i.e., LOS prior to bus bulb installation).

Table 34-4 | HCM Pedestrian Level of Service

Pedestrian Level of Service (LOS)	Area (ft^2)/Pedestrian	Priority for Bus Bulb to Improve LOS
A	60+	Low
B	40–60	Low
C	24–40	Moderate
D	15–24	Moderate
E	8–15	High
F	< 8	High

34.4.4.1. Safety

Safety impacts must be considered when designing bus bulbs. If available, historic crash data within the project limits should be analyzed to understand future impacts bus bulbs may have on pedestrians, cyclists, vehicles (non-transit) and buses.

Table 34-5 notes possible safety-related advantages and disadvantages for right-of-way users when a bus bulb is installed.

Table 34-5 | Outcomes for Right-of-Way Users from Bus Bulb Installation

User	Advantages	Disadvantages
Pedestrians	• Increased line of sight • Decreased exposure to vehicles • Fewer conflicts while walking due to more sidewalk area • Reduced crossing time • Space for a 5’×8’ ADA landing pad	None
Cyclists	• Increased line of sight • Fewer conflicts with buses (where there are on-street bike lanes)	• Potential conflict with vehicles when passing stopped buses (where there are on-street bicycle lanes)
Vehicles (Non-Transit)	• Increased line of sight to the bus stopped in the travel lane • Increased line of sight for seeing pedestrians when approaching a crosswalk	• Risk of rear-end collisions due to buses stopping within the travel lane • Possibility of unsafe driving maneuvers when changing lanes to avoid a stopped bus
Buses	• Elimination of the bus weaving maneuver in/out of the travel lane • Potential increase in bus speed due to elimination of re-entry problems	• Risk of rear-end collisions with passenger cars while stopped in the travel lane

34.4.4.1. Site Traffic Analysis

The Designer must work with DDOT and WMATA to determine if a traffic analysis is required to understand the traffic impacts of bus bulbs in the project area. The analysis should consider operations with and without bus bulbs to conduct a fair comparison. Furthermore, the analyses should be done for a future design year.

34.4.4.1.1. Analysis Recommendations

An appropriate traffic analysis should be performed to evaluate the bus bulb. The Designer will coordinate with the DDOT Transportation Operations Administration for approval of required analysis. Analysis includes, but is not limited to:

- Assessing capacity of the project area, including at least two signalized intersections both upstream and downstream
- Identifying impact of study area LOSs, queuing and parking
- Determining possible increase in side-swiping and rear-end crashes

34.4.4.1.2. Simulation Recommendations

To fully analyze a site to determine how bus bulbs will affect traffic within the project limits, microsimulation with transit modeling capability such as VISSIM is preferred. VISSIM is a very effective tool for simulating transit behavior because it can model various transit routes and transit vehicle types, dwell time of passengers, and reliability impacts (e.g., bus bunching), which in turn helps capture the dynamic interaction between buses and general traffic. A pedestrian simulation software in conjunction with the traffic simulation software (e.g., VisWalk combined with VISSIM) may also be desirable in areas where pedestrians can influence the flow of traffic or the length of bus dwell time due to platform crowding (i.e., typically pedestrian areas with poor LOS).

Synchro, a macroscopic analysis method based primarily on **TRB HCM**, or SimTraffic, Synchro's microsimulation module with no transit modeling capability, can also be used where VISSIM is not feasible or desired. The software selected must be approved by DDOT and WMATA before performing the traffic analysis. Data that will be incorporated into the model should include at least the following:

- Vehicle volumes (the Designer should use design year volumes when analyzing the study area)
- Pedestrian volumes
- Cyclist volumes
- Bus schedules

- Bus boarding and alighting information
- Signal timing plans
- Vehicle travel times through the study area for calibration
- Bus travel times through the study area for calibration

AutoTurn turn simulations should be performed to verify that buses can make turns around proposed bus bulbs. This analysis should be performed for all bus bulb stops, including those where there are currently no turns in the bus routes.

34.4.5. Design Considerations

This section provides guidance on determining where a bus bulb is appropriate in the project area and how the bus bulb space can be used.

34.4.5.1. Bus Bulb Location

Based on the unique characteristics of each intersection, bus bulbs can be designed in three different configurations—near side, far side, or mid-block—each of which has advantages and disadvantages, which are noted in Table 34-7. Near-side bus stops are located immediately before an intersection, as shown in Figure 34-1. Far-side bus stops are located immediately after an intersection, as shown in

Figure 34-2. Mid-block bus stops are located between intersections, as shown in

Figure 34-3. The Designer must work with DDOT and WMATA to determine which stop location is best suited for bus bulb installation. WMATA may also consider relocating bus stops in cases where the existing stop location cannot support a bus bulb.

34.4.5.2. Bus Bulb Amenities

Bus bulbs should be located where there is adequate space for the desired amenities. Depending on the type of bus stop being constructed, which will vary based on the needs of the study area, different amenities are required.

34.4.5.2.1. Basic/Primary Bus Stops

Basic bus stops are used by most transit agencies and serve as primary access points to Metrobus services. These stops may include the following elements:

- Bus stop sign
- ADA 5-foot by 8-foot landing pad minimum, 6-foot by 8-foot landing pad preferred
- Paved sidewalk (minimum 4 feet wide connecting stop to public sidewalk)

- Lighting (when evening service is provided)
- Seating (site dependent)
- Shelter (for 50+ boardings per day)
- Trash receptacle (site dependent)
- Information case
- System map (if shelter is provided)

Table 34-6 | Recommendations for Bus Bulbs by Location

Stop Type	Advantages	Disadvantages	Recommended Uses
Near Side	• Vehicles turning from a side street are safer because the bus will not be in the receiving lane for the turning vehicles, reducing the likelihood of a collision. • Passengers are allowed to board the bus immediately adjacent to the crosswalk, which minimizes walking distances. • Traffic back-up into an intersection is reduced because vehicles waiting immediately behind a bus are not in an intersection.	• A "zero throughput" scenario, where both travel lanes in one direction are blocked, is possible when there are two lane approaches with permitted left turning without an exclusive turn lane. • A bus "triple stop" is possible at intersections. The first stop occurs because the queue in front of a bus blocks the stop. The second stop occurs to serve bus passengers. The third stop happens when a bus misses the green signal while serving the stop, particularly when the duration of a green signal is short. • Conflicts occur between buses and approach right turning vehicles when right turn vehicles drive around buses to make the turn. (No conflict when this turn is marked illegal.) • Approach capacity is reduced and may increase delay to non-transit traffic as well as for buses because buses are in mixed traffic.	• If far-side traffic volumes are heavier than near-side traffic volumes. • When there are pedestrian safety concerns on the far side of the intersection such as obstructed sight distance, potential for jaywalking, or conflicts with cyclists.
Far Side	• Buses avoid a "triple stop" scenario. • Conflicts between right turning approach vehicles and buses are eliminated. • Encourages pedestrians to cross at a crosswalk behind the bus.	• Vehicles turning from the side streets when a bus is waiting for boarding and alighting passengers need to navigate around the bus, increasing the chance of a collision. • While buses are waiting for boarding and alighting, queued vehicles may block the intersection. • Rear-end collisions may increase. • Vehicles may change lanes in the middle of the intersection to get around the stopped bus.	• When near-side traffic volumes are heavier than far-side traffic volumes. • At intersections with heavy approach right turn volumes. • At intersections with transit signal priority.

Stop Type	Advantages	Disadvantages	Recommended Uses
Mid-Block	• Traffic congestion is reduced due to fewer conflicts between bus and turning vehicles. • Sight distance concerns for pedestrians are minimized.	• Unsafe pedestrian crossings and jaywalking are encouraged if there is no designated mid-block pedestrian crosswalk. • Walking distances to bus stops increase for passengers crossing the street. • Bus stopping is unexpected to motorists behind bus; rear-end collisions are more likely.	• When there is a major attraction for pedestrians at the mid-block location.

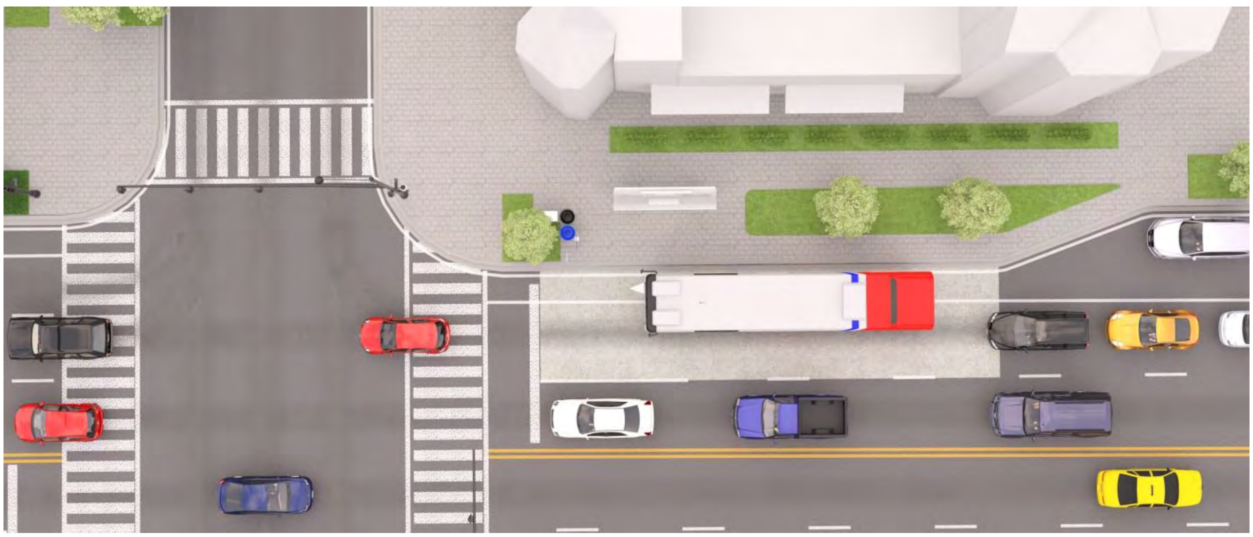


Figure 34-1 | Near-Side Bus Stop Location

Figure 34-2 | Far-Side Bus Stop Location

Figure 34-3 | Mid-Block Bus Stop Location

34.4.5.2.2. Enhanced Bus Stops

Enhanced bus stops serve limited stop/skip stop service and/or Bus Rapid Transit. A higher LOS must be provided at enhanced stops because they only occur at select locations in specific study areas. Enhanced stops may include the following elements:

- Bus stop sign
- ADA 5-foot by 8-foot landing pad minimum, 6-foot by 8-foot landing pad preferred
- Paved sidewalk (minimum 4 feet wide connecting stop to public sidewalk)
- Lighting
- Seating
- Expanded boarding and alighting area (for rear-door access, site dependent)
- Shelter
- Trash receptacle
- Information case
- System map
- Real-time display of travel information (through interactive information display and pushbutton audio system)

34.4.5.2.3. Optional Amenities

Optional amenities can also be incorporated into the bus bulb, depending on the needs of the study area. Optional amenities can include:

- Bike racks
- Vendor boxes
- Real-time passenger information signs (shelters only)

34.4.5.3. Drainage

A bus bulb must adequately drain to avoid ponding on the sidewalk and bus bulb. For bus bulbs with slopes similar to that of the adjacent roadway, the difference in slope between a bus bulb and adjacent sidewalk may cause unwanted ponding at the joint between the two areas. Additionally, if the longitudinal slope of the street is less than the cross slope, there is a high potential for ponding in the "no parking" area where the grade of the street slopes down to the bus bulb. The Designer must analyze the existing drainage network to understand the site drainage requirements, and drainage structures must be installed to avoid ponding, especially at curb ramps if present, and encourage positive flow along the gutter line. Such drainage facilities can include:

- Trench drains
- Inlets/catch basins
- Green Infrastructure, discussed in **Section 34.4.5.7**.

Refer to **Chapter 28** of this manual and the **DDOT Green Infrastructure Standards** for requirements on drainage areas, stormwater conveyance, sizing and hydraulic design for traditional drainage infrastructure, Low Impact Development and Green Infrastructure.

34.4.5.4. Bus Bulb Construction

Refer to **Section 34.2.4** for guidance on bus stop and bus pad design including pavement materials, thickness and scoring. Also, see **Section 34.4.5.7** and **Chapter 31** for other streetscape requirements such as ADA requirements and requirements for design in historic districts.

34.4.5.4.1. Curb Design

Curb design and materials must be in accordance with the **Chapter 31** of this manual and **DDOT Standards Specifications**.

Curb height of bus bulbs must be in accordance with current DDOT and WMATA guidelines. Standard curb height for streets in the District of Columbia is 7 inches. Non-standard curb heights may be approved by DDOT in certain situations, such as to mitigate impacts on adjacent roadway grading.

Required curb height at bus bulb edges may change the cross slope of the sidewalk or the paved area behind the curb, causing changes in sidewalk elevation at building faces. Grading of the area behind the curb should be carefully examined to maintain consistent drainage.

34.4.5.5. Utilities

The Designer must consider the existing utilities on site when determining the best bus bulb location. Impacts on aboveground and underground utilities should be avoided.

All utilities, including communication and electric lines, gas lines, water and sewer lines, street lights and fire hydrants, may remain within bus bulb areas; however, locations of utilities may require modifications or resetting and must not conflict with bus operations or ADA requirements.

All underground utility locations at bus bulbs require review by the corresponding utility. Street lights, traffic signal poles and fire hydrants may exist in bus bulbs as long as the requirements of this manual are met and poles are more than 2 feet away from the curb.

34.4.5.6. Street Trees

Street trees are needed to meet District requirements and goals for increased tree canopy, and must be considered in all streetscape plans. Bus bulb installation must not reduce the number of street trees or inhibit future street tree plantings; bus bulb installation must include the addition of one or more street trees whenever possible. For street tree installation, refer to **Chapter 37**.

Street tree installation in or adjacent to bus bulbs must be designed to fit harmoniously with the other amenities of the bus bulb. Trees must not inhibit installation of required bus bulb amenities, such as ADA landing pads or shelters. Trees must be maintained such that branches do not inhibit bus movement.

34.4.5.7. Green Infrastructure in Bus Bulbs

Green Infrastructure (GI) is a method of managing stormwater in the built environment that mimics the natural water cycle by retaining stormwater or slowing stormwater release rates into sewer systems or natural waterways. Retaining and/or treating urban stormwater runoff with GI reduces negative hydrologic and water quality impacts from runoff that traditional stormwater drainage practices may not address, and the use of GI supports the goals of WMATA’s Sustainability Agenda and the Sustainable

DC Act. Moreover, GI implementation is necessary to meet stormwater retention requirements of the 2013 DC Stormwater Regulations.

GI types to be considered for implementation in bus bulbs are those that are acceptable in public rights-of-way and are discussed in detail in the **DDOT Green Infrastructure Standards** (2014). Specific design and engineering criteria not covered here can be found in the **DDOT Green Infrastructure Standards** and the latest versions of the **DOEE Stormwater Management Guidebook**.

34.4.5.7.1. Competition for Space

Space in a bus bulb is limited, and many other elements compete with GI for space in public rights-of-way, influencing the location and size of each GI site. The needs for specific items in bus bulbs depend on several factors, some of which are discussed below.

34.4.5.7.1.1. Streetscape Layout

- **Sidewalk**. The minimum required sidewalk width for the street must be maintained. Installation of GI in a bus bulb must not inhibit the clear pedestrian path of the sidewalk.
- **ADA Ramps**. Installation of GI in bus bulbs must not replace or inhibit installation of required ADA ramps or landing pads.
- **Tree Space**. The tree space or amenity zone, i.e., the area between the curb and the sidewalk, may be used to install GI. GI placed in the bus bulb area may expand into the tree space adjacent to the bulb if feasible.
- **Traffic Sight Lines**. Installation of GI in bus bulbs must not inhibit required traffic sight lines. Designers must consider traffic sight lines when choosing GI facilities, specifically ensuring that plant heights in bioretention practices are appropriate for the location.

34.4.5.7.1.2. Bus Stop Amenities

- GI cannot prevent the installation of the required amenities for basic bus stops and enhanced bus stops, as laid out in **Section 34.4.5.2**.
- Optional elements at bus stops, such as those described in **Section 34.4.5.2.3**, may take precedence over GI, depending on the needs of each stop location.
- GI should not prevent access to rear doors of buses at stops.
- At least 2 feet of space must be maintained between the face of curb at the stop and any trees, signs, or poles to avoid conflict with the side mirrors of the buses.

34.4.5.7.2. Drainage

Installing GI at or near the joint of a bus bulb and the adjacent sidewalk should be considered as a means of capturing excess runoff. A trench drain can be used along the interface between bulb and sidewalk to carry runoff to a GI facility.

Overflow devices and outlets must be incorporated into GI facilities in bus bulbs to eliminate the risk of ponding stormwater in passenger boarding or waiting areas.

34.4.5.7.3. Applications

34.4.5.7.3.1. Types of GI Facilities

Types of GI facilities that can be considered for bus bulbs include bioretention planters, curb extension in-street bioretention areas, permeable pavements (excluding bus pads), and tree spaces, street trees or other landscape areas. For details and descriptions on these types of GI practices, refer to **Chapter 28** of this manual, the **DDOE Stormwater Management Guidebook** and **DDOT Green Infrastructure Standards**.

GI facilities can capture runoff from the sidewalk, bus bulb and street with minimal impact on the pedestrians' comfort level on the sidewalk. Table 34-7, adapted from the **TRB HCM**, gives general guidance for types of GI to choose based on available square footage per pedestrian. In general, as the available square footage per pedestrian increases, the size of the GI facilities on the bus bulb increases. If a low pedestrian LOS is provided at a bus stop, a tree space and/or permeable pavement would likely be the most appropriate choice because these facilities leave more space for waiting passengers than bioretention.

34.4.5.7.3.2. Maintenance Considerations

- Anticipate the level of care GI facilities will receive once installed at the bus bulb. Choose plant types appropriate for the anticipated level of care. (Use the bioretention and tree space plant lists in the **DDOT Green Infrastructure Standards**.)
- Design GI facilities to minimize future maintenance needs.
- Pretreatment areas should be added when possible to collect trash and debris in one area of a facility.

Table 34-7 | Recommended GI for Various Walkway Levels of Service

Level of Service	Area (ft²)/Pedestrian[1]	GI Types
A	60+	Curb Extension In-Street Bioretention Bioretention Planter Tree Space Permeable Pavement
B	40 –60	Curb Extension In-Street Bioretention Bioretention Planter Tree Space Permeable Pavement
C	24–40	Bioretention Planter Tree Space Permeable Pavement
D	15–24	Tree Space Permeable Pavement
E	8–15	Tree Space Permeable Pavement
F	< 8	Permeable Pavement

[1]Areas are from the **Highway Capacity Manual**, as noted in **Table 34-4**.

34.4.5.8. Future Development

In coordination with DDOT and WMATA, planned changes in the project area or vicinity must be considered and analyzed to ensure that bus bulbs will be an effective and meaningful investment. Such planned changes can include:

- Bus type changes
- Bus route changes
- Road diets (i.e., road reconfigurations or lane reductions)
- Bike lane modifications
- Evacuation/snow routes

34.4.6. Conceptual Engineering Plans for Bus Bulbs

34.4.6.1. Description and Contents of Drawings

In addition to the requirements of this manual, projects that include bus bulbs must include the following on drawings and construction documents:

- Locations and dimensions of bulbs
- Grading and elevations of bulbs
- Locations and types of GI in or near bulbs (See **Section 34.4.5.7**)
- Curb profile of bulb
- Cross section of bulb

34.4.6.2. Drawings

Conceptual engineering drawings for bus bulbs are in development for the latest edition of, or supplement to, the **DDOT Standards Drawings**.

35 Guidelines for the Design of Ground-Mounted Sign Supports along Highways

35.1. Introduction

The designer will select sign structures from the tables in this chapter when the standard DDOT sign structures cannot be used on the project.

Ground-mounted signs can be of two sizes:

- Small highway signs have an area less than 50 square feet
- Large highway signs have an area larger than or equal to 50 square feet

This chapter covers the design guidelines for ground-mounted sign supports. These guidelines were developed based on the current editions of the following:

- American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets
- AASHTO Roadside Design Guide
- AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals
- Federal Highway Administration Manual on Uniform Traffic Control Devices (MUTCD)

To minimize any impact the sign support may have on traffic, the Designer has four options from which to choose when locating signs in a highway right-of-way:

- Locate the sign beyond the clear zone; the clear zone should be in accordance with the **AASHTO Roadside Design Guide** and based on the posted speed limit
- Mount the sign overhead
- Use a breakaway support to reduce impact severity
- Shield the sign with a longitudinal barrier and/or crash cushion

Sign locations and the design of the sign support must be considered early in the design development stage. As mentioned above, ground-mounted signs should desirably be located beyond the clear zone, and all ground-mounted highway signs are to be installed on breakaway supports unless otherwise stated herein. When a sign is located behind a traffic barrier, non-breakaway supports may be used. In cases where noise walls are required at a particular sign location, additional berm widths may be necessary. In addition, where sign supports must be shielded, the Designer must determine the minimum area needed to accommodate both the sign supports and a guiderail or crash cushion.

35.2. Small Highway Signs

Small highway signs are those with total panel areas less than 50 square feet. When this category of sign is used, it must be supported on driven steel "U" post sign supports, the District's standard sign post. The "U" post must be 12 feet in length and weigh 3.0 pounds per foot before punching and galvanizing. Posts must be manufactured in accordance with **ASTM A499**, Grade 60 with a minimum yield strength of 60,000 pounds per square inch. Galvanizing must be in accordance with **ASTM A123**. Special poles, such as aluminum poles, will be used for special situations, such as street name signs. Posts are to be driven 3 feet into the ground or encased in concrete as directed. Where applicable, DDOT also allows square steel tube sign supports, steel I-beam sign supports and wood sign supports. Aluminum posts are not permitted for small highway signs. Small highway signs must not be placed in front of guiderails, and the posts must not straddle guiderails. All small highway sign supports must be of the breakaway type with the exception of those installed behind guiderails or behind other roadside barriers.

The Contractor and Designer are responsible for determining the horizontal offset with the concurrence of the DDOT traffic engineer. The Contractor and Designer will determine the quantity of posts, and their sizes and lengths, by following the steps in **Section 35.4** (breakaway) or **Section 35.5** (non-breakaway).

35.3. Large Highway Signs

Large highway signs are those with a panel area equal to or greater than 50 square feet. When this category of sign is used, the support must be of the breakaway type with the exception of those installed behind guiderails or behind other roadside barriers. When a non-breakaway sign support is placed behind a guiderail, the support should be a minimum of 4 feet from the back of the rail to the face of the signpost. When a non-breakaway sign support is placed behind a barrier curb, the support must be a minimum of 1.5 feet from the back of the barrier curb to the face of the signpost. The sign can be up to 30 feet away from the edge of pavement.

The Contractor and Designer are responsible for determining the horizontal offset with the concurrence of the DDOT traffic engineer. The Contractor and Designer will determine the quantity of posts and their sizes and lengths, by following the steps in **Section 35.4** (breakaway) or **Section 35.5** (non-breakaway).

35.4. Breakaway Sign Post Design

The following steps are used to determine the proper number of sign posts and their lengths. For further details, see the Metal Breakaway Post Selection section of the **DDOT Standard Drawings** and the latest version of the **MUTCD**.

35.4.1. Step 1: Determine Horizontal Offset

Once the required panel size is known, determine the horizontal offset from edge of pavement to the inside edge of sign**,** by applying Section 2A.19 of the MUTCD as follows:

- Urban installations: 1 foot minimum from curb face where sidewalk width is limited or existing poles are close to the curb
- Interstate and freeway installations: 6 feet minimum from edge of shoulder, but not less than 12 feet from the edge of traffic or auxiliary lane

Note: When there is a sidewalk or trail adjacent to the highway, the post must be place outside the effective width of the trail or sidewalk.

35.4.2. Step 2: Determine Sign Height

When determining the height of ground-mounted signs, the following checks should be made:

- When signs are installed on slopes 10H:1V or flatter, the minimum vertical clearance above the edge of pavement to the bottom of the sign panel are as follows:
  - Sign Panels:
    - For single-post installations, if possible, the minimum distance from the edge of pavement to the bottom of any panel must be 7 feet in accordance with the MUTCD. If other signs are attached to the post, the minimum distance from the edge of pavement to the bottom of the bottom-most sign is 6 feet.
    - For multi-post installations, the minimum distance above the edge of pavement to the bottom of a main sign panel is 7 feet.
  - Secondary Sign Panels:
    - The District frequently places several sign panels on a single sign post. When the height of the secondary panels falls below the minimum 7-foot level, engineering judgment

should be exercised to avoid placing these signs in or near pedestrian crossing areas. However, if the bottom of a secondary sign is mounted below another sign and is less than 7 feet above a pedestrian sidewalk or pathway, the secondary sign must not project more than 4 inches into the pedestrian facility (MUTCD Mounting Height Section).

- For signs along interstates and freeways, the bottom of the main sign must be a minimum of 7 feet above the edge of pavement, and the secondary sign panel must be a minimum of 5 feet above the edge of pavement.

NOTES:

- Sign supports must not be placed on slopes steeper than 10H:1V except where that grading or flatter cannot be obtained or where the supports will be behind a traffic barrier.
- Where grading of 10H:1V or flatter cannot be obtained or where there is a curb or berm more than 4 inches high, the minimum vertical clearances will be measured from the ground line to the bottom of the sign.

35.4.3. Step 3: Select Sign Post

Determine the size and quantity of posts per sign from the Metal Breakaway Posts Selection section in the **DDOT Standard Drawings**, for height (H) from 2 to 15 feet and width (W) from 2 to 30 feet.

Note: When the plotted values of height and width indicate an undefined section of the Post Selection Chart in the Metal Breakaway Post Selection section in the **DDOT Standard Drawings**, then an alternative design for the sign post must be initiated.

- The maximum sign width (W) for single-post installations is 3 feet.
- It is possible to have multiple options for the number and size of posts that the sign can attach to. When that happens:
    - The first criterion is to choose the fewest number of posts.
    - The second criterion is to choose the lightest material.

Example: H = 5 feet
W = 14 feet
L = 10 feet

The number of posts that may be selected are:

- Three – S4 x 7.7
- Two – W6 x 9

Choose two W6 x 9 posts

35.5. Non-Breakaway Sign Post Design

The following steps are used to determine the proper number of sign posts and their lengths. For further details, see **DDOT Standard Drawings** for Metal Non-Breakaway Post Selection and the latest version of the **MUTCD**.

35.5.1. Step 1: Determine Horizontal Offset

Once the size of the main panel is known, determine the horizontal offset, X_1, from the edge of pavement to the edge of panel. The recommended offset is 8 feet, and the minimum offset is 7 feet. When there is a sidewalk or trail adjacent to the highway, the post must be place outside the effective width of the trail or sidewalk.

35.5.2. Step 2: Determine Road to Sign Height

Determine the elevation from the edge of pavement to the bottom of the main panel. For fill sections, the minimum elevation is 7 feet. For cut sections, the bottom of the sign must be a minimum of 7 feet above the ground line and a minimum of 1.33 feet above the top of the berm.

35.5.3. Step 3: Select Number of Posts (P)

Determine the number of posts required for the specified panel based on a maximum sign area per post of 192 square feet.

Example: A_1 = 30 feet
H = 15 feet
AREA = 450 square feet

Where:

A_1 = Main panel width
H = Main panel height

- The calculated sign area suggests a minimum of three posts (450 ft^2/192 ft^2 = 2.3, or 3 posts)
- The required spacing between posts for a three-post system is $A_1/3$

- This translates to a 10-foot spacing between posts

35.5.4. Step 4: Determine Footing to Sign Height

Determine the distances from the top of footings to the bottom of the main panel, L, for each post by meeting the minimum height requirements laid out in the **MUTCD** and **DDOT Standard Drawings**.
L varies based on the sign height requirements above.

NOTE: The minimum height of any post from ground line to the bottom of the main panel is 2.5 feet.

35.5.5. Step 5: Determine Sign Characteristics

Determine the required values of L_{max}, H, and A_1 where:

L_{max} = Maximum post length to bottom of main panel (feet)

H = Main panel height + exit panel height (feet)

A_1 = Main panel width (feet)

35.5.6. Step 6: Determine Moment of Sign Area (MSA)

Determine MSA per post using the formula below:

$$MSA = [A_1 * H * (L_{max} + (H/2))]/P$$

where P = Number of sign posts

35.5.7. Step 7: Determine Post Diameter

Using the value obtained in Step 6, determine the post diameter, wall thickness and base type from Table 35-1. Use this selection for all posts in the structure.

Table 35-1 | Post and Base Selection Table

Post Dimensions

MSA (ft^3)	Outside Diameter (in.)	Wall Thickness (in.)	Base Type
420	6	1/4	A
800	8	1/4	A
1300	10	1/4	B
1920	12	1/4	B
2510	12	3/8	B

35.6. Bolting and Mounting

35.6.1. Post Bolts

Two 5/16-inch by 2-inch and 2-1/2-inch hex head plated nuts and bolts (full threaded) are used to attach sign posts to sign anchors (stubs). These bolts are installed at two of the pre-drilled post holes positioned apart and at 90 degrees to one another.

35.6.2. Sign Bolts

Signs are mounted to the post with a minimum of two bolts (5/16-inch with nylon and metal washers) or standard rivets (TL3806 EG, drive rivets) with nylon washers placed against the sign face. The bolt or rivet system is used to fasten signs to the Telspar post.

35.6.3. Other Sign Mounts

Streetlights and approved utility poles, when located appropriately, may be used for warning, parking, and speed limit signs. Streetlight locations should be checked for potential sign installation during the design process and shown on the sign plan sheets. Signs installed on streetlights and utility poles are installed with stainless steel straps, buckles and sign-mounting brackets with standard nuts and bolts of appropriate lengths and widths.

35.7. Non-Vegetative Surface under Overhead Signs and Large Ground-Mounted Signs

To reduce soil erosion and highway maintenance costs associated with spraying or trimming vegetation underneath signs, non-vegetative surfaces should be applied around the foundation of overhead signs and underneath large ground-mounted signs as summarized in Table 35-2.

Table 35-2 | Non-Vegetative Use Table

Sign Types	Conditions Warranting Use of Non-Vegetative Services
Overhead Signs	
Sign bridge	All cases
Sign cantilevers	All cases
Ground-Mounted Signs	
Breakaway sign supports*	Mowable areas
Non-breakaway sign supports	Mowable areas

***NOTE: Surface treatment is not to be used at breakaway steel "U" post sign support locations.**

36 Barriers

36.1. General

The following guidelines are based on the current American Association of State Highway and Transportation Officials **(AASHTO), A Policy on Geometric Design of Highways and Streets** and the **AASHTO Roadside Design Guide**. This chapter is intended to help the Designer determine conditions that warrant the installation of guide rails and traffic barriers on freeways. It is important that these guidelines be applied in conjunction with engineering judgment and thorough evaluation of site conditions to arrive at a proper solution. The AASHTO Manual for Assessing Safety Hardware (MASH), Latest Edition or NCHRP 350 must be used when determining the appropriate barrier.

In some cases, another type of traffic barrier may be more effective than a guide rail. The Designer should consider alternatives and choose the most suitable solution based on safety requirements, economic limitations, maintenance and aesthetic considerations. It should be emphasized that guide rails and barriers should not be installed indiscriminately. Every effort should be made to eliminate the obstruction for which the guide rail is being considered. In the District, many roadways are off-system, and guide rails or median barriers are not practical; in such cases curbs may be considered reasonable barriers.

36.2. Guide Rails

36.2.1. General

Guide rails are longitudinal barriers whose primary functions are to prevent penetration and to safely redirect an errant vehicle away from a roadside or median obstruction.

36.2.2. Warrants for Guide Rails

A warranted obstruction is defined as a non-traversable roadside or a fixed object in the clear zone (defined in **Section 36.2.3**). The physical characteristics are such that injuries resulting from an impact with the obstruction would probably be more severe than injuries resulting from an impact with a guide rail.

An obstruction's physical characteristics and its location within the clear zone are the basic factors to be considered in determining if a guide rail is warranted. Special cases will arise where it is not clear whether a guide rail is warranted. Such cases must be evaluated on an individual basis using engineering judgment.

36.2.2.1. Non-Traversable Roadside

Examples of non-traversable roadsides that may warrant guide rails include rough rock cuts, large boulders, streams or permanent bodies of water more than 2 feet in depth. Any fill slope steeper than 3H:1V and more than 5 feet high is considered non-traversable.

36.2.2.2. Embankment (Fill) Slopes

A critical slope is one on which a vehicle is likely to overturn. Slopes steeper than 3H:1V generally fall into this category. If a slope steeper than 3H:1V begins closer to the traveled way than the suggested clear zone distance, guide rail might be warranted if it is not practical to flatten the slope. Guide rail warrants for critical slopes are shown in Table 36-1.

Table 36-1 | Critical Slope Warrants

Critical Embankment (Fill) Slopes	Maximum Height Without Guide Rail
1.5H:1V	3 ft
2H:1V	6 ft
2.5H:1V	9 ft

A non-recoverable slope is defined as one that is traversable but on which a vehicle can be expected to travel to the bottom of the slope before steering can be recovered. Embankments between 3H:1V and 4H:1V generally fall into this category. Fixed objects should not be constructed or located along such slopes that begin closer to the traveled way than the suggested clear zone distance. A clear runout area at the base of these slopes is desirable. The Designer should, therefore, evaluate each site before providing 3H:1V slopes without guide rail.

When flattening existing slopes to remove the need for a guide rail, the proposed side slopes should be recoverable, that is, 4H:1V or flatter. Where embankment slopes are being constructed, the Designer should investigate the feasibility of providing a recoverable slope instead of a critical slope with guide rail. Rounding should be provided at slope breaks.

36.2.2.3. Slopes in Cut Sections

Slopes in cut sections do not ordinarily warrant guide rail. However, there may be obstructions on the slope that warrant shielding, such as bridge piers, retaining walls, trees and rocks, that may cause excessive vehicle snagging rather than permit relatively smooth redirection.

Slopes in cut sections of 2H:1V or flatter are considered traversable; however, as the cut slope steepens, the chance of rollover increases. Where feasible, slopes steeper than 2H:1V should be flattened. If there is a warranting obstruction on the cut slope, the following apply:

- Guide rail should be installed if the warranting obstruction is on a slope flatter than 0.7H:1V and is within the clear zone width specified for a 3H:1V slope.
- Guide rail should be installed if the warranting obstruction is on a slope of 0.7H:1V or steeper and is less than 6 feet (measured along the slope) from the toe of the slope and is within the clear zone width specified for a 3H:1V slope.
- Guide rail is not required if the warranting obstruction is on a slope of 0.7H:1V or steeper and is 6 feet or more (measured along the slope) from the toe of the slope.

36.2.3. Clear Zone

Clear zone is defined as the area from the edge of the traveled way that is available for safe use by errant vehicles. The width of the clear zone varies with the design speed, roadside slope and horizontal roadway alignment. See **Chapter 30** of this manual for information on design speed selection.

The **AASHTO Roadside Design Guide** contains the suggested range of clear zone distances on tangent sections of roadway based on selected traffic volumes, speeds and roadside slopes. Clear zones may be limited to 30 feet if previous experience with similar projects or designs indicates satisfactory performance. The Designer may provide clear zone distances greater than 30 feet if accident history justifies it.

Horizontal alignment does affect the clear zone width; clear zone widths should be increased on the outside of horizontal curves.

36.2.4. Drainage Features

Channels should be designed to be traversable to avoid unnecessary barrier installation, and where feasible, existing channels should be reconstructed to be traversable.

36.2.5. Fixed Objects

Fixed objects that may warrant guide rails include overhead sign supports, traffic signal and luminaire supports of non-breakaway design, concrete pedestals extending more than 4 inches above the ground, bridge piers, abutments, parapet and railing ends, wooden poles or posts with a cross-sectional area greater than 50 square inches, and utility and drainage structures.

In no case will breakaway, bend-away or non-breakaway sign supports, highway lighting, trees, utility poles, fire hydrants, mailboxes and signs on new or upgraded guide rail installations remain in front of guide rail.

Overhead sign supports should be protected by guide rail or impact attenuators. Breakaway sign structures are not recommended in DC because a falling sign is considered more dangerous than a rigid signpost.

Overhead sign supports should be located as close to the edge of the right-of-way (ROW) as practical. Guide rail protection for all overhead sign supports should be provided regardless of location beyond the clear zone. This will limit damage from impacts to the sign support.

36.2.6. Trees

Trees 6 inches or more in diameter are considered fixed objects. However, trees are not considered a warranting obstruction. The following guidance is provided for the treatment of trees within the clear zone:

- On freeways and interstate routes, trees must not be located within the clear zone.
- The aesthetic appeal of trees will cause opposition to their removal. Removal of trees may not be environmentally acceptable. Factors such as accident history, traffic volume, speed and roadway geometry should be evaluated.
- Sick and diseased trees that are beyond reasonable repair, dead trees, trees that cause sight distance problems, and trees with a significant accident history must be removed. Also, trees that will be harmed beyond reasonable repair due to construction must be removed. The Urban Forestry Administration of DDOT should be consulted for the tree's physical assessment.
- Cityscape trees must not be removed without permission from DDOT's Urban Forestry Administration. As a minimum, branches overhanging the roadway must be removed up to a height of 16 feet. The following areas should be checked for sight distance problems:
    - Along the inside of horizontal curves
    - Ramp and jug handle entrances and exits
    - Within the sight triangle at intersections
    - Sign obstructions
- If clearing work is necessary within existing utility lines, the Designer should request the utility company to perform regular trimming maintenance (at its own cost) during the utility notification process.

36.2.7. Utility Poles

On existing highways where utility poles do not meet the offset requirements, the Designer should prepare an accident analysis of existing pole locations to determine if it is warranted to relocate utility poles farther from the edge of a through lane.

Utility poles should not be placed in vulnerable locations, such as in gore areas, small islands or on the outside of sharp horizontal curves. For the purpose of these guidelines, a sharp horizontal curve is considered as any horizontal curve with a safe posted speed lower than the design speed.

In no case are utility poles on new or upgraded guide rail installations allowed to remain in front of the guide rail. Relocate the pole behind the guide rail. The face of the pole should be 4 feet or more from the back of the rail unless this would place the pole on the sidewalk, in which case the pole may be placed as close as 1 foot from the back of the guard rail. Where the offset is less than 4 feet, reduce post spacing and double the rail element (one set inside the other). Where a pole will be located directly behind a post, the minimum pole offset should be no closer than 18 inches from the back of the rail. Guide rail is an obstruction in itself and should be placed as far from the traveled way as possible, but should be located between the sidewalk and the traveled way.

36.2.8. Fire Hydrants

Fire hydrants must be of the breakaway type or located as far from the traveled way as possible. However, they must be located where they will be readily accessible at all times.

Where guide rail is required for some other reason and will be in front of a hydrant, the preferred treatment is to raise the hydrant so that connection can be made over the guide rail.

36.2.9. Pedestrians

Guide rails or barriers may be used where there is a reasonable possibility of an errant vehicle encroaching on an unprotected sidewalk or other area used by pedestrians, such as playgrounds or school yards. The basis for assessing the need for a barrier should be the accident history of the immediate area and the specific causes of the accidents.

Sometimes existing guide rail and the top of a steep slope are both located directly behind a pedestrian sidewalk area. If new guide rail is installed in front of the sidewalk area, the existing guide rail should be removed and a fence installed in its place.

36.2.10. Approach Length of Need (L.O.N.)

The approach L.O.N. is the minimum length of guide rail required in front of the warranting obstruction to shield it effectively. See the **AASHTO Roadside Design Guide** for L.O.N. guidance.

36.3. Dimensional Characteristics of Guide Rails

36.3.1. General Design Considerations

- Guide rails should not restrict sight distance. Sight distances should be checked when guide rail is to be installed at intersections, ramp terminals, driveways, along sharply curving roadways, etc. If the sight distance is determined to be inadequate, the guide rail placement must be adjusted.
- Whenever part of an existing guide rail run is lengthened, reset or upgraded, the entire run, including bridge attachments, must be upgraded to current standards. Also, always end a project outside the limits of a guide rail run.
- Gaps between individual guide rails or concrete barriers should be avoided.
- Guide rail shorter than 200 feet is not recommended due to the lower strength.
- Guide rail should not be installed beyond the ROW unless easements are acquired or the ROW is extended.
- Avoid using different types of barriers and transitions in short lengths.
- Guide rails that will be set flush with the curb line along intersections and radius returns should be checked for damage. Existing guide rail along radius returns where truck overhang or oversteering accidents have happened either must be moved farther from the curb line or the radius returns should be redesigned for a larger design vehicle.
- The grading work necessary for the construction of the guide rail end treatments must be shown on the construction plans.
- For conduits, the plans must indicate the location of existing conduits or clearly designate where there is a possibility of conflict with guide rail posts.
- Surfaces under guide rails should be non-vegetative to reduce soil erosion and highway maintenance costs associated with spraying or trimming vegetation underneath guide rails.
- New barriers developed without crash performance testing must be developed in accordance with the Federal Highway Administration **Manual for Assessing Safety Hardware**.

36.3.1.1. Placement Without a Curb or Raised Berm in Front of Guide Rail

Guide rail should be placed far enough away that it will not be perceived as a threat by the driver. In general, the following offsets and slopes should be used:

- To the extent possible, guide rail should be located as far as possible away from the traveled way to provide a recovery area for errant vehicles and ensure adequate sight distance along horizontal curves and at intersections.
- On interstate highways and freeways, the front face of the guide rail should be 4 feet or more from the outside edge of shoulder.
- On roadways where there is a sidewalk or other area used by pedestrians, the guiderail offset from the edge of roadway should be determined by the design speed. Refer to the **AASHTO Roadside Design Manual** for additional information.
- Where guide rail is located at the top of an embankment slope, the posts should be a minimum of 2 feet from the top of slope to the center of the post. When post is located less than 2 feet from the top of an embankment slope, the additional post lengths shown in Table 36-2 should be used.

Table 36-2 | Additional Post Length Requirements Where Distance from the Top of Slope to Center of Post Is Less than 2 Feet

Embankment Slopes	Additional Post Length
Flatter than 6H:1V	No Change
6H:1V to 4H:1V	1 ft
3H:1V to 2H:1V	2 ft
Steeper than 2H:1V	4 ft

- Guide rail must be placed on slopes 10H:1V or flatter.

36.3.1.2. Placement With a Curb or Raised Berm in Front of Guide Rail

Curbs or raised berms in front of guide rails should be avoided.

New vertical curb is not allowed to be installed on freeways and interstate highways. Sloping curb may be constructed on urban freeways and urban interstate highways, but the overall curb height must not exceed 4 inches.

On projects that involve upgrading existing roadways where there is a curb or a raised berm in front of the guide rail, removal or modification of the curb or raised berm should be the first consideration.

36.3.2. Rub Rail

When guide rail is constructed less than 3 feet from a curb or raised berm that is 4 inches or more in height, the mounting height is measured from the top of the curb or raised berm, and rub rail is required. Where guide rail is set flush to the gutter line, spans short sections of the curb (i.e., less than 100 feet long at each location) and is 4 inches or less in height, the mounting height may be measured from the gutter line, and rub rail is not required.

On all projects involving new guide rail or the upgrading of existing guide rail, every effort should be made to eliminate or reduce the need for rub rail.

Acceptable methods for reducing or eliminating the need for rub rail include providing sufficient offsets, removing or revising earth berms, providing designs without curb and eliminating the existing curb where feasible.

36.3.3. At Fixed Objects

Where guide rail is used to shield an isolated obstruction, it is very important that the guide rail be located as far from the traveled way as possible to minimize the probability of impact. The distance from the back of the rail to the face of the obstruction should be 4 feet or greater. If it is less than 4 feet, then the guide rail system must be designed for deflection restrictions.

36.3.4. On Bridges

On existing freeway and interstate structures with safety walks, where it is not feasible to install a concrete safety-shaped barrier, a crashworthy steel traffic rail, not guide rails, must be placed across the structure along the gutter line. Where the offsets of the approach guide rail and bridge parapets differ, a transition flare rate of 15:1 should be used.

36.3.5. End Treatments

36.3.5.1. Guide Rail Terminals

Use the current DDOT-approved standard guide rail terminals and anchorage on the approach and trailing ends of beam guide rails.

A guide rail terminal must be placed a minimum distance of 12.5 feet beyond the L.O.N.

A guide rail terminal typically should not be installed behind a curb higher than 4 inches. Where there is an existing curb or proposed curb more than 4 inches high, the approach and exit of the guide rail terminal must be removed and replaced with a 4-inch mountable vertical curb.

A clear area must be provided behind a guide rail terminal installation. Slopes in front of guide rail and 6 feet behind the guide rail terminal must be graded at 10H:1V or flatter.

Where guide rail is installed along a horizontal curve, the post offsets for the parabolic flare are measured from a line tangent to the horizontal curve.

36.3.5.2. At Gore Areas

A traversable and unobstructed gore area is preferred, since the gore area may serve as a recovery area for errant vehicles. This preference may be hindered in urban areas, wetlands, parklands, etc. where guide rail-warranting obstructions such as critical embankment slopes, parapets or abutments are placed close to gore areas. The closer the obstruction is to the gore area, the more likely that a guide rail will be needed. The preferred scenario would be for gore areas not to need any guide rails.

36.4. Median Barrier

A median barrier is a longitudinal system used to separate opposing directions of traffic on a divided highway. Common types include concrete barriers, guide rails and cable barriers.

36.4.1. Warrants for Median Barriers

36.4.1.1. Interstates and Freeways

On interstates with low Average Daily Traffic (ADT) counts, the probability of a vehicle crossing the median is relatively small. Therefore, for ADT less than 20,000 vehicles per day, a median barrier is warranted only if there is a history of cross-median accidents. Likewise, for relatively wide medians, the probability of a vehicle crossing the median is also low. Thus, for some medians wider than 30 feet and a design speed lower than 45 mph, the need for a barrier will depend on the cross-median accident history. Flat medians that are wider than 50 feet do not warrant a barrier unless there is a significant history of across-the-median accidents.

36.4.1.2. City Streets/Parkways

Careful consideration should be given to the installation of median barriers on city streets/parkways or other roadways with partial access control, because median barriers must be terminated at each intersection or median crossover, and this can create problems.

The number of crossovers, accident history, alignment, sight distance, design speed, traffic volume and median width should be evaluated before installing median barriers on parkways. Each location should be evaluated individually, with the prevailing reason for its installation being to decrease the number of crossover accidents.

36.4.2. Median Barrier Types

When a median barrier is warranted, the type to be installed is related to median width, as shown in Table 36-3.

Table 36-3 | Median Width vs. Median Barrier Type

Median Width	Median Barrier Type
Up to 12 ft	Concrete Barrier
12–26 ft	Concrete Barrier (Preferred) or Dual Face Beam Guide Rail
Over 26 ft	Dual Face Beam Guide Rail

There must be a minimum offset of 3.25 feet from the face of curb to the face of the obstruction because high-profile vehicles have a tendency to lean when impacting curbs higher than 4 inches at a high speed of 60 mph or greater and at an angle of 25 degrees or more, causing the vehicle to strike the obstruction behind the curb. Concrete barrier or guide rail should be used to shield obstructions such as bridge piers, abutments and sign bridges.

Architectural barriers with stone facing or stamped concrete should be considered on projects with aesthetic requirements. The barrier should be installed flush with the curb, or mountable curbs may be considered when it is not practical to install the barrier flush with the curb.

36.4.3. End Treatments

When terminating the approach end of dual-face beam guide rail beyond the clear zone, an end anchorage with end section (buffer) is required. When terminating the approach end of a concrete barrier beyond the clear zone, a tapered concrete terminal section is required. Where a median barrier terminates within the clear zone on freeways and interstate highways, a crashworthy end treatment must be used.

37 Landscape Design Criteria

37.1. General

This chapter provides a framework for designing landscapes within the District's rights-of-way (ROWs) and public areas. These criteria are not intended to direct designers in development of private landscape or other on-site development. Throughout the design process, the landscape designer should collaborate with other professional disciplines. All landscape design projects within a ROW must be reviewed by the Urban Forestry Administration (UFA) and Infrastructure Project Management Administration (IPMA) Green Infrastructure (GI) team to ensure the landscape being provided will thrive and that safety and regulatory standards will be met. Project-specific environmental commitments made by the environmental specialists during project development must be incorporated into the design plans, whether by an Environmental Impact Statement or Environmental Assessment, or made during minor project development. Project-specific mitigation commitments generally involve avoidance, protection, minimization or replacement of protected resources. Where possible, landscape designers should use GI practices to improve stormwater quality following the concepts and objectives of Low Impact Development (LID).

Development projects that include work within the ROWs and public areas must conform to the requirements of this chapter and all applicable District regulations. This work requires a permit from the Public Space Regulation Administration. Any approved and permitted non-standard items will require a maintenance agreement.

Landscape plans may include tree protection, planting, grading, erosion control, soil volume, maintenance practices and agreements, environmental mitigation such as wetland replacement and architectural features, depending on the scope of the project.

When developing preliminary landscape plans, conduct the following activities:

- Generate an existing conditions plan including a current tree survey. See the following ArcGIS link to the live data or site plan: http://www.arcgis.com/home/webmap/viewer.html?webmap=fea6079cf9bc4310a8b6c94f8c2bf1da&extent=-77.0109,38.9148,-77.0049,38.9177.
- Determine alternate designs based on pre-design meetings and appropriate standards.
- Coordinate Tree Removal, Tree Replacement and Tree Planting Permits as required for mitigation.
- Verify the availability of all plant material for use in the proposed plan.

- Coordinate with the Program/Project Manager and neighborhood groups if required.

The final landscape design will be completed based on the following, which will be documented in the project plans and specifications:

- Preliminary Design Review minutes, revisions and written safety and design decisions
- Tree Removal, Tree Replacement and Tree Planting Permit requirements
- Special Provisions for specifications of non-standard materials
- Coordination with UFA and IPMA GI staff
- Final Design Review changes and review minutes for final sign-off
- Fulfillment of landscape requirements as mandated by DDOT policy and District and federal regulations
- Adherence to DDOT GI plant lists for trees and bioretention plants
- Environmental mitigation requirements
- Maintenance practices and agreements

NOTE: Federal Aid projects must include the planting of native wildflowers, seedlings or both, as provided in Title 23 of the Code of Federal Regulations, Part 752.11(b), unless a waiver is granted.

37.2. Intent

The intent of these design criteria is to beautify the District's ROWs and its many public areas by planting trees, shrubs, groundcovers and grasses and the appropriate use of hardscape, while practicing water conservation through the specification and planting of native and/or adapted species of plants. Sound maintenance principles and practices must be considered when selecting plant materials for use in public space. The District is committed to the reduction of water consumption in the landscape and encourages the application of xeriscape design and maintenance principles. All plant materials and related work must meet the **American Nurseryman Standards (ANSI Z60.1)**.

37.3. Landscape Design

Landscape design is the treatment given to the local streets, arterials, collectors and gateways to conserve, enhance and effectively display the natural beauty of green spaces through which the roadway passes. Landscape Design Plans must be submitted as an integral part of the plans as defined in **Chapter 12** of this manual. The costs of such improvements must be included in the Project Cost Estimate for Public Improvements. All non-hardscape areas within the ROW must be mulched, seeded or planted in accordance with the design criteria of this chapter. Employing these landscape treatments as appropriate into final design enhances and emphasizes the natural beauty of the roadside.

Some neighborhoods in the District, such as the Downtown, NoMa and Mount Vernon Triangle, have adopted additional landscape design requirements that have been developed in partnership with the District of Columbia Office of Planning (OP). These standards and guidelines identify specific features such as paving materials, streetlight type and tree species to be used, helping to further identify the neighborhood and enhance the quality of the existing neighborhoods. For more information, contact the OP Public Space Program Manager at (202) 442-7600 or the Transportation Neighborhood Planner at DDOT Policy Planning and Sustainability Administration at (202) 673-6813.

37.3.1. Public Parking

The public parking area is the portion of the ROW to be devoted to open space or greenery parks that lie between the property line, which may or may not coincide with the building restriction line, and the edge of the actual or planned sidewalk. Communities and abutting property owners, commercial or residential, must design, plant and maintain these areas.

All non-hardscape areas within the public parking area must be mulched, seeded, planted or covered according to the guidelines of this chapter. All landscaping in the ROW must be designed in accordance with this chapter, applicable neighborhood streetscape design standards and guidelines, the **Public Realm Design Manual**, **DDOT Green Infrastructure Standards** and environmental regulations to include, but not be limited to, the **District Department of Energy and the Environment Stormwater Regulations**.

37.3.2. Tree Space

The tree space is the unpaved area of the ROW that lies between the curb and sidewalk, commonly reserved by the District government for planting trees. For all streets, commercial or residential, adjacent property owners may plant in this area provided they follow **District of Columbia Municipal Regulations Chapter 24, Section 109, Beautification of Tree Spaces**.

Tree space beautification undertaken by the abutting property owner will be at the owner's sole personal expense and risk, and is under the immediate care and keeping of the owner.

The District reserves the right to enter the tree space for construction or maintenance activities. DDOT will give notice to the abutting property owner if removal of beautification materials within the tree space is required; this will allow the owner to remove plants and materials prior to construction work.

However, should the property owner want to beautify the tree space beyond the scope of the **Beautification of Tree Spaces** regulation, then a public space permit will be required from the Public Space Regulation Administration for the work.

This area may contain vegetated stormwater retention systems designed and constructed in accordance with **DDOT Green Infrastructure Standard** drawings, the design and maintenance procedures in **Chapter 28** of this manual and the planting guidelines in this chapter.

37.3.2.1. Tree Boxes

To ensure normal tree development, the minimum dimensions for a tree box opening is 4 feet by 9 feet. Trees are not to be planted if the stated threshold cannot be met.

Tree boxes may be protected with an ornamental iron tree fence on the three sides away from the curb. Tree fence design must meet or exceed current DDOT specifications.

No landscape fabric or plastic sheeting, gravel, rocks, brick, stone or concrete pavers, or any other paving material is permitted in tree boxes, except as authorized by a public space permit.

Tree boxes in the areas that have adopted additional landscape design requirements as designated under **Section 37.3** must be in accordance with the latest version of the **Streetscape Design Standards and Guidelines** for that neighborhood.

This area may contain vegetated stormwater retention systems designed and constructed in accordance with **DDOT Green Infrastructure Standard** drawings, the design and maintenance procedures in **Chapter 28** of this manual and the planting guidelines in this chapter.

37.3.2.2. Continuous Planting Strips

Planting strips must be at least 4 feet wide to accommodate healthy tree root systems. On arterials, all sidewalks must be set back from the curb a minimum of 6 feet to create a continuous planting strip between sidewalk and curb. No planting strip on a District street is allowed to be less than 4 feet in width measuring from the back of curb.

Turf or low-growing perennials must be provided where the average width of the planting strip is 4 feet or more. This turf or low-growing perennials should not interfere with vehicular sight distances and pedestrian safety. Planting strips less than 4 feet, or those in high traffic areas, may be paved with brick, flagstone or concrete pavers, colored or scored concrete, and/or permeable pavements. All planting strips in areas designated by the District as high commercial use must be hardscaped. Planting strips may not be elevated.

37.3.3. Medians

To ensure normal tree development, the minimum width dimension for a median with trees is 10 feet. If a median is between 4 feet and 10 feet, it is at the District's discretion whether the median should be hardscaped or landscaped. All medians or sections of medians that are less than 4 feet wide must be completed in hardscape, including stamped concrete, brick, flagstone, exposed aggregate concrete or permeable pavement. No landscape will be allowed on medians that are narrower than 4 feet. Medians must be elevated.

37.4. Plantings

All plantings, including trees, should fit the microclimate, soils, sun, moisture, budget and maintenance environment in which they are planted. This is a major concern in areas with high levels of pollution, and automobile or pedestrian damage. Plantings selected for urban streets should be able to tolerate pollution, compacted soils, road salt, minimal water and low maintenance.

37.4.1. Street Trees

Design for street trees should be appropriate for the specific street. The following are guidelines for determining how and when trees should be planted in landscaped areas:

- UFA will identify the type of species to plant.
- Select trees that will fit when they are mature.
- When selecting tree species, consider above- and below-grade obstructions, such as utility vaults and overhead wires.
- When replacing trees in an existing ROW, select new trees with similar characteristics to those being replaced, including species, form, scale, texture, size and color.
- Trees near walks should be thornless and fruitless to minimize maintenance and to reduce pedestrian hazards. They must be strong-wooded, resistant to most diseases and insects, single-trunked, with upright growth and a medium to long life expectancy. Branches should resist breaking.
- Along commercial streets, trees should be selected that will minimize the obstruction of views to retail signs. Use trees with a form and character that suit the neighborhood, and use tree spacing that supports this concept.
- Tree grates or pavers may be used with UFA approval where pedestrian traffic is high, as well as to protect tree roots and pedestrians where planting strips do not exist. Tree openings in the tree grates are to be a minimum of 24 inches in diameter.
- Trees may be grouped in areas upon DDOT approval.

37.4.2. Perennials

Perennials are plants that persist for more than two growing seasons; the top portion of the plant dies back each winter and then regrows the following spring from the same root system. Perennials provide seasonal color and serve as a buffer between people and cars. Perennial plantings provide functional and aesthetic benefits; however, maintenance is extremely important. Plantings other than trees in the streetscape may include turf, ground covers, ornamental grasses or shrubs. In commercial streetscapes with a wide area between the sidewalk and the street or low pedestrian volume, ornamental grasses and ground covers may be most appropriate. This buffer area helps soften the street environment along the street edge.

Specific site conditions must be fully understood prior to plant selection. Local microclimates and soils are key factors that determine which plants will thrive. Where possible, plants requiring minimal water should be selected. Native and low-maintenance plants that require less water will thrive better if placed in planting beds rather than turf beds.

37.4.3. Turf Grasses

Turf should be planted on prepared soil from seed or sod. A wider selection is available for seeds, but seeding requires approximately 6 months and regular maintenance to become established. Sod is best installed upon delivery and should not be allowed to dry out. Both seed and sod require protection from pedestrians and must be kept moist until the seeds germinate or the sod roots produce good contact with the soil. Acceptable grass mixes are as follows:

- **Mixed Fine Fescue, Rye Grass and Bluegrass.** This mix works in sun and shade, suits a number of climate and soil conditions, and has better shade, disease, salt and moisture stress tolerance over pure bluegrass.
- **Tall Fescue / Turf Type.** This alternative has a deep green color, is shade and salt tolerant, and is drought-resistant because of its deep root system. Include at least three improved varieties of tall fescue / turf type in the blend.

37.4.4. Vegetated Stormwater Areas

Selection of plant species, locations and spacing within vegetated stormwater management facilities (bioretention) will be based on the following parameters:

- Light: full sun, partial shade full shade.
- Water: Some plants will succeed in areas that are frequently inundated with water, while others will do well only in the driest part of the facility.

- Salt: Plants that have a high salt tolerance are the best choice for facilities that will receive a large amount of salt-tainted runoff.
- Pollution: Generally, plants in more polluted areas will require more maintenance and care throughout their lifespan to remain aesthetically pleasing.
- Maintenance: Areas that are not regularly maintained should be planted with plants that do not require intensive care. Areas that will be maintained several times a year can be planted with plants that require more attention.
- Survivability in urban environment: All of the above factors relate to the plant's ability to survive in an urban ROW LID facility.
- Size: Plants should be the appropriate size for the site when mature. Site viewing lines and pedestrian and vehicle safety should be considered. Except for street trees, plants between the curb and sidewalk should be less than 18 inches high above the sidewalk at maturity.

The designer will select the plants for bioretention facilities from the current DDOT-approved plant list. The list is organized in accordance with the above factors, and is grouped into three maintenance categories: low level of care, medium level of care, and high level of care.

37.5. Tree Space Design

Street trees must be selected from DDOT's approved list and placed in appropriate locations in the public ROW. Surrounding soils, including nearby soils under sidewalks, must comply with the design requirements noted below.

37.5.1. Tree Size

All trees must be 2 to 2-1/2 inches in caliper when planted (unless otherwise designated by UFA) and must be guaranteed for 2 years or replaced. The following recommendations and requirements also apply:

- Trees planted in tree boxes or continuous planting strips should be 2 inches in caliper, at a minimum.
- The branching height of a tree on the traffic side of the street must be at least 15 feet above the street.
- The branching height of mature trees on the pedestrian side of the street must be at least 8 feet above the sidewalk.
- Small varieties of thornless and fruitless trees may be used only in median areas or traffic islands where lower branching habits will not interfere with pedestrians, vehicles or driver visibility.

- Small to medium trees must be used where overhead power lines would not allow a large street tree to reach maturity without severe pruning.
- Designers are encouraged to use drought-resistant plantings on all medians or sections of medians over 4 feet wide.

37.5.2. Tree Placement

The designer must consider the mature tree's shape and size to ensure it will have room to grow within the designed space. Where signs, lights, overhead or underground utilities, utility poles and fire hydrants would limit mature tree size, adjustments in species or location should be considered to avoid excessive pruning. The following are suggestions or guidelines in landscape design for trees:

- Plant trees with regular spacing in straight rows to create a continuous street edge. Adjust spacing only slightly for driveways and lights.
- On arterials, the planted trees may be varied for visual appeal.
- Locate trees in a straight line midway between the curb and detached walk, even where the width of the tree lawn varies.
- Tree spacing should be as follows, using the smaller dimension as the preferred option:
    - Where no overhead wires are present, space 30 to 40 feet apart (i.e., for large trees; see Figure 37-1)
    - Where overhead wires are present, space 20 to 25 feet apart (i.e., smaller trees are needed; see Figure 37-2)

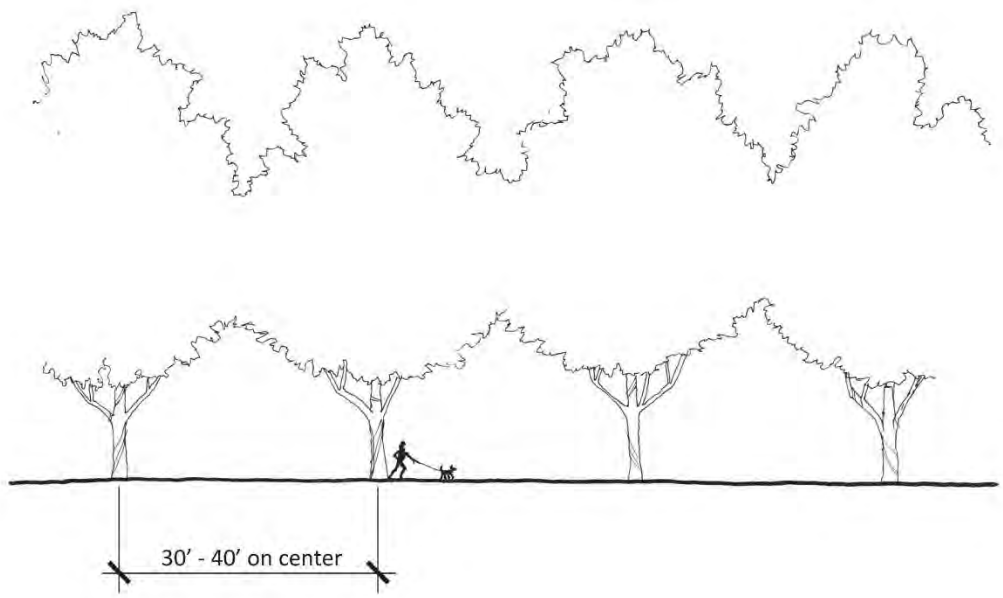


Figure 37-1 | Large Tree Spacing with No Overhead Utilities

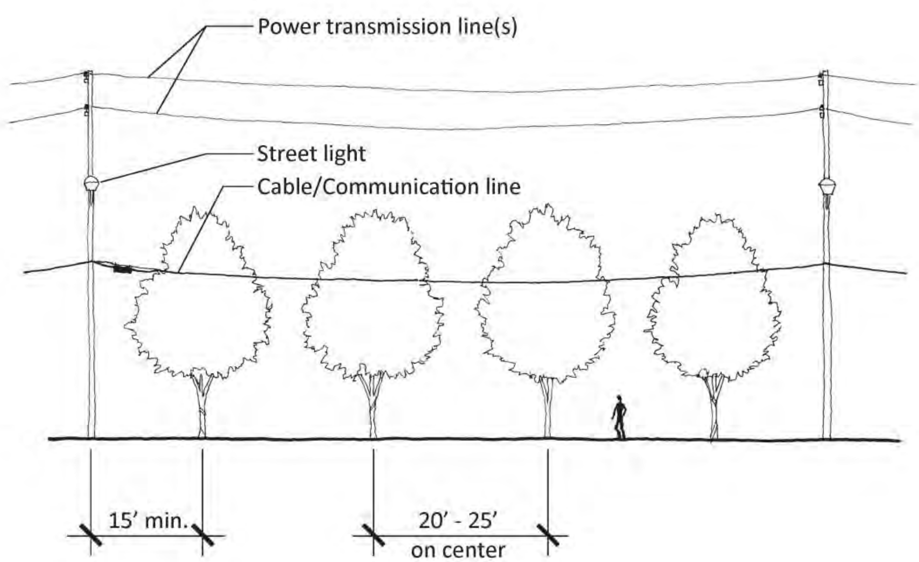


Figure 37-2 | Small Tree Spacing at Overhead Utility Lines

The following are landscape design requirements for tree placement to reduce utility conflicts and sightline interruptions:

- Trees are not to be planted closer than 40 feet from the curb face at intersections and street corners within the site distance triangle.

- Trees are not to be planted within 40 feet of a controlled intersection or other traffic control device (this does not include "No Parking" signs).
- Within the sight distance triangle, non-plant materials and perennials should be no more than 3 feet high, and tree limbs should begin at a height of no less than 8 feet.
- Maintain the minimum sight distance triangle and corner triangle distances for safe view of oncoming traffic and pedestrians as follows:
  - Distance between trees and a driveway or alley: see **Chapter 31, Section 31.5.5**.
  - Trees should be planted a minimum of 15 feet from a light pole, preferably 20 feet.
  - Trees must be planted a minimum of 10 feet from a fire hydrant.
  - Trees should be located in the middle of the planting space.
  - Trees must be placed to ensure drivers can see all regulatory signs.
  - Additionally, tree plantings should be avoided:
    - Directly in front of a lead walk or the steps to a dwelling
    - Where existing public or private tree cover will interfere with a tree's growth
    - In front of forested or open areas where there are no existing dwellings

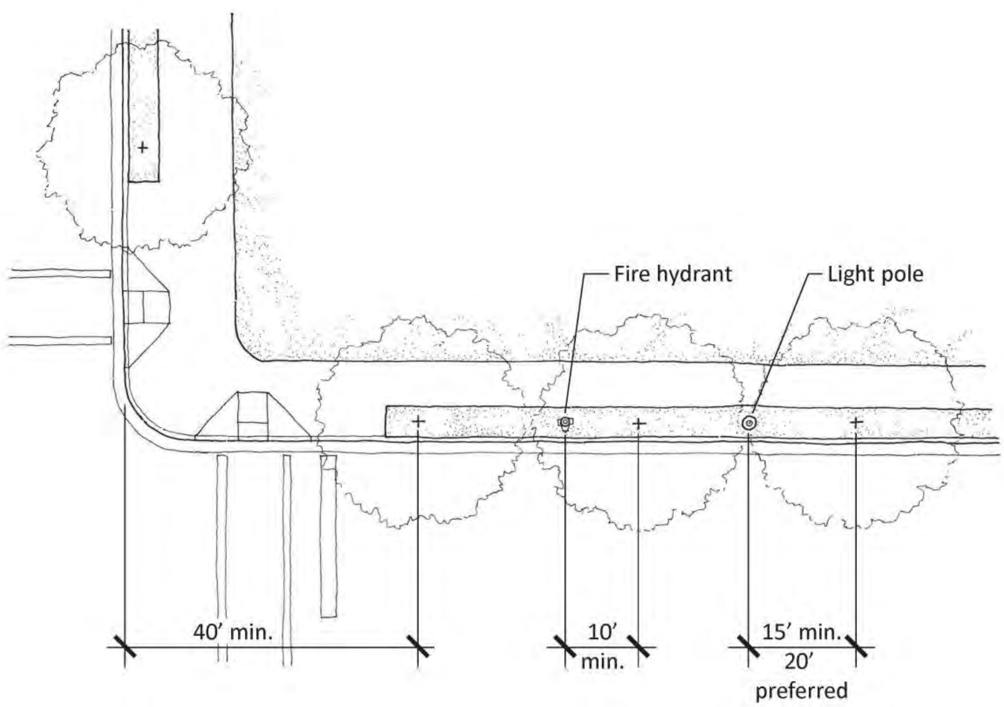


Figure 37-3 | Tree Clearances to Streetscape Elements

37.5.3. Minimum Soil Volumes

For the trees on the DDOT-approved list, the following are the minimum allowable soil volumes for tree rooting:

- Large trees: 1500 cubic feet of soil within a 27-foot radius.
- Medium trees: 1000 cubic feet of soil within a 22-foot radius.
- Small trees: 600 cubic feet of soil within a 16-foot radius.
- Where trees are planted in a continuous, shared soil volume and spaced to allow the maximum radii to overlap, the overall soil volume required can be reduced up to 25 percent.
- For trees designed to have a covered soil volume that connects to an open area (for example behind the sidewalk), the open area can be considered part of the required soil volume.
- For existing trees to remain, the root structure of the existing tree must be protected to the extent feasible and provided with additional soil volumes to meet the above requirements.
- Soil volume is calculated as:
    - (Area of Open Soil x Depth of Soil) + (Area of Covered Soil x Depth of Soil)
    - All soil types are calculated at full volume
    - There may be multiple soil volume areas included in the calculation, depending on design

37.5.3.1. Tree Planting Design in New or Reconstructed Streetscapes

- Maximizing the open soil area for tree planting is the most cost-effective method of achieving the required soil volume.
- Tree boxes on sidewalks that have soil volume beneath the pavement should have a minimum opening of 4 feet wide by 6 feet long. Larger areas may be required to accommodate large root balls or additional plant materials.
- Tree planting space with continuous open areas adjacent to a sidewalk may be one of the following:
    - Turf area between trees, defined as a “lawn strip”
    - Mulched area between trees, defined as a “plant bed”
- The size of the open tree planting area is influenced by the site as follows:
    - For narrow public space areas equaling 10 feet or less, the open tree space will typically be set at the minimum opening, with a goal of providing additional paved surface for pedestrian use.

- For wider public space areas, the open tree space can be continuous, with pedestrian crossings as required in **Section 37.5.3.7**.
- In areas where pedestrian activity is not expected to be significant, it is not necessary to follow the above guidance.

37.5.3.2. Tree Planting Design in Confined Spaces

- Reductions in tree planting space and soil volumes must be justified by physical constraints and approved by DDOT.
- Open tree planting space on existing sidewalk areas that do not have soil volume beneath pavement will be a minimum of 6 feet wide by 9 feet long.
- To the extent feasible, soil rooting volumes should be expanded by creating grass or planted areas adjacent to trees longitudinally, or by placing soils beneath pavements extending along the sidewalk or across the sidewalk.
- Other soil expansion techniques are reducing compaction, air spading around roots and adding planting soil, or other methods as recommended by an arborist or landscape architect.

37.5.3.3. Covered Soil for Meeting Tree Soil Volume Requirements

To provide adequate soil volume for street trees, horticulturally appropriate soils must often be placed beneath adjacent paved surfaces. Acceptable soil systems include suspended pavements, structural cells, and several types of structural soils:

- **Suspended pavements** consist of structural slabs that span structural supports, allowing uncompacted growing soil beneath the sidewalk, and are commercially available. Manufacturer details and certification must be provided for commercial systems. Structural calculations and details must be provided for suspended pavement installations. Soil placed beneath suspended pavements must be a minimum of 30 inches of bioretention soil or per the manufacturer's specifications.
- **Structural cells** are commercially available structural underground systems that support the sidewalk and are filled with soil. Manufacturer details and certification must be provided for commercial systems. Soil in structural cells must be a minimum of 30 inches of bioretention soil or per the manufacturer's specifications.
- **Sand-Based Structural Soil (SBSS)** is a non-propriety soil system that typically consists of a minimum of 6 inches of open graded crushed stone over a minimum of 30 inches of Sand-Based Structural Soil. Aeration of the overlying stone and a source of water are essential components.

- **CU soil** is a patented product and can only be obtained from licensed facilities. CU soil must not be used in conjunction with stormwater infiltration.
- **Stalite structural soil** is a proprietary product consisting of lightweight aggregate with a horticultural application.

37.5.3.4. Tree Space Soil Volume Cross Section

Soil Types

Soil types used in the tree space, in accordance with the DDOT-approved specifications, are generally described as follows:

- **Plant Bed Soil:** Used for the top 12 inches of open planting beds.
- **Lawn Soil:** Used for the top 12 inches in turf or other areas that will experience moderate or heavy foot traffic.
- **Bioretention Soil:** Used in bioretention basins, bioswales and curb extensions, and beneath suspended pavements.
- **SBSS:** Used to support pavements and as horticultural subsoil beneath plant beds and lawn soils.
- **CU Soil:** Used to support pavements and obtained only from licensed CU soil providers.

Soil Profile

- The soil profile of tree space soil volume using SBSS is as follows:
  - For plant beds, 12 inches of plant bed soil over a minimum of 24 inches of SBSS, or a minimum of 36 inches of plant bed soil.
  - For turf infiltration strips, 12 inches of lawn soil over a minimum of 24 inches of SBSS, or a minimum of 36 inches of lawn soil.
  - For covered soil volume, a minimum of 12 inches of plant bed soil over 24 inches of SBSS at open tree areas. In covered areas, 30 inches of SBSS with 6 inches of washed open graded aggregate between SBSS and covered surface.
- Prior to placing the bottom layer of the soil profile, the sub-soil should be loosened by tilling, ripping, trenching or a similar means to maximize infiltration.
- See **Section 37.5.3.6** for sand and underdrain requirements underneath structural soil.

37.5.3.5. Stormwater Retention and Treatment Volume

Tree space with expanded soil volume can capture and retain the required 1.2 inches of stormwater in accordance with Department of Energy & Environment (DOEE) requirements. These facilities can be designed to meet the requirements of DOEE's bioretention type "Engineered Tree Box" when surface ponding volume is provided, whether designed as an enclosed plant bed with covered soil volume or as a continuous open area (either mulched or with turf) with soil volume under the adjacent sidewalk. The tree space can function as "Disconnected Impervious Surface" per the **DOEE Stormwater Guidebook** to capture runoff from the sidewalk.

37.5.3.6. Stormwater Conveyance for Irrigation of Soil

- Soils beneath pavements should receive water flow from no less than 0.5 times, and no more than 4.0 times, the open surface area.
- For tree rooting soils beneath pavements, the optimum strategy for providing an even distribution of stormwater for irrigation and infiltration purposes is the use of permeable pavements.
- Where feasible, permeable pavements should be used over suspended pavement, structural cell or structural soil installations. Approved geogrids should be placed beneath non-interlocking permeable pavements.
- Where permeable pavements are not used, linear drains with grates discharging directly to structural soil spaced at 6-foot intervals, or small watersheds draining to catch basins with distribution perforated pipes to the soils, should be provided.
- Where the covered soil volume includes impervious cover of not more than 6 feet in width, the use of linear drains or catch basins is optional.
- An aeration layer should be created over all suspended pavement soil, structural cell soil or structural soils by using 6-inch minimum depth of uniformly graded crushed stone materials, such as #8 or #57 stone.

- For subsurface drainage, Natural Resources Conservation Service (NRCS) soil mapping hydrologic units may be used to estimate subsoil infiltration rates, or soils may be tested directly by measuring in-place infiltration rates. Where infiltration rates are measured directly, tests must be at a frequency of not less than one test per 1000 square feet. DDOT may require additional testing where variable soil conditions are anticipated. Table 37-1 summarizes infiltration rates by NRCS Soil Group and subsurface requirements.

Table 37-1 | Soil Infiltration

Infiltration Rate	NRCS Soil Group	Subsurface Requirement
≥ 0.5 in./hr	A or B	None
Between 0.14 and 0.5 in./hr	C	12” of sand beneath street tree soil volume
< 0.14 in./hr	D	12” of sand with 4” perforated underdrain (with geotextile surround) beneath street tree soil volume connected to the storm drainage system

37.5.3.7. Access and Safety Barriers

- Pedestrian crossings of continuous open planting strips adjacent to curbs are required as follows:
  - 6-foot paved area between each tree in high-volume pedestrian areas
  - Alternating every other tree in other areas, with surface material appropriate to surrounding area (paved, grass, mulch)
- Parking egress strips between 12 and 36 inches wide (measured from face of curb) may be provided adjacent to curbs in metered/paid street parking zones where total public space width is at least 12 feet between face of curb and back of sidewalk, using the remaining space available after deducting the required walkway width and minimum open tree space dimension requirements.
- Ornamental fencing meeting DDOT requirements may be required around open tree planting space to protect soil from pedestrian foot traffic.
- Bike racks may be combined with ornamental fencing around open tree planting space. Type of rack will be selected in coordination with the DDOT Project Manager.

37.5.3.8. Structural Support

All structural elements, including pavements and curbs, must be founded over structurally stable soils. Stable soils should extend laterally from the point of support at a slope of 1 horizontal to 2 vertical in the downward direction. Plant bed, lawn and bioretention soils are not structurally stable. SBSS and CU Soil are considered structurally stable.

37.6. Freeways and Interstate Highways

37.6.1. Landscape Treatment

The extent of landscape treatment will vary according to the amount of landscape manipulation and area visibility. The most visible areas must receive the most attention. To achieve the necessary blending, concentrate the landscape effort near the base of the fill and the top of the cut lines. When planting larger trees, specify that they be placed near the top of the cut slopes or on the toe of the fill. Keep them beyond the clear zone and, if required, beyond the snow storage area in snow plowing areas.

On the higher-speed roadways, planting groups of at least two or three tree species can be adequate treatment. More species diversity along with appropriate perennial plantings is preferred in urban planting situations.

Open areas adjacent to highways may contain vegetated stormwater retention systems designed and constructed in accordance with **DDOT's Green Infrastructure Standards**, the design procedure in **Chapter 28** of this manual and the planting guidelines in this chapter.

37.6.2. Earthwork

Design cut-and-fill slopes not only to satisfy slope stability and balance material quantities, but also to improve the appearance of the final project. Use variable slope ratios for both cut and fill slopes. Avoid using constant slope ratios. The use of slope rounding at the top of cuts is commonplace. Round the ends of cuts, and blend the ends of fill slopes into cut slopes.

When practical, include in the design slope molding techniques to imitate existing landscape context. Slope molding goes beyond variable slope and rounding concepts. With slope molding, a deliberate attempt is made to break up the uniformity of a finished slope. On long-cut slope faces, form the land to create artificial valleys and ridges to avoid a uniform slope. Warp slopes around boulders and rock outcrops.

In areas of natural valleys or swales, lay back or flatten the cut slope to match that of the natural form. This only generates a small amount of additional material and greatly enhances the appearance of the cut slope. This material can be used to flatten fill slopes or mold then into natural land forms common to the project area.

37.6.3. Vegetation Clearing

The emphasis should be to promote scenic views and enhance the natural beauty of any project. There should be a balance of vegetation patterns above and below the highway slope.

37.6.4. Revegetation

Revegetated slopes are not only pleasing to view but, also stabilize the slope and require little or no maintenance. Re-established vegetation is also important as cover and food for wildlife.

Select grass seed that is native to or adaptable to the area. The seed mixture must satisfy criteria for elevation and slope exposure changes. Several seed mixtures may be required to satisfy all conditions on a relatively long or elevated (side slope, hillside) project area. Use soil mulches and netting to stabilize and protect the ground until grass is established.

Where practical, conserve topsoil from the project limits and replace it on the finished slopes. Topsoil not only provides needed fertility and a growing medium for grasses, it also contains an abundance of native seeds. These forbs, weeds, and grasses usually grow fast and densely, and will blend in with the undisturbed vegetation that effectively brings the background vegetation onto the cut slope.

Shrubs and trees can be planted to beautify the disturbed roadside areas and blend them into the undisturbed areas. Using hydrophilic shrubs, such as willow and birch, grouped in areas of excess soil moisture, will aid in stabilizing the area. Locate all plant groupings where they will be most visible to motorists.

It is Federal Highway Administration policy that at least 1/4 of 1 percent of funds expended for landscape projects be used to plant native wildflowers, except in ornamental landscapes, or unless a waiver is granted by the District. Waivers must be documented with adequate justification in support of all findings and conclusions. An ornamental landscape is one that is irrigated and has barked shrub beds and routinely mowed grass.

Requests for waivers can be granted only for the following conditions:

- Wildflowers cannot be satisfactorily grown
- The available ROW is to be used for agricultural purposes
- There are no suitable planting areas
- The planting poses a threat to endangered or rare plant species

Erosion control seeding is not a landscape item, although wildflower seeding associated with the erosion control seeding mix can satisfy wildflower-seeding requirements in a landscape project. For wildflowers to perpetuate themselves, they must be permitted to go to seed and become dormant. Identify on the plans all areas to be seeded with wildflowers. Provide in the contract a requirement to install suitable markers to identify the wildflower seedbeds for roadside management and maintenance personnel and to prevent inappropriate mowing.

38 Requirements for Traffic Impact Analysis

DDOT requires all projects that are expected to modify roadway capacity to undergo a Traffic Impact Analysis (TIA). This applies to any project that may generate a transportation-related impact, including streetscape projects, roadway diets, new roadway construction and other proposed roadway design or operational changes. A TIA will include the analyses described in this chapter.

For development projects, the TIA functions as a portion of the greater Comprehensive Transportation Review (CTR). Based on the size and zoning action of the proposed development, the Applicant may be required to complete a CTR without a TIA component. Designers should refer to the latest version of the **DDOT Guidelines for Comprehensive Transportation Review (CTR) Requirements**, which outlines the elements required for a CTR.

38.1. Purpose of a Traffic Impact Analysis

The primary purposes of a TIA are to evaluate the impacts of a roadway project or proposed development on the transportation network and to assess the efficacy of a proposed transportation improvement.

For roadway projects, the TIA helps inform the design of the project, assesses the potential impacts of the project on roadway users, and determines if improvements are required to mitigate the potential impacts of the project. For development projects, the TIA assists in DDOT's decision-making process on whether to support a proposed development project and helps determine what mitigation measures may be required to accommodate the additional traffic generated by the development.

For the purpose of these guidelines, the "Applicant" is defined as the designated agent responsible for preparing the TIA.

38.2. When Is a Traffic Impact Analysis Required?

For roadway projects, a TIA is required when any of the following are proposed:

- Reduction or addition of travel lanes;
- Change in street directionality or one-/two-way operation;
- Installation of or modification to an existing traffic control device;
- Geometric modifications to an intersection; or
- As deemed necessary by DDOT.

The requirement to prepare a TIA for development projects may be waived if all of the following conditions are met:

- Daily trip generation for the proposed development will be less than 300 vehicles;
- Peak hour trip generation will be less than 25 vehicles in the peak direction; and
- No more than 250 vehicles per day are projected to access an existing collector or local road.

A waiver from the TIA requirement must be submitted in writing to DDOT, and the Applicant must show that the above conditions are met. A waiver from the requirement must be obtained in writing from DDOT; a verbal authorization is not acceptable. Of note, a waiver from the TIA requirement does not waive the requirement to complete a CTR. Refer to the latest version of the **DDOT Guidelines for Comprehensive Transportation Review**, which outlines CTR thresholds.

When an Applicant proposes to amend or update a previously completed and approved TIA, a new TIA is required if any of the following conditions are met:

- The original TIA was prepared for a phased project and needs to be updated for subsequent phases; or
- The data used in the original TIA is more than 2 years old.

The following sections outline the scope and requirements for a TIA.

38.3. Traffic Impact Analysis Scope

This section defines the scope of the TIA. For a roadway project, this scope should be confirmed with the DDOT Transportation Operations Administration before conducting the study. For development projects, the scope of the TIA will be determined during the scoping process for the CTR; see the latest version of the **DDOT Guidelines for Comprehensive Transportation Review** for details.

38.3.1. Planning Horizons

To assess the impacts of the proposed project, the TIA must present an analysis with and without the proposed project at short-term and long-term horizon years. The intent of the short-term planning horizon is to investigate the immediate impact of the proposed project on the roadway network. The intent of the long-term planning horizon is to evaluate the impacts of the proposed project on the long-range transportation conditions.

For roadway projects, the short-term horizon is typically based on the existing conditions. For large infrastructure projects or phased projects, the number of years in the short-term horizon is based on the construction timeline for the project. The long-term horizon is based on a 20-year planning horizon.

For development projects, the short-term horizon is typically defined as the full build-out and occupancy of the project. The long-term horizon is based on a 20-year planning horizon. The short- and long-term horizons for development projects are to be approved by DDOT during the CTR scoping process.

The baseline surface transportation network (without the proposed project improvements) assumed for the short-term planning horizon should reflect existing facilities plus any firmly committed improvements by the District and other development projects in the study area. All planned surface transportation facilities in the study area must be included in the baseline assumptions for the long-term planning horizon analysis.

38.3.2. Study Area Selection

The TIA study area must be defined to include all portions of the transportation network that may be affected by the proposed project.

At a minimum, the study area for roadway projects must include the following:

- All major signalized and unsignalized intersections located within the project boundaries
- The nearest signalized and unsignalized intersections of the project roadway with major streets, including arterials and collector roadways
- Any signalized intersections along the project roadway at a minor street that are between the project boundary and the nearest intersection with a major street where the signals are synchronized
- Signalized intersections along adjacent arterials and major collector roadways that are expected to realize large numbers of new through trips or a moderate number of turning movements due to the proposed project
- Adjacent intersections where traffic resulting from the proposed project may necessitate a change in traffic control

For development projects, see the latest version of the **DDOT Guidelines for Comprehensive Transportation Review**, which outlines the requirements for each study area by mode. Study areas may differ by mode (vehicular, transit, bicycle, and pedestrian), and must be approved by DDOT during the CTR scoping process.

38.3.3. Selection of Analysis Periods

The critical time periods for analysis are typically the weekday morning and afternoon peak hours of the transportation system, when commuter volumes on District roadways are heaviest; these are the most likely times traffic will be affected by a proposed roadway or development project. In general, the weekday morning peak period occurs between 7:00 AM and 9:00 AM, and the weekday afternoon peak period occurs between 4:00 PM and 6:00 PM, although local area characteristics may result in slightly different weekday peak periods.

At a minimum, the TIA must include an analysis during the weekday morning and afternoon peak hours. However, additional analysis periods may be required by DDOT based on the project location. This includes weekend peak periods for developments with significant retail uses, Sunday peak periods for projects including or adjacent to church uses, and weekday evening game-day peak periods for projects adjacent to major sporting facilities, such as Nationals Park.

For development projects, see the latest version of the **DDOT Guidelines for Comprehensive Transportation Review**, which outlines the requirements for analysis periods. The periods of analysis must be approved by DDOT during the CTR scoping process.

38.3.4. Project-Generated Traffic

For roadway projects, the traffic generated by the project is typically normal traffic volumes rerouted by the proposed project. For projects consisting of a reduction or addition of travel lanes, the installation or modification of an existing traffic control device, or geometric modifications to an intersection, traffic would be rerouted due to changes in capacity and drivers adjusting their travel routes accordingly. For changes in street directionality or one-/two-way operation, traffic would be rerouted due to changes in vehicular circulation.

For development projects, potential impacts are forecast for the planning horizons as outlined in **Section 38.3.1**. The steps in this process include trip generation, modal choice, trip distribution, and traffic assignment. See the latest version of the **DDOT Guidelines for Comprehensive Transportation Review** for details.

38.3.5. Methods of Evaluation

Several Methods of Evaluation (MOEs) are available to assess the project impacts on the surrounding roadway network. These include:

5. Peak hour level of service (LOS) for intersections
6. Average and 95th percentile queue lengths at intersections during the peak hour
7. Merge/diverge/weave analysis
8. Peak hour volume-to-capacity (v/c) ratio
9. Roadway threshold capacity
10. Person throughput on a corridor

At a minimum, the TIA must include an evaluation of the LOS for the peak hours selected for analysis. The average and 95th percentile queue lengths are likely to be requested for inclusion in the TIA. For study areas that include ramp segments, a merge/diverge/weave analysis must be performed. The remaining MOEs, as well as others not included in this list, may be requested at DDOT's discretion. The requirements for these evaluations are outlined below.

38.3.5.1. Peak Hour Level of Service

The principal objective of the LOS analysis is to identify the impact of the project on the capacity of the study area intersections based on the procedures outlined in the most recent edition of the Transportation Research Board **Highway Capacity Manual (HCM)** or other DDOT-approved method.

The HCM defines LOS as a function of the average vehicle control delay, and classifies them as Levels A through F, with A having the least delay. The average vehicle delay can be calculated per movement or per approach for any intersection configuration. An average intersection vehicle delay can also be calculated for signalized and all-way-stop intersections.

An LOS grade is assigned to each vehicle delay value based on the durations in Table 38-1.

Table 38-1 | LOS Based on Delay at Intersections

LOS	Signalized Intersection	Unsignalized Intersection
A	≤ 10 sec	≤ 10 sec
B	> 10-20 sec	> 10-15 sec
C	> 20-35 sec	> 15-25 sec
D	> 35-55 sec	> 25-35 sec
E	> 55-80 sec	> 35-50 sec
F	> 80 sec	> 50 sec

An intersection LOS analysis (reported by approach and intersection average, when available) must be conducted for each intersection in the study area. The impact of the project on the intersection LOS is assessed by comparing the LOS results for each peak period with and without the proposed project during the short- and long-term planning horizons.

Mitigation measures must be recommended if the proposed project results in a significant impact on intersections in the study area. A significant impact is defined as:

- When the proposed project causes any one or more intersection approaches to exceed the established LOS threshold. This threshold will be set for each project and will be defined as LOS “E” or “F” as requested by DDOT; or
- When the proposed project causes any one or more intersection approaches with an existing LOS “E” or “F” to experience an increase in vehicle delay of 5 percent or more.

38.3.5.2. Average and 95th Percentile Queue Lengths

The average and 95th percentile queue lengths are critical factors in determining the length of turn lanes, the location of driveways and curb cuts, the spacing and timing of signalized intersections, and other traffic engineering tasks.

At a signalized intersection, the average and 95th percentile queues are estimated for the duration of the red signal. The queue lengths are based on the number of vehicles that do not clear the intersection during a given green phase. Queue lengths at signalized intersections are defined as the distance between the intersection signal and the last car in the queue.

At unsignalized intersections, the 95th percentile queues can be estimated at two-way stop controlled intersections only. The queue length is based on the number of vehicles waiting to proceed across an approach controlled by a stop sign or waiting to turn across a free-flowing approach.

Queue lengths must be calculated using the procedures outlined in the most recent edition of the HCM or other DDOT-approved method. For projects along major arterials or in congested areas, micro-simulation using SimTraffic, VISSIM, or other approved software may be requested by DDOT.

Queue length analyses (reported by lane group) are highly desired and may be required for each signalized and unsignalized intersection in the study area. The impact of the project on the queue lengths is assessed by comparing the queue results for each peak period with and without the proposed project during the short- and long-term planning horizons.

Mitigation measures must be recommended if the proposed project results in a significant impact on study area intersections. A significant impact is defined as:

- When the proposed project causes the queue length to exceed the available capacity of an approach or turn lane; or
- When the proposed project causes any 95th percentile queue lengths that exceed the available capacity in the short- or long-term planning horizon to experience an increase in queue of 150 feet or more.

38.3.5.3. Merge/Diverge/Weave Analysis

When the study area for the TIA includes uninterrupted-flow roadways, roadways that have no fixed causes of delay or interruptions external to the traffic stream, a merge, diverge, and weave analysis must be performed based on the procedures outlined in the most recent edition of the HCM or other DDOT-approved method.

Traffic enters and exits an uninterrupted-flow roadway via ramps. Merge segments focus on locations where two or more traffic streams combine to form a single traffic stream; diverge segments are where a single traffic stream divides to form two or more separate traffic streams. Where merge and diverge segments are closely spaced and the traffic streams to and from the ramps must cross each other, a weave segment exists.

The HCM defines LOS for uninterrupted-flow roadways as a function of the density in the segment. For uninterrupted-flow roadways, the boundary between stable and unstable flow (LOS “E” and “F”) occurs when the demand flow rate exceeds the capacity of the segment.

An LOS grade is assigned to each merge/diverge segment based on the traffic densities shown in Table 38-2.

Table 38-2 | LOS for Merge/Diverge Segments

LOS	Density (passenger cars per mile per lane)	Comments
A	≤ 10	Unrestricted operations
B	> 10 to 20	Merging and diverging maneuvers noticeable to drivers
C	> 20 to 28	Influence area speeds begin to decline
D	> 28 to 35	Influence area turbulence becomes intrusive
E	> 35	Turbulence felt by virtually all drivers
F	Demand exceeds capacity	Ramp and roadway queues form

An LOS grade is assigned to each weave segment based on the values shown in Table 38-3 below.

Table 38-3 | LOS for Weave Segments

LOS	Density (passenger cars per mile per lane)	
	Freeway Weave Segments	**Weave Segments on Multilane Highways or Roadways**
A	0 to 10	0 to 12
B	> 10 to 20	> 12 to 24
C	> 20 to 28	> 24 to 32
D	> 28 to 35	> 32 to 36
E	> 35	> 36
F	Demand exceeds capacity	

A merge/diverge/weave LOS analysis must be conducted for each ramp segment in the study area. The impact of the project on the segment LOS is assessed by comparing the LOS results for each peak period with and without the proposed project during the short- and long-term planning horizons.

Mitigation measures must be recommended if the proposed project results in a significant impact to study area ramp segments. A significant impact is defined as:

- When the proposed project causes any one or more intersection approaches to exceed the established LOS threshold. This threshold will be set for each project and will be defined as LOS “E” or “F” as requested by DDOT; or
- When the proposed project causes any one or more intersection approaches with an existing LOS “E” or “F” to experience an increase in vehicle density of 5 percent or more.

38.3.5.4. Peak Hour Volume-to-Capacity Ratio

The v/c ratio reflects how closely a roadway is operating to its capacity. Sustainable values of v/c range from 1.0 when the flow rate equals the capacity to 0.0 when the flow rate is zero. By definition, the volume of traffic using a roadway cannot exceed the roadway’s capacity. Therefore, a v/c value of over 1.00 indicates that vehicle demand exceeds capacity, which results in unstable traffic flow and may cause excessive delay and queuing.

At signalized and unsignalized intersections, v/c ratios are calculated for each lane group or movement. Analysis of v/c ratios may be requested at study area intersections, as delay (and the resulting LOS values) may be low while the v/c ratio is high. Acceptable delay and LOS values do not automatically ensure that capacity is sufficient.

On an uninterrupted flow facility (freeway, multi-lane highway, etc.), the v/c ratio is a function of the weaving type, number of lanes, free-flow speed, length and weaving ratio.

Analysis of the v/c ratio (reported by lane group) may be requested for either intersections or roadway segments in the study area. The impact of the project on the v/c ratio is assessed by comparing the v/c results for each peak period with and without the proposed project during the short- and long-term planning horizons.

Mitigation measures must be recommended if the proposed project results in a significant impact to study area intersections or segments. A significant impact is defined as:

- When the proposed project causes the v/c ratio to increase above 1.0; or
- When the proposed project causes any existing v/c ratios to increase by 5 percent or more.

38.3.5.5. Roadway Threshold Capacity

In the District, threshold capacities are defined for roadways based on the functional classification of the roadway, as determined by the most recent version of the **DDOT Functional Classification Map**. The roadway functional classification is assigned based on criteria published by the United States Department of Transportation Federal Highway Administration, and helps determine how the roadway system is configured, used and planned.

Table 38-4 shows the threshold capacity for average daily traffic by roadway type for planning purposes.

Table 38-4 | Threshold Capacities by Road Type

Facility Type	Number of Lanes	Threshold Capacity
Local Street (Residential)	2	1500
Local Street (Non-Residential)	2	2500
Collector	2	10,000
Collector	4	20,000
Minor Arterial	4	20,000
Major Arterial	4	30,000
Major Arterial	6	45,000

The impact of the proposed project on the threshold capacity is determined by comparing the projected future average daily traffic volumes with and without the proposed project during the short- and long-term planning horizons. Mitigation measures or reclassification of a roadway must be recommended if the proposed project results in the average daily traffic exceeding the established threshold.

38.3.5.6. Person Throughput on Corridor

Person throughput on a corridor is a measure of the relative productivity of a roadway system. The throughput is the number of persons processed through the system during the analysis period and indicates how well the system is doing at moving people.

Person throughput is defined as the number of people (by vehicle or by transit) entering and exiting the system during a specified analysis period. The throughput is divided into five categories according to whether or not the vehicle entered, exited, never entered, or never exited the system during the analysis period:

1. Number of persons present at the start of the analysis period who were able to successfully exit the system before the end of the analysis period
2. Number of persons not present at the start of the analysis period who were unable to successfully exit the system before the end of the analysis period (this class is usually zero except for cases of severe congestion)
3. Number of persons able to enter the system during the analysis period but unable to successfully exit the system before the end of the analysis period
4. Number of persons who tried to enter the system during the analysis period but were unsuccessful (this class is usually zero except for cases of extreme congestion)
5. Number of persons who entered the system during the analysis period and were able to successfully exit the system before the end of the analysis period

The percent of incomplete trips is equal to the sum of vehicle classes 1, 2, 3, and 4, divided by the sum of all vehicle classes. Higher throughputs and lower percentages of incomplete trips are desired, since that means the transportation system is productive.

If person throughput is used as an MOE for a proposed project, the system of roadways in the study area must be evaluated. The impact of the proposed project is determined by comparing the projected future percent of incomplete trips with and without the proposed project during the short- and long-term planning horizons. Mitigation measures must be recommended if the proposed project results in the percent of incomplete trips through the system greater than 5 percent.

38.3.6. Mitigation Measures and Recommendations

This section describes the location, nature and extent of all transportation improvements that the Applicant recommends to yield to reasonable operating conditions in each horizon year with the land use action approved as requested. For this discussion, the following terms apply:

1. Planned: Improvements that have committed funding, including those identified by the District in short-term capital improvement programs
2. Background committed: Improvements committed to by previously approved developments in the study area
3. Project-generated: Improvements required to mitigate impacts of the proposed project and to mitigate traffic to established LOS

The reason that “necessary” improvements must be explored is that often the “background committed” or “planned” improvements, and the improvements that the Applicant typically commits to, are not adequate to provide the established LOS, and the Applicant is required to identify mitigation actions to achieve established LOS. The Applicant should ensure that all practical solutions have been considered when developing the list of “necessary” improvements, so that the resulting operating conditions approach the established LOS.

To identify improvements (to be implemented by either the Applicant or the District) that may yield an acceptable LOS, the cost of the improvements are considered a limiting constraint in the context of the TIA. However, the goal of the evaluation is to identify cost-effective solutions that yield a reasonable LOS. Extremely high-cost solutions may not be cost-effective, but it is important to identify solutions so that decision-makers are cognizant of options.

The Applicant should complete a “Recommended Improvements Summary Sheet” to present the recommendations. One sheet may be used for both design years if all the improvements can be conveniently described thereon. If not, one or more sheets should be completed for each design year.

All recommended improvements should be identified on the summary sheet, including “planned,” “background committed,” “applicant committed” and “necessary.” Each project should be briefly described as to its location, the type of project, flow line and right-of-way (ROW) needs (for roadways), signal or turn lane improvements (for intersections) and, at a sketch planning level, cost of the improvement. In addition, commitment to the improvement must be identified by either the District or the Applicant (this may include both the “background committed” and “necessary” projects). Identification of a project as “not currently committed” may be an appropriate description for many needed projects, including some that are “planned.” However, the goal of the recommendations should be to identify a program of improvements that will support the proposed land use and associated traffic in each design year.

It is further required that all geometric improvements such as pavement markings, signs, adding through or turn lanes, adding project access and assorted turn lanes, acceleration lanes, and changes in medians, be presented in scaled drawings, preferably on a current aerial map. Sufficient dimensions must be identified to facilitate review. ROW needs must also be identified on the plan.

38.3.7. Safety

38.3.7.1. Crash Data Analysis

An analysis of existing crash data is required to evaluate the study area, determine if the proposed project creates or exacerbates safety issues, and develop countermeasures. Three years of crash data must be obtained from DDOT for analysis at the study area intersections.

The crash data analysis should consider the following items:

- Total number of crashes
- Number of crashes by type or causation factor
- Type of vehicle involved
- Pedestrian involvement
- Bicyclist involvement
- Accident severity
- Type of traffic control present
- Roadway or intersection geometry
- Cause of crash
- Time of crash
- Environmental conditions

The crash data analysis must also include a collision diagram when requested by DDOT. Crash data analysis must be performed in accordance with the latest edition of the **Manual of Transportation Engineering Studies**, published by the Institute of Transportation Engineers.

38.3.7.2. Sight Distance Analysis

Sight distance analysis at intersections is typically used to determine if an adequate field of vision is provided to ensure driver can make visual contact with conflicting vehicles, pedestrians, and bicyclists. For proposed projects that will result in changes to public space, the TIA must include a sight distance analysis (at intersections or driveways) conforming to the requirements outlined in **Chapter 30** of this manual. Additionally, the TIA must show how potential conflicts between roadway users will be minimized.

38.3.7.3. School Route Plan

When requested by DDOT, a school route plan must be developed. This plan is a drawing showing the recommended travel paths of school children between their home and school. This plan should be developed by the school. The plan must consist of a map showing the streets, the school, existing traffic controls and intersections with sufficient gaps in the traffic to allow safe crossing by students. The plan may identify a longer route in order to avoid potentially hazardous crossings. The plan must conform to the standards outlined in the latest edition of the **Manual on Uniform Traffic Control Devices (MUTCD)** and be coordinated with the DDOT Safe Routes to School program.

38.3.8. Special Analysis/Issues

In addition to the six MOEs for TIA, DDOT may request focused traffic analysis relevant to the proposed roadway project or development. This could include the following types of vehicular studies:

1. Gap study
2. Spot speed
3. Travel time and delay
4. Parking
5. Geometric review
6. Traffic control device study
7. Cut-through
8. Alternate routes

DDOT may also request detailed pedestrian, bicycle and transit analysis. This analysis could include quality of service analysis, as well as capacity analysis. For development projects, see the latest version of the **DDOT Guidelines for Comprehensive Transportation Review** for details.

38.3.8.1. Gap Study

A gap study is the review of the time intervals between successive vehicles as they pass a point on a roadway segment. These intervals, called gaps, are used to determine if their frequency and duration are sufficient to permit the safe crossing of vehicles and pedestrians, as well as the merging of vehicles in traffic. Particular attention should be given to children and elderly pedestrians, who have slower than average walking speeds.

Gap studies must be performed in accordance with the latest edition of the **Manual of Transportation Engineering Studies**, published by the Institute of Transportation Engineers.

38.3.8.2. Spot Speed Study

Spot speed studies are typically used to identify and evaluate safety and setting speed limits on roadways. Spot speed studies involve measuring the instantaneous travel speed of vehicles at a specific location by using electronic devices, such as radar, or by calculating the average speed over a relatively short section of roadway.

The following guidelines should be followed for taking spot speed samples:

- Observations should be made at about half-mile intervals or at locations where traffic or roadway features change.
- Observation sites should be located on tangent or mid-block sections of roadways so that the speed distribution is not influenced by stop signs, traffic signals, curves and other traffic flow interruptions.
- Samples should normally consist of at least 100 observations, although 50 observations is acceptable on low-volume roadways. Samples should be composed of randomly selected vehicles to ensure a reliable speed distribution. The percentage of trucks in the sample should be approximately the same as the percentage of trucks in the traffic stream.

The average speed and 85th percentile speed will be determined from the adequate size sample of spot speeds, in accordance with the latest edition of the **Manual of Transportation Engineering Studies**, published by the Institute of Transportation Engineers.

38.3.8.3. Travel Time and Delay Study

Travel time studies are typically used in LOS analyses, traffic assignment and cost/benefit calculations, and are often used as inputs to air-quality modeling analyses. Travel time varies inversely with travel speed and is a good indicator of the average speed and level of service being provided on a given route. The difference between travel times over a route during low traffic volumes and during high traffic volumes is the operational delay. This delay consists of such items as time spent at a stop sign waiting for cross traffic to clear; time spent at an uncontrolled intersection awaiting the ROW; and time losses resulting from congestion, interference with parked vehicles, parking maneuvers, and waiting for turning traffic.

Delay is the time consumed when the traffic is stopped or greatly impeded, and is usually expressed in seconds per vehicle. Delay may be either fixed delay, which is normally experienced by vehicles during low traffic volumes at stop signs or traffic signals, or operational delay, which is caused by the interference of other traffic.

Travel time data should be collected in the field using the moving vehicle method, as described in the latest edition of the **Manual of Transportation Engineering Studies**, published by the Institute of Transportation Engineers.

38.3.8.4. Parking Study

Parking studies are used to manage on- and off-street parking spaces and lots, and are essential to effective parking management. Parking studies provide data on:

- Accumulation – the number of vehicles parked in a location over time
- Occupancy – the percentage of spaces used in a location at a point in time
- Generation – the average or peak number of parked vehicles associated with a specific land use or zone
- Duration – the average length of stay of a parked car in a space
- Turnover – the number of different cars that park in a particular space during a time period of interest

The two most-common techniques used to collect parking data are counting vehicles driving in and out of parking facilities and surveying the parking facility space occupancies at different times of day.

38.3.8.5. Geometric Review

The following items should be considered in a geometric review for roadway projects:

- Intersection alignment – A review of the physical design and configuration of the intersection must consider at least:
    - The number of approaches
    - The presence of horizontal and vertical curves on approaches that limit sight distance and may necessitate additional traffic control such as a reduced speed limit or a multi-way stop
    - The presence of skewed intersections that create blind spots for approaching motorists
    - The capability of existing channelization to accommodate the various kinds and classes of traffic
    - The presence of approach grades in excess of 3 percent that may necessitate abnormal stopping distance and time required for crossing vehicles to clear the intersection

- Number and spacing of intersections – A physical count of the total number of intersections and driveways along the study section of roadway and their use.
- Railroad grade crossings – A review of railroad grade crossings must consider at least:

- The adequacy of the intersection sight distance for drivers at an unsignalized railroad grade crossing. Drivers must be able to see approaching trains so they can stop their vehicle in advance of the crossing.
- The presence of a train preemption phase at signalized roadway intersections that would allow vehicles within 200 feet to cross the tracks safely. The preemption system must prevent unnecessary queuing of roadway traffic and clear the railroad grade crossing when a train is approaching.

- Roadway cross section – A review of the roadway's crown and superelevation and the presence or absence of shoulders, shoulder drop-offs and sidewalks. Determine whether the existing cross section meets the standards presented in **Chapter 30** of this manual.
- Roadway surface features – A qualitative review of the roadway riding surface to consider holes, dips, bumps, rutting and other factors.
- Roadway width – A transverse measurement of the roadway between the curbs or the two edges of the roadway, exclusive of shoulders and sidewalks, but including parking lanes and parking maneuver areas.
- Roadway horizontal and vertical alignment – A review of the roadway's grades, length of vertical curves, the degree of curvature of horizontal curves, and turning radius at intersections. Determine whether large vehicles can make safe turns.
- Safety improvements – Evaluate the need for safety improvements beyond the curbs and edges of roadways. Consideration should be given to sidewalks, shoulder guiderails, pavement markings and signage.

38.3.8.6. Traffic Control Device Study

Traffic control devices are studied for a wide range of reasons. Typically studies are conducted to:

- Support warrants for the installation or removal of traffic control devices
- Determine the effectiveness of existing traffic control devices
- Assess the conditions of traffic control devices
- Assess ongoing maintenance and improvement programs

Traffic control device studies will be requested by DDOT for inclusion in a TIA, most commonly, when a proposed project recommends the installation of a traffic signal or other change in traffic control at an intersection. The traffic control device study in these cases must include an overview of the existing and future conditions at the intersection, as well as a warrant analysis. The warrant analysis must be conducted in accordance with the latest edition of the **MUTCD**.

38.3.8.7. Cut-Through Study

Cut-through studies are used to determine the number of vehicles traveling through a defined zone without ending their trip. The most common type of data collection is a license plate study. Cut-through studies should be performed in accordance with the latest edition of the **Manual of Transportation Engineering Studies**, published by the Institute of Transportation Engineers.

38.3.8.8. Alternate Route Evaluation

The evaluation of alternative routes is requested to determine their capability to handle additional vehicular traffic detoured or diverted due to a proposed project. This review should consider the following:

- The structural capability to support the load from the kinds and classes of traffic to be detoured.
- The capability to safely accommodate the additional traffic volumes at a reasonable level of service and provide access to intermediate points of interest without an excessive increase in distance.
- Restrictions along the alternate route that would create problems for certain kinds or classes of vehicles. For example, steep grades, sharp curves, signalized intersection already operating at maximum capacity, substandard intersection geometrics that would restrict turning movements of certain kinds and classes of vehicles, narrow or one-lane bridges, or underpasses and underpasses with substandard vertical clearances.
- Compatibility of the land use along an alternate route with the volume and classification of vehicles to be diverted.

38.4. Traffic Impact Analysis Report Requirements

For roadway projects, the TIA typically includes the elements outlined below, as well as those detailed in Appendix H. The TIA report should be typed and bound, and contain a table of contents and a list of figures and tables.

For development projects, the TIA will function as a portion of the CTR document; a separate TIA report is not necessary. See the latest version of the **DDOT Guidelines for Comprehensive Transportation Review** for the documentation requirements and expected deliverables.

38.4.1. Executive Summary

The first section of the report will be the Executive Summary. The Executive Summary should be a condensed, stand-alone document. Summary maps and tables should be included in this section, as well as any maps and tables from the individual sections required to provide a complete summary of the analysis in the TIA.

38.4.2. Introduction

The introduction of the report includes a description of the proposed project, an overview of the project location and study area boundaries and an outline of the existing and future transportation network.

38.4.2.1. Project Description

This section summarizes the proposed roadway project and any conceptual or engineering drawings. A discussion of why a TIA is required for the proposed project should be included, including an overview of the scope of the TIA.

38.4.2.2. Project Location and Study Area Boundaries

This section summarizes the project location and study area and should include a vicinity map showing the project site, the study area, and the surrounding surface transportation network. A brief description of the location of the project within the District and the region should be included. The limits of the study area should be discussed with a description of how and why the study area boundary was determined, according to **Section 38.3.2**.

38.4.2.3. Existing and Proposed Uses in Vicinity of Project

This section should identify the existing and anticipated land uses in the vicinity of the project in order to understand other influences on area traffic patterns. Specific attention should be paid to property adjacent to the site and any undeveloped land in the study area. A map should be prepared for the project vicinity that graphically depicts the location of approved and proposed developments; the map should include other jurisdictions within the project vicinity.

38.4.2.4. Existing and Committed Surface Transportation Network

This section should include a map showing the planned surface transportation network for the short- and long-term planning horizons.

Improvements in the study area that are committed and funded by the District should be identified. Sources of funds should also be identified for District projects, when available. The long-term improvements should also include those documented in other District-wide long-term planning studies.

Short- and long-term improvements that are planned and/or funded by other local jurisdictions, agencies and developments in the study area should also be identified. The nature of their improvement projects, their extent, implementation schedule and responsible party should be identified.

38.4.3. Existing Traffic Conditions

The TIA first examines the existing traffic conditions in the study area. This typically consists of collecting peak hour turning movement counts at the study area intersections, including vehicle, pedestrian and bicycle volumes. The existing vehicular data collection may also include average weekday traffic on all major streets in the study area and other data requested by DDOT. The existing data collection scope is based on the study area determination as outlined in **Section 38.3**.

The source of any existing traffic data should be explicitly stated, and a summary of all data collected should be included in an appendix. A map of the existing roadway network should be prepared that presents lane geometrics, traffic control devices, traffic volumes, existing access, speed limits and any other notable features. A summary of the existing crash data, and any other analyses requested, must also be presented.

The existing conditions are assessed based on the MOEs outlined in **Section 38.3.5**. Additional data collection may be required depending on the MOEs chosen for evaluation. A summary of the existing conditions should be presented using the MOEs chosen for evaluation. A map of the existing conditions analysis results should also be prepared for each MOE.

38.4.4. Background Traffic Conditions

To determine the impacts of a proposed project, the TIA assesses the future traffic conditions without the proposed project (background traffic conditions) for comparison to the future traffic conditions with the proposed project (total future traffic conditions). The future study years are based on the determination of planning horizons as outlined in **Section 38.3.1**. For projects where the short-term planning horizon is based on the existing conditions, background traffic conditions do not need to be assessed.

The background traffic conditions typically consist of the existing traffic conditions plus traffic generated by other changes in the study area. This includes traffic from two sources: (1) trips generated by other developments with an origin or destination in the study area that have been proposed and approved (but not yet built); and (2) trips generated by inherent growth on the roadways that travel through the study area and do not have an origin or destination in the study area.

The growth rate for the future conditions may be based on several sources. When possible, regional traffic model forecasts should be used to develop the growth rate; historical traffic counts may be used when data from the regional traffic model is not available.

The source of any traffic data used to project the background conditions must be explicitly stated, and a summary of all background data should be included in the appendix. A map of the background roadway network should be prepared that presents lane geometrics, traffic control devices and traffic volumes.

The background conditions are assessed using the MOEs chosen for evaluation of the existing conditions. A summary of the background analysis should be presented, and a map of the analysis results should also be prepared for each MOE.

38.4.5. Total Future Traffic Conditions

The future traffic conditions with the proposed project (total future traffic conditions) are compared to the future traffic conditions without the proposed project (background traffic conditions) to evaluate the impacts of the proposed project. If a significant impact is projected due to the proposed project, mitigation measures must be presented, as outlined in **Section 38.3.6**.

The total future traffic conditions consist of the background traffic conditions plus traffic generated by the proposed project, as outlined in **Section 38.3.4**. A map of the total future roadway network should be prepared that presents lane geometrics, traffic control devices and traffic volumes. A map of the traffic volumes generated by the proposed project should also be presented.

The total future conditions are assessed using the MOEs chosen for evaluation of the existing conditions. A summary of the total future analysis should be presented, and a map of the analysis results should also be prepared for each MOE.

38.4.6. Project-Generated Impacts and Mitigation Measures

This section outlines the impacts of the proposed project using the MOEs chosen for analysis and presents mitigation measures. The impacts of the project on the crash rate and any other analyses requested must be presented, as well as any sight distance analyses or school route plans. Mitigation measures are selected based on what improvements are necessary to yield acceptable total future conditions. **Section 38.3.6** outlines the types of mitigation measures.

The mitigation measures identified should be described, and the section should include a summary of the proposed improvement, a sketch of the improvement and a preliminary cost estimate. All geometric improvements such as pavement markings, signs, adding through or turn lanes, and changes in medians should be presented in scaled drawing, preferably on a current aerial map. Sufficient dimensions should be shown to facilitate review. ROW needs should also be identified on the plan. For all proposed signals, a signal warrant analysis based on the **MUTCD** must be included. Proposed traffic signals must be designed according to the standards outlined in **Chapter 41**.

The mitigation measures are assessed using the MOEs chosen for the existing conditions, by comparing the future conditions with and without the proposed mitigations. A summary of the total future analysis with the proposed mitigation measures should be presented, and a map of the analysis results should also be prepared for each MOE.

39 Construction Traffic Control

39.1. General

This chapter defines the Construction Traffic Control design criteria for all roadway construction projects in the District.

DDOT will provide the Designer with a set of Maintenance of Traffic (MOT) requirements clearly showing lane control requirements, peak and non-peak traffic flow, permission for working at night and work zone protection required during construction to meet regulations and maintain an acceptable flow.

39.2. Traffic Control Plan

The Designer will develop a detailed Traffic Control Plan (TCP) as a part of the construction plan to meet MOT requirements. The TCP is a de-facto plan for Contractor bid preparation. Specifications for traffic control restrictions and control devices, quantities and costs to implement the plans are also part of the TCP. It is the Contractor's option to adopt the TCP or submit temporary traffic control plans to maintain traffic during construction.

The construction TCP must be designed to move all modes of traffic (motorists, pedestrians [ensuring compliance with the Americans with Disabilities Act (ADA)], and bikes) safely through a work zone. Elements of a TCP include information about placement and maintenance of traffic control devices, methods and devices for delineation and channelization, MOT phasing schedule, application and removal of pavement markings, roadway construction lighting requirements, traffic regulations, work zone protection and flagging operations.

Design of construction traffic control plans should include design speed, clear zone, horizontal and vertical alignment, typical section, (e.g., lane width, super-elevation and shoulder design) horizontal and vertical sight distance, clearance, curve radii, temporary barrier with (properly designed end terminals), surfacing requirements, approach ties, environmental mitigation and construction traffic control signage. All designs for traffic control plans shall be in compliance with the latest version of the Federal Highway Administration (FHWA) **Manual on Uniform Traffic Control Devices (MUTCD)**, the **D.C. Temporary Traffic Control Manual**, and applicable regulations such as the **Pedestrian Safety and Work Zone Standards** and the **Safe Accommodations for Pedestrians and Bicyclists**.

In particular, the Designer must consider vertical clearance to overhead structures such as bridges or falsework, especially when utilizing shoulders, where clearance is often less than one travel lane. A detour should be provided off the constructed street to allow traffic to move around the construction area and avoid congestion. Adequate space should be provided for the contractor to work without impeding the flow of detour traffic.

39.3. Detours

During construction, traffic can be maintained on the site or detoured to other roads with a similar classification. Detouring through traffic to local roads with lower classifications and lesser geometric characterists is not permitted without the approval of the Chief Engineer.

When planning a detour, the Designer must consider running speed, barrier widths, offset required to barriers, and clear distance to construction activities including typical construction sign placement. Temporary drainage is also an integral aspect of a detour design. The length of the detour should be minimized and designed according to the surrounding topography. The Designer should also consider the duration for which the detour will be needed and the amount of traffic demand.

Important considerations when designing a detour are safe passage of motorists through the construction zone when work is taking place adjacent to the traveled way and maintaining a safe construction work area. Construction work areas should not delay or impede traffic whenever conditions and economics permit. Priorities for providing a proper detour are:

- Safety for pedestrians, motorists, cyclists and workers
- Adequate construction work area
- Maintaining reasonable detour design speeds
- Providing adequate roadway capacity
- Providing proper direction and warning signs
- Providing economical detour design
- Consideration for vehicles type, weight, and height. The detour alignment should be as smooth as possible in relation to the major roadway alignment; it is desirable to maintain the lane width and other geometric properties of the main roadway as determined by its original design speed. A detour should be designed with a design speed as close to the original design speed as is reasonably possible. However, a detour through a residential neighborhood should be designed to calm traffic and not upset residents.

The Designer should anticipate the level of motorist compliance with the reduced speed in a detour zone when deciding on the detour design speed. Many motorists do not comply with the reduced speed zones despite adequate signage. However, when safety considerations warrant it, the detour's posted speed may be lower than the design speed. This allows the motorist to better read and follow the directional signs.

The Project Manager, in coordination with Infrastructure Project Management Administration (IPMA) traffic engineers and traffic control staff, is responsible for scoping and designing the detour. The design should include all pay items for the detour including provisions for maintenance, removal and disposal. On projects with Federal oversight, the Designer must meet all Federal standards and obtain FHWA concurrence with the design.

NOTE: Signage and striping for the detour should be included in the Traffic Control Plan and submitted for preliminary, pre-final and final review.

39.4. Construction Signage

Signage is an essential and integral part of any roadway construction project. The District has adopted the **MUTCD**, the **DDOT Temporary Traffic Control Manual** and **Chapter 44** of this manual as guidelines for signs in all construction work zones. The **MUTCD** and **Chapter 44** of this manual provide examples of typical construction signs, methods of erection and sign schemes to handle a variety of construction activities. Although the signs and support are temporary and so need not be made from standard durable material, they should be able to withstand environmental conditions and be in accordance with the **MUTCD** and **Chapter 44** of this manual.

39.5. Channelizing Devices

Channelizing devices are designed to alert drivers of physical constraints created by construction or maintenance operations on or near the traveled way, to protect workers in the work zone and to guide and direct drivers and pedestrians safely past obstacles. These devices are used to provide a smooth and gradual transition when it is necessary to move traffic from one lane to another or onto a bypass or detour, or when the width of the lane is reduced. Channelizing devices must always be preceded by a series of warning devices adequate in size, number and placement for the roadway. In accordance with the above-stated manuals, their design should be such that they minimize damage to vehicles that may inadvertently strike them.

The taper created by channelizing devices is one of the most important purposes of construction traffic control device systems. Tapers may be necessary in both the upstream and downstream directions of traffic depending on the construction activity. The requirements for tapers and their layout are provided in the **DDOT Temporary Traffic Control Manual,** which has guidelines on a variety of channelizing devices that are acceptable for use in construction projects. These channelizing devices must meet crash-worthiness standards established by the National Cooperative Highway Research Program and must be acceptable for use in construction projects. They include, but are not limited to:

1. Traffic cones
2. Tubular markers
3. Vertical panels
4. Drums
5. Barricades
6. Concrete barriers
7. Arrow panels
8. Variable messaging boards/signs
9. ADA barricades

Traffic cones are used for daytime work only. All other barriers must be usable for nighttime and daytime activities. The Designer must show the type and placement of these devices in the TCP.

39.6. Special Devices

Other special traffic control devices may be used during the construction process to direct traffic flow or convey messages to drivers and pedestrians. These devices include variable message boards, lane-use signals, crash cushions or other similar devices. These devices must be shown on the plans with the appropriate spacing and location in accordance with **MUTCD**, Part VI, and the **DDOT Work Zone Safety and Mobility Policy**, which is found in the **DC Work Zone Management Manual**.

39.7. Construction Staging/Phasing

Traffic control plans must detail the construction stages and scheduling for all phases of the construction project.

39.8. Plan Layout

The TCP must be developed at the same scale as the roadway plans. Larger-scale drawings may be used to show the detour and locations of signs. However, their use must be approved by the Chief Engineer or his/her designee. The TCP must include all existing striping, signage, temporary traffic controls and any signs or striping that should be removed or relocated during construction. All traffic control devices and striping must be delineated on the TCP along with lengths and distances.

39.9. Review and Approval

Traffic control plans must be submitted with the construction plan for review and approval. DDOT IPMA will coordinate the review and approval of the TCP in the various stages of submission. The Chief Engineer has final approval authority on all IPMA construction projects.

39.10. Work Zone Safety and Mobility Requirements

Refer to the latest **DC Work Zone Safety and Mobility Policy**, which is found in the **DC Work Zone Management Manual**, for detailed conditions, requirements and needed actions.

40 Traffic Calming

40.1. General

"Traffic calming" is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users. As opposed to traffic control devices that are regulatory and require enforcement, traffic calming measures are intended to be self-enforcing. Specific to DDOT, this means developing ways to tame traffic to protect and enhance neighborhood quality of life while also maintaining operational efficiency for all modes. This chapter identifies traffic safety concerns, issues and problems where traffic calming is needed, and defines methods of neighborhood traffic calming measures that the District deems applicable to existing local and collector roadways. Additionally, this chapter provides specific design criteria and applications for a number of traffic calming methods.

For additional information and criteria relative to traffic calming, refer to the current edition of the Institute of Transportation Engineers(ITE)/ Federal Highway Administration (FHWA) publication, **Traffic Calming, State of the Practice** and the **DDOT Traffic Calming Assessment Application** (http://ddot.dc.gov/sites/default/files/dc/sites/ddot/publication/attachments/traffic_calming_application.pdf).

40.1.1. Intended Use

Through a system of design and management, traffic calming aims to create a balanced multi-modal environment in which cars, bicyclists and pedestrians can safely coexist with one another. These methods are intended to make streets safer by reducing speeding and aggressive driving, while simultaneously enhancing pedestrian and bicycle movement. In particular, traffic on local and collector roadways in residential areas have direct access to residences along the street, and can conflict with through traffic. In these instances, traffic calming devices should be applied to improvement overall roadway traffic operation.

40.1.2. Design Principles and Components

Traffic calming measures must be designed at all new local and collector streets, as well as for the roadways where DDOT Traffic Calming Assessments have been performed and recommended the measures to be implemented. A Traffic Calming Assessment is an evaluation conducted by DDOT that responds directly to a citizen or related parties who have concerns of traffic impacts in their neighborhood or area. Community involvement is a key element in a traffic calming project, as general concurrence and a fully informed neighborhood is essential to ensuring a successful traffic calming project. More details on these assessments and recommended approaches can be found in the **DDOT Traffic Calming Assessment Application**.

The design of traffic calming measures must be in accordance with principles and guidelines established by DDOT and ITE/FHWA's **Traffic Calming, State of the Practice**. The designer should review the geometric roadway design criteria with the American Association of State Highway and Transportation Officials' (AASHTO's) **A Policy on Geometric Design of Highways and Streets** (Green Book, current version)**,** and the application in urban environments set forth in the National Association of City Transportation Officials' **Urban Street Design Guide, 2013,** as well as signage and pavement marking specifications in accordance with **Manual on Uniform Traffic Control Devices (MUTCD)**. Guidelines for pavement markings and signage are also documented in **Chapter 44** of this manual.

NOTE: The design of roundabouts must be based on guidelines established by current U.S. Department of Transportation/FHWA publication, **Roundabouts: an Informational Guide**, **DDOT Standards and Specifications** and **MUTCD**.

40.1.2.1. Drainage

It should be noted that the addition of traffic calming devices may alter drainage patterns. It is important for the Designer to provide for adequate drainage design to account for these changes. Drainage should always be designed and considered in accordance with the latest DDOT standards.

40.1.2.2. ADA Requirements

In addition to proper drainage design, all traffic calming measures must meet requirements set forth in the Americans with Disabilities Act. Special attention should be paid to any measures designed to have an effect on pedestrian movements.

40.1.2.3. Emergency Service Vehicles

As many traffic calming measures affect the accessibility to roadways and residences, it is imperative that emergency service providers are informed and consulted on accessibility conditions for all proposed traffic calming projects.

40.1.2.4. Traffic Calming-Related Landscaping

Landscaping is a key component of many traffic calming measures. Plant type, growth and location should be considered to avoid potential safety hazards. Adding trees creates a potential collision hazard for motorists and pedestrians. In addition, all landscaping should be designed to ensure adequate sight distance is maintained.

40.1.2.5. Maintenance

Maintenance practices and responsibilities should be considered when implementing traffic calming devices. For example, raised speed reducers (humps and tables) may be damaged by snow removal. Additionally, in heavily trafficked areas, these physical features may require increased maintenance. Landscaping must be properly maintained to prevent overgrowth that could lead to sight-distance problems.

40.1.3. Traffic Calming Design for New Streets

For new roadway projects (on local streets and collectors), the Designer should consider minimizing cut-through traffic volumes and reducing vehicle speed while maximizing the efficiency of the roadway to provide a safe and comfortable multi-modal experience for all users of the roadway including cars, pedestrians, bicyclists, and especially disabled persons.

40.2. Traffic Safety Concerns

Through the **DDOT Traffic Calming Assessment Application Petition**, citizens can voice their concerns about traffic safety issues such as speed and volume, as well as behavior (such as aggressive driving). These petitions alert DDOT of areas where traffic calming measures could be applied to minimize these issues and enhance the quality of life in the neighborhood.

40.2.1. Speeding

Drivers may speed on roadways that make them feel safe while exceeding the posted speed limit. Factors that contribute to this perception include long, unbroken lines of sight, downhill grades, wide roadways, low-density developments, low pedestrian activity and large building setbacks. In addition, speeding may occur where the roadway design allows a higher driving speed than originally intended.

One way to gauge speed on any street is to determine the 85^{th} percentile speed. The 85^{th} percentile speed is the speed at which, or below which, 85 percent of the vehicles travel. If the 85^{th} percentile speed is at or below the posted speed limit, speeding is not an adverse traffic operating condition, and remedy may not be needed. However, if the 85^{th} percentile speed is over the posted speed limit by 25 percent, either the posted speed limit may be inappropriate or a speeding problem may exist and traffic calming may be needed. Traffic calming is needed if speeding is observed on the local streets and collectors. While this statistic may be used as a guideline, in most cases it is not a defining factor. The need for traffic calming is based on several factors as determined by DDOT during the Traffic Calming Assessment.

40.2.2. Traffic Intrusion (Cut-through Traffic)

Traffic intrusion is created by drivers who switch from an arterial to a local street in an effort to avoid traffic congestion and delay. Excessive cut-through traffic in a residential area can cause a local street to function more like a major collector street and raise safety concerns in the neighborhood. Cut-through traffic along a neighborhood street should be discouraged by implementing traffic calming methods to make the local streets less desirable or inaccessible to cut-through traffic and improving traffic conditions on major streets.

40.2.3. Pedestrian and Bicycle Safety

Pedestrian safety is a key concern in neighborhoods, particularly those that routinely encounter speeding vehicles, cut-through traffic or aggressive driving. This concern is even greater in areas near neighborhoods with schools and parks, senior residents and mid-block pedestrian crossings, particularly on streets with on-street parking causing visibility issues. All of these areas require special consideration for the safety of the pedestrian and bicycles.

40.3. Traffic Calming Measures

Traffic calming can involve traffic control changes or additional traffic signage, reduction in speeds, street alignment, installation of barriers, and other physical measures, such as curb extensions, chicanes, chokers, traffic circles, speed humps, speed tables or raised crosswalks. Traffic calming measures are usually classified according to their dominant effect and are as follows:

- **Speed Control**. The primary purpose of speed control measures is to reduce the speed of vehicles, especially in residential neighborhoods and school zones, and discourage motorist speeding. The following are traffic calming measures that control the speed of vehicles on the street:
    - Speed humps, bumps and tables
    - Raised crosswalks
    - Raised intersections
    - Textured pavements
    - Gateway/entry treatments
    - Bulb-outs/curb extensions
    - Chicanes
    - Chokers
    - Neighborhood traffic circles

- On-street parking

- **Traffic Throughput Control**. The primary purpose of volume control measures is to divert traffic and discourage cut-through traffic. If an alternative route through a residential neighborhood is available, it encourages motorists to use the residential cut-through as their normal route of travel. Volume control measures that will divert traffic and reduce the cut-through traffic include:
  - Half street closures/semi-diverters
  - Movement control median barriers
  - Forced turn/channelization islands

40.3.1. Speed Control Measures

40.3.1.1. Raised Speed Reducers

There are several varieties of speed reducers, including rounded and flat-topped humps, such as speed humps, speed tables and raised, flat-topped pedestrian crossings. Speed humps are not recommended for bus routes, bike routes and emergency response routes because of the potential discomfort to bus passengers and cyclists, and delay of emergency response time. The decision to use speed humps should be based on the factors of inconvenience, discomfort and vehicle damage, as well as general ineffectiveness, as cars usually accelerate to make up for such sudden speed stops.

A speed table is typically 22 feet in the direction of travel with 6-foot ramps on each end and a 10-foot flat section in the middle. The most common height of a speed table is between 3 and 4 inches. Speed tables are longer than speed humps and cause less delay. Speed tables are not recommended for use on routes with significant (more than 5 percent) truck and bus traffic. If speed tables are selected as the method of traffic calming, they should be well-designed and properly installed. In addition, because emergency response times may increase, emergency service providers should be consulted before installing speed tables.

Details regarding installation and engineering design guidelines of speed humps and speed tables for traffic calming can be found in the **DDOT Speed Hump Request Procedures and Engineering Guidelines.**

40.3.1.2. Raised Crosswalks

Raised crosswalks are a kind of speed table outfitted with crosswalk markings and signage to channelize pedestrian crossings, providing pedestrians with a level street crossing. Also, by raising the level of the crossing, pedestrians are more visible to approaching motorists. Raised crosswalks are good for locations where pedestrian crossings are significant and vehicle speeds are excessive. Drainage must be considered at locations of raised crosswalks. Unlike speed bumps, raised crosswalks may be installed on minor arterials as well as collector and local streets, taking into account other factors such as traffic and truck and bus volumes.

40.3.1.3. Raised Intersections

Raised intersections are created by raising the elevation of the crosswalks and the central area between them. Raised intersections enhance the visibility between motorist and crossing pedestrians. Like raised crosswalks, design of this speed control measure requires drainage considerations.

40.3.1.4. Textured Pavements

Textured pavements may include differential pavements, a colored concrete pad in an asphalt street, rumble strips, stamped concrete or other similar treatments to make the driver aware of a crosswalk, a congested intersection or other situations that may require special driver attention.

40.3.1.5. Gateway/Entry Treatments

Gateway treatments use bricks, stamped concrete or other colored materials to create alterations in the pavement surface to signal to drivers that they are entering a residential neighborhood or community that requires slower speeds. Gateways are used to emphasize either an entire intersection or a pedestrian crossing, and are sometimes used along an entire block. Gateways are appropriate at locations with higher pedestrian traffic.

Treatments must be in accordance with DC Historic or Special District requirements. Please refer to **Chapter 30**.

40.3.1.6. Bulb-out/Curb Extension

Bulb-outs or curb extensions extend the sidewalk and shorten the pedestrian crossing. They increase pedestrian visibility at intersections where vehicles parked in a parking lane would otherwise block the visibility. Also, where bus stops are on either side of the intersection, the bulb-out should be long enough to accommodate both the front and back doors of the bus opening onto the bulb-out (about 30 feet from the bus stop flag). In addition, bulb-outs and curb extensions are ideal locations for implementing green infrastructure techniques. For details on green infrastructure design, see **Chapter 28**. For details on bus bulb-out design, see **Chapter** 34. Curb extensions should extend into the street no more than 7 feet for streets with bike lanes and 6 feet for streets without bike lanes.

40.3.1.7. Chicanes

Chicanes are series of fixed objects, usually extensions of the curb, that alternate from one side of the street to the other, forming S-shaped curves. Chicanes discourage high speeds by forcing horizontal deflection. They are also called deviations, serpentines, reversing curves, twists and staggerings. There are many variations of traffic calming chicanes, but they generally fall into one of two broad categories:

- Single-lane working chicanes, which consist of staggered build-outs, narrowing the road so that traffic in one direction has to give way to opposing traffic
- Two-way working chicanes, which use build-outs to provide deflection, but with lanes separated by road markings or a central island

40.3.1.8. Roadway Chokers

Lane-eliminating chokers are another option. This design eliminates a lane of traffic, thereby increasing traffic volume in another lane, which decreases speeds. Capacity and delay should be investigated for feasibility of installing such lane-eliminating chokers.

40.3.1.9. Neighborhood Traffic Circles

Neighborhood traffic circles are small circular islands or roundabouts, usually less than 26 feet in diameter, located at the intersections of neighborhood streets.

Refer to the section on roundabouts in **Chapter 32** of this manual for considerations in designing such traffic circles.

40.3.1.10. On-Street Parking

On-street parking will have impacts on traffic along the street. Parked vehicles usually cause street traffic to slow down to have better sight distance.

40.3.2. Volume Control Devices

These devices are intended to control the number of vehicles in a corridor or specific area. There are several methods of controlling traffic, as discussed below.

40.3.2.1. Half Closures/Semi-Diverters

Semi-diverters prevent drivers from entering or exiting certain legs of an intersection. Strategically located, semi-diverters can effectively reduce traffic volumes on a street by prohibiting some turning and through movements. Generally, these are used on non-transit and non-emergency vehicle streets only. Signs may also be used to prohibit turns that are disruptive to the flow of traffic or to minimize the cut-through traffic into a residential neighborhood. Enforcement will be needed since there is no physical deterrent, but emergency vehicles would be exempt.

Diverters should allow access for pedestrians and possibly bicycles to the street.

40.3.2.2. Center Islands/Medians

Generally, center islands are more effective as a pedestrian refuge area, but may be used in conjunction with chicanes to discourage traffic by slowing down vehicular speeds. These islands should be a minimum of 4 feet wide (refer median section in **Chapter 31** in this manual for details).

These physical barricades limit vehicular traffic from continuous through movement or left turns in the intersection. The diverters/islands may be created as a temporary solution using removable concrete barriers, or as a permanent situation with a wall or trees or other fixed devices.

40.3.2.3. Forced Turn Barrier (Pork Chop)/Channelization Island

This device is used on local roads or driveways to prohibit straight movements across congested streets. It forces the motorists to turn. A pork chop island should be designed with a minimum size of 50 square feet.

41 Traffic Signal Design

41.1. Introduction

A traffic signal is an electrically powered traffic control device, other than a barricade warning light or steady burning electric lamp, by which traffic is alerted and directed to take some specific action. The objective of traffic signal design is to properly distribute the right-of-way to approaching traffic so that vehicles and pedestrians can move through an intersection or a specific area smoothly and safely.

The following types and uses of traffic signals are discussed in this chapter: Traffic Control Signals, Pedestrian Crossing Signals, Pedestrian Hybrid Beacon (HAWK) Signals**,** Street Car Signals, Transit Priority Signals, Bicycle Signals, Ramp Metering Signals, Flashing Beacons, Lane-Use Control Signals, Traffic Control at Movable Bridges, Preemption Control of Traffic Signals, Traffic Signals for One-Lane, Two-Way Facilities, School Warning Flashers, Electric Signs and Displays and Traffic Signals for Construction Zones.

Traffic control signals:

- Assign the right-of-way to various traffic movements
- Have one or more of the following advantages:
    - Provide for the orderly movement of traffic
    - Can increase the traffic handling capacity of the intersection
    - Reduce the frequency of certain types of accidents, especially the right angle type
    - Can be coordinated to promote continuous or nearly continuous movement of traffic at a definite speed
    - Permit minor street traffic, vehicular or pedestrian, to enter or cross continuous traffic on the major street

Data compiled over a number of years indicate that, while the number of right-angle collisions decreases after traffic signals are installed, the number of rear-end collisions increases. In addition, the installation of signals may increase overall delay and reduce intersection capacity. Consequently, it is of the utmost importance that a thorough study of traffic and roadway conditions be conducted by an experienced and trained engineer in the field before considering signal installation and selection of equipment. Equally important is the need to check the efficiency of a traffic signal in operation to determine the degree to which the type of installation and timing program meet current traffic demands.

41.2. Traffic Signal Warrants

The justification for the installation of a traffic signal at an intersection should be evaluated based on guidance in this manual and the warrants stated in the most current edition of the **Manual on Uniform Traffic Control Devices (MUTCD)**. Typical warrant studies should include estimation of projected delays, analysis of gaps and review of time-space diagrams. The decision to install a signal should not be based solely upon the warrants, since the installation of traffic signals may increase certain types of collisions. Traffic congestion, approach conditions, pedestrian safety, driver confusion, future land use or other evidence of the need for right-of-way assignment beyond that which could be provided by stop signs must be demonstrated.

41.3. Removal of Existing Signals

Changes in traffic patterns may result in a situation where a traffic signal is no longer justified. When this occurs, consideration should be given to removing the traffic signal and replacing it with appropriate alternative traffic control devices, consistent with the provisions of **MUTCD**, community consensus and municipal regulations.

41.4. Traffic Signal Development Procedures

41.4.1. Introduction

The cost of traffic signals on Federal Aid highway projects is eligible for federal participation under certain conditions. A project study report may be required before installing a new traffic signal, or for modification and replacement of an existing traffic signal, if federal funds will be used to hire the Engineer to design the project. DDOT runs the risk of having to reimburse the Federal Highway Administration (FHWA) for design costs if traffic signals are not moved to construction within 10 years of design completion.

41.4.2. Procedures

A traffic signal plan must be prepared whether the work will be performed by the District of Columbia or by others, and it should include the following specific procedures:

1. **Data Collection**

   Obtain the base survey information that is required for the traffic signal plan. This will include the location of the edge of pavement or curb lines, pavement markings, surface evidence of underground and overhead public and private utilities, any existing traffic signal equipment if present, and property lines that may affect the design. Elevation contours may be required at locations with steep slopes that could affect the design. Approach grades for each leg of the intersection are also needed to develop clearance intervals. Typically, underground and overhead utilities should be identified and located within the public right-of-way throughout the entirety of the intersection interior, and also within 25 to 50 feet past the point of curvature for each of the intersection-curb radii. As a rule of thumb, it is also suggested to obtain survey information at a minimum of 10 feet beyond the edge of right-of-way in case additional right-of-way or easement will be required as part of the traffic signal design. During the survey phase, approach grades should also be documented for use in calculating clearance intervals.

2. Prepare Base Plan

The base plan sheet must include the following (at a minimum):

- North arrow
- Graphic scale
- Speed limits
- Street names and route numbers
- Finished roadway elements (to scale)
- Approach grades for use in calculating clearance intervals
- All existing and proposed underground and overhead utilities in place when project is completed
- Right-of-way limits

3. Site Visit and Verification

The Designer should verify in the field the intersection geometry and confirm that the traffic signal base plan appears to be accurate. It is highly recommended for the Designer to take pictures of key observations to verify the surveyed approaches and all roadside features in and near right-of-way. This initial field visit can be combined with the initial meeting with the appropriate DDOT representative. Additionally, the Designer could confirm information required for the preliminary plan. The Designer can meet with the DDOT traffic signal technician to discuss the location of the power source, potential signal controller location, etc.

4. Traffic Signal Design Procedures

The signal design must include the following procedures at a minimum:

- Document intersection geometric design to verify sight distance and proposed intersection geometry
- Establish crosswalks, curb ramps and stop lines
- Determine locations of signal poles, signal heads, pedestrian signals and push buttons
- Identify signage requirement for the traffic signal

- Design signal pole and mast arm details, electrical service connection, handboxes, conduit runs, vehicle detectors and controller cabinet
- Develop wiring diagram showing signal wiring and conduit layout/sizing
- Develop utility plan incorporated with signal design
- Design Sequence of Operation (TS) sheets showing signal phasing and schedule
- Develop traffic signal timing plans for DDOT review and approval
- Develop communication and interconnect plan

41.5. Traffic Signal Design

41.5.1. Introduction

Traffic signal design is the creation of engineering plans suitable for construction by a contractor. Components of a traffic signal design may include one or more of the following:

- Signal (S) Drawing: A Signal Drawing shows all existing and proposed underground and above-grade appurtenances**,** intersection curb lines and geometry, and communication cable routing, signing, and pavement marking, consistent with the operation of the new traffic signal. The Signal Drawing must feature sufficient detail to enable a contractor to install the traffic signal. A documented field visit including measurements must be used to precisely establish the location of all above- and belowground features for a distance not less than 150 feet in all directions from each intersection corner. Computer-generated maps and images, as well as archived data, must be verified with field measurements before included in the design S Drawing.
- Sequence of Operation (TS) Drawing. A Sequence of Operation Drawing describes the operation of the traffic signal. The TS Drawing may appear in the actuated or pre-timed format consistent with the software requirements of the location's intersection controllers and the central traffic signal system. Traffic signal sequences of operation must be submitted in BiTran 233 (MC1) or 2033 format for DDOT approval. Electronic and paper copies are required.
- Traffic Signal Timing Plan Dial Sheet. The Dial Sheet shows the amount of time in the signal operation allocated for all signal intervals or phases, and the offset relationship between adjacent signalized intersections. Traffic signal timing plans must be submitted in BiTran 233 (MC1) or 2033 format for DDOT approval. Electronic and paper copies are required.
- Signing and Pavement Marking Plan.
- Communication Plan, which must be included with the S Drawing.
- Controller Configuration Package. This is a computer-generated package that translates traffic signal timing and phasing parameters into a format used by the traffic signal controller.

- Contract Special Provision. This document outlines work to be performed by a contractor performing traffic signal work and features clarifications of or additional work not outlined in the referenced content of the standard specifications for Highways and Bridges.
- Time-Space Drawings. These drawings show the interrelationship between traffic signals in a corridor for each timing plan and determine the offset to be entered in the Dial Sheet and the Controller Configuration Package.

Traffic signal design work may be performed by in-house personnel and by private engineering consultants. District of Columbia personnel will always create the controller configuration package. Either the Consultant or in-house personnel may create other components of the traffic signal design as outlined in the Consultant's scope of work. The scope of work negotiated by the Consultant and DDOT will fully describe all Consultant deliverables.

Consultants selected to perform traffic signal design work in the District of Columbia must be registered on DDOT's Architect/Engineer Schedule in the Traffic Signal, Street Light category. This condition applies to consultants performing stand-alone traffic signal design work, subconsultants performing traffic signal design on a larger DDOT project, and consultants retained by a developer, private contractor or government agency to modify a traffic signal consistent with their plans.

Consultants performing stand-alone traffic signal design work are required to submit one original large vellum S Drawing and original traffic signal sequence of operation in standard DDOT format, and one original traffic signal timing plan Dial Sheet. Those performing work as a subconsultant or under contract to another agency must submit two original large vellum S Drawings and one original traffic signal Sequence of Operation Drawing. One large vellum S Drawing will be provided to DDOT for inclusion in its Traffic Signal Files, and the other must be provided to the prime Consultant or to the other agency. Additionally, the Consultant must submit an electronic version of all engineering plans, traffic signal Sequences of Operation Drawings, and traffic signal timing plan Dial Sheets to DDOT. Signal designs must be approved by a Consultant registered as a Professional Engineer in the District of Columbia.

A traffic signal engineer in DDOT must sign and approve all S Drawings and TS Drawings submitted by the Consultant. The signed drawings will be the Consultant's notification that his or her work on this task is complete and that all deliverables itemized in the scope of work, in paper and electronic format, can be submitted to DDOT. The Consultant is required in every case to submit to DDOT all S Drawings and TS Drawings in both paper and electronic format. Traffic signal plans included in any project authorized for receipt of competitive bids must feature the signature of the traffic engineer designated to formally approve such work.

The design of DDOT traffic signals is based on the following publications:

- This manual (DDOT)
- The most current edition of the DDOT Standard Specifications for Highways and Structures
- Standard Drawings (DDOT)
- Manual on Uniform Traffic Control Devices for Streets and Highways (FHWA)
- The 1994 Deregulation Agreement between the District of Columbia Government and the Potomac Electric Power Company for Traffic Signal Service

Additional references that may be used include:

- Transportation and Traffic Engineering Handbook, Institute of Transportation Engineers (ITE)
- Manual on Traffic Signal Design (ITE)
- Traffic Control Systems Handbook (FHWA)
- Transportation Research Board National Cooperative Highway Research Program Publications
- Traffic Control Systems Standards, National Electrical Manufacturers Association
- American Association of State Highway and Transportation Officials (AASHTO) Publications
- Traffic Control Devices Handbook (FHWA)
- Signal and Lighting Design Guide (California Department of Transportation [CALTRANS])
- Ramp Meter Design Guidelines (CALTRANS)
- Highway Design Manual (CALTRANS)
- DDOT Guidelines for Basic Timing Parameters
- MUTCD Interim Approval for the Optional Use of Bicycle Signal Face (IA-16) and Following Official Ruling 9(09)-47(I)
- DC Streetcar Concept of Operations

41.5.2. Traffic Signal Operation

A prime factor to consider in selecting the type of traffic signal operation is adequacy. While it may be true that a sophisticated signal control will operate satisfactorily at any intersection, the intersection should not be provided with a type of control that is unnecessarily complex and expensive.

The type of traffic signal operation to be used will depend on the variations in traffic and pedestrian demand. The two main types of signal operation are pre-timed and traffic-actuated. Traffic-actuated operation can be further classified as full-traffic-actuated or semi-traffic-actuated. With full-traffic-actuated operation, all traffic movements or phases are sensed by detectors. In semi-traffic-actuated operation, certain phases (usually the coordinated phases) do not have detectors.

If pedestrians are present during the majority of the signal cycles for a particular leg of an intersection (typically the major street crossing), the pedestrian signal phase should be automatic ("pre-timed"), and pedestrian actuation should not be used. However, in areas with intermittent pedestrians, pedestrian actuation may be used to reduce unnecessary stops and delays for vehicular traffic. While this policy is applied during the design of new signal installation and rehabilitation projects, the final determination will be made on a case-by-case basis to achieve a balance between all modes of traffic.

Pre-timed and semi-traffic-actuated operation should be used in coordinated systems only. They should not be installed at isolated intersections (more than 1 mile from the closest signalized intersection).

Where the distance between signalized intersections is 1/2 mile or less, coordination of signals must be considered, and a time-space diagram and evaluation of the cost-effectiveness of coordination must be prepared.

Discretion should be used with phasing at offset intersections, as it may introduce operational problems, which should be recognized and avoided. The most critical of these problems is where one approach right-of-way is terminated while the opposing approach continues with a green indication.

41.5.2.1. Detection Options for Signals

Signal detection has two basic sensory modes: presence and passage.

- Presence Detection

  Presence detection senses when a vehicle is in the detection zone; once a vehicle leaves the detection zone, the call is dropped. These detectors are typically used on side streets and left turn bays at the stop line when it is critical to detect if a vehicle is waiting for green.

- Passage Detection

  Passage detection uses a point or pulse sensor that indicates that a vehicle has gone through a detection zone, and the memory of the vehicle is stored in the controller. The passage detection in the controller extends the green time for that movement. These detectors are typically used on mainlines and as system detection.

The commonly used signal detection technologies include:

- **Sampling Detection.** The preferred sampling detection technology is 6-foot by 6-foot inductive loop detectors. They provide more accurate presence and occupancy readings and are typically placed downstream of an intersection in a location with free flow of traffic.
- **Video Imaging.** Video imaging camera detectors are the preferred type of presence detection and can also be used for passage detection.
- **Microloop Sensor.** A microloop is a transducer that converts changes in the vertical component of the earth's magnetic field to changes in inductance. These sensors are alternatives to inductive loops.
- **Inductive Loop.** Inductive loop detectors are placed underground for presence and passage detection. These loops are formed by saw-cutting the roadway, placing a #14 AWG wire encased in flexible tubing in the sawcut, and then sealing the sawcut.
- **Microwave Detector.** A micro-wave detector essentially functions as a self-contained Radio Frequency system, with the transmitter, receiver and output circuit in one unit.
- **Wireless Sensor.** Wireless sensors have emerged as a cost-effective technology in today's market and are typically installed to collect traffic volume and occupancy data. These sensors can also be utilized for presence detection and travel time estimation purposes.

DDOT preferred detection technologies are induction loops and video imaging. Microwave detectors and wireless sensors can be used as backup or temporary presence detection but require DDOT's pre-approval.

Pedestrian detection or activation is required for all crosswalks where pedestrian signals are provided except when the pedestrian phase is recalled at all times. The most common pedestrian detection is push button. Passive detection such as video detection can be used as an alternative.

Bicycle detection or activation is recommended whenever vehicle detection is present. A symbol may be placed on the pavement indicating the optimum position for a bicyclist to actuate the signal. A sign may also be installed to supplement the pavement marking.

41.5.2.2. Signal Communication Options

Signal communication is the connection of two or more signals using land-line communication, such as hard-wire interconnector (copper), fiber optic cable, or wireless spread spectrum to create a system. If a signal has an existing interconnector or is part of a proposed interconnection, then it should be part of the conceptual design. The type of communication used, as well as the system as a whole, should be identified. A proposed design that will use existing interconnectors must be designed to be constructed without causing down time to the interconnected system. This may require some temporary interconnections.

41.5.2.3. Electrical Service to Signals

The most convenient and most common service source is a utility pole or a mid-span tap to a secondary cable. Occasionally an underground vault or secondary conduit system may be more convenient. All service (line) conductors to a traffic control cabinet must be contained in a dedicated electrical conduit with no other cables. The service is never direct buried. The size of the conduit is usually 2 inches. The electrical service needed to operate a traffic signal is 120 volts. Electrical service is provided by the Potomac Electric Power Company (PEPCO).

41.5.2.4. Signalized Intersection Lighting

Normally the street lighting system is separate from the traffic signal system. Both systems are owned by the District. However, the electrical utility service connections are independent from each other. The streetlights are wired separately and run to the designated power source as determined by the Designer. . If there is no lighting system, spot roadway lighting may be desired and included in the traffic signal installation. Lighting installed as part of a signal design is termed intersection lighting. Intersection lighting is typically attached to the signal poles via a bracket arm, but still wired separately. See **Chapter 43** for placement of luminaires at intersections. The lighting is wired separately and run to the designated power source as determined by the Designer, but is usually maintained by an independent meter.

41.5.2.5. Signalized Intersection Signage and Pavement Markings

Signalized intersection signing and pavement markings should follow DDOT standards and the **MUTCD** (latest edition) and any other guidance required for safe and efficient operation at the location. Unusual geometric conditions, signal phasing, specific signing needs and operations peculiar to a specific location may suggest other treatments. The placement of the sign should take into consideration the size of the sign, position to travel lanes and offset from the nearest signal head to the edge of the sign plate. The types of pavement markings may include crosswalks, stop lines, message/arrow markings, lane lines, channelizing lines, and edge lines; existing markings may need to be removed. The Designer is responsible for detailing new pavement markings to a point where they can be transitioned into the existing markings.

41.5.2.6. Signal Support Structure

There are several types of signal supports that may be used on a project. The decision of which type of structure to use is based on several factors, including location of overhead utilities, intersection geometrics, proposed location of traffic signal heads, aesthetics and local requirements. Surrounding signal types must also be considered. The main types of signal supports are signal poles (with mast arm), pedestal poles, wood pole supports and bridge mounts.

41.5.2.7. Signal System Considerations

Signal systems should be designed to move traffic platoons on arterial roadways and/or for queue control. Emphasis should be placed on the development of a wide "green band" to favor the flow of arterial street traffic while not restricting the flow of other traffic. Sometimes the volume of traffic entering or leaving the system from side streets may exceed the through volume on the arterial. Every effort should be made to define the origin and destination of traffic in the system and ensure that the major flows are incorporated into the progression.

The procedure for determining the type of coordination for a new signal system or a revision to an existing signal system should be a multiple-stage process aimed at providing a signal system that is efficient and expandable, as well as consistent with DDOT standards. The process may include traffic engineering analysis, signal system analysis, selection of alternative systems and coordination methods, and final system design.

41.5.3. Selection of Left-Turn Phasing

There are various methods to signalize left turn movements, as shown in Figure 41-1.

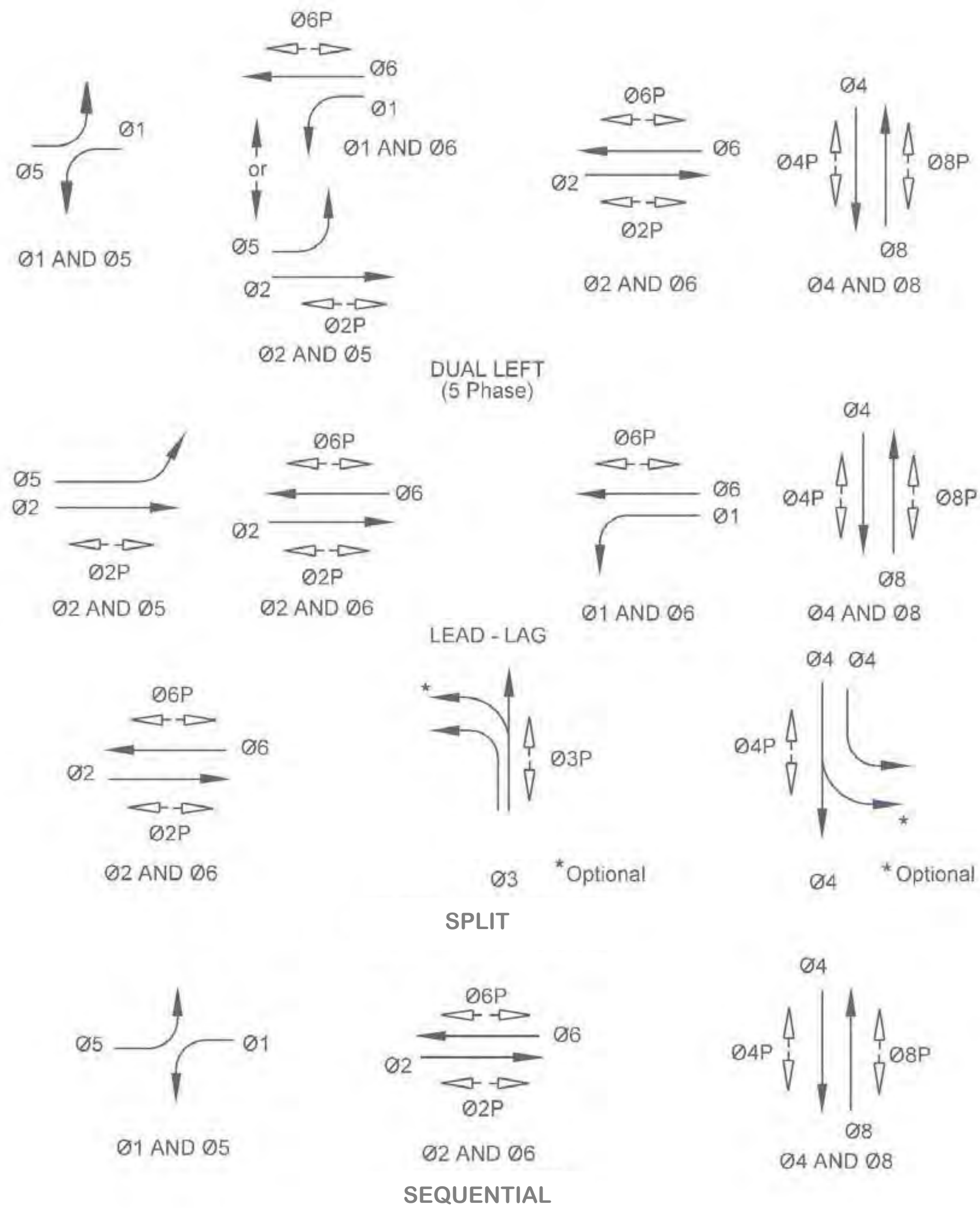


Figure 41-1 | Left Turn Movement Signalization Methods

If the left turn volume is 300 or more vehicles per hour, or if delays to traffic at the intersection can be significantly reduced, a two-lane left turn configuration should be considered, except in urban areas, where left turn lanes should be limited to a single lane. The Designer needs to consider the safety benefits of adding turn lanes while minimizing pedestrian crossing distance.

41.5.3.1. Simultaneous or Dual Left

This method is most effective during free or isolated operation with actuation. It is the most efficient means of providing protected left turn movements because the various phases and combinations of phases are activated based on demand. A through movement is allowed to go with its associated left turn movement where there is no opposing left turn traffic.

41.5.3.2. Lead-Lag Left Turns

This operation can be either pre-timed or traffic-actuated. Normally, “Lead-Lag” phasing should be considered for coordinated signals when the offset timing determined by the system time-space diagram results in the arrival of the two directions of traffic at different times during a cycle. This will provide the most efficient progressive bandwidth. Lagging green performs better where a left turn lane is provided. At intersections with high pedestrian volumes, lagging green is preferred.

41.5.3.3. Split Left Turns

Split-phase operation should be used where the left turn volume per lane is very high in either direction and is about equal to or greater than the companion through movement. This method is especially useful when one of the through lanes is shared with the left turning movement or where a separate left turn lane cannot be provided.

41.5.3.4. Sequential Operation

Sequential operation can be either pre-timed or traffic-actuated. When left turn volumes on either direction are fairly equal and qualify for turn phases, such operation is preferred.

41.5.3.5. Protected-Permissive Left-Turn Phasing

This type of operation allows vehicles to make left turns during a fully protected interval with a green arrow indication, or to make a permissive left turn with a circular green indication when there are adequate gaps in opposing traffic. Such left turn phasing may be either pre-timed or traffic-actuated. Examples of the operation may be found in the **Traffic Control Devices Handbook** (FHWA).

Protected-permissive left turn phasing normally uses one of two sequences:

- **Leading Protected-Permissive.** With this operation, left turn traffic is first directed to turn left on the display of a green arrow and then permitted to turn during the non-protected interval on the display of a circular green.

- **Lagging Protected-Permissive.** With this operation, the left turn traffic is first permitted to turn during the non-protected interval on the display of a circular green and then directed to turn left on the display of a green arrow.

The advantages of this operation over fully protected left turn phasing only are:

- Reduced delay, as the left turning vehicles may have an opportunity to make their left turns during the green interval or yellow change interval for through traffic.
- Allows the use of shorter cycle lengths in coordinated systems by reducing the time of the fully protected green interval for the left turn movement.
- Less chance of disrupting traffic in adjacent through lanes as left turn queues are less likely to exceed the length of the left turn lane.
- When a protected-permissive left turn phasing operation is used for a signal system, no additional sign is necessary. If a sign is used, it must be an **MUTCD** R10-12, LEFT TURN YIELD ON GREEN (Green Ball symbol) sign on streets with turning bays.

The flowchart in Figure 41-2 and the supporting information in Table 41-1 should be used as guidelines for selecting the type of left turn phasing. These guidelines were adapted from the FHWA Signal Timing Manual (2008) and guidelines from other transportation departments, including existing DDOT guidelines.

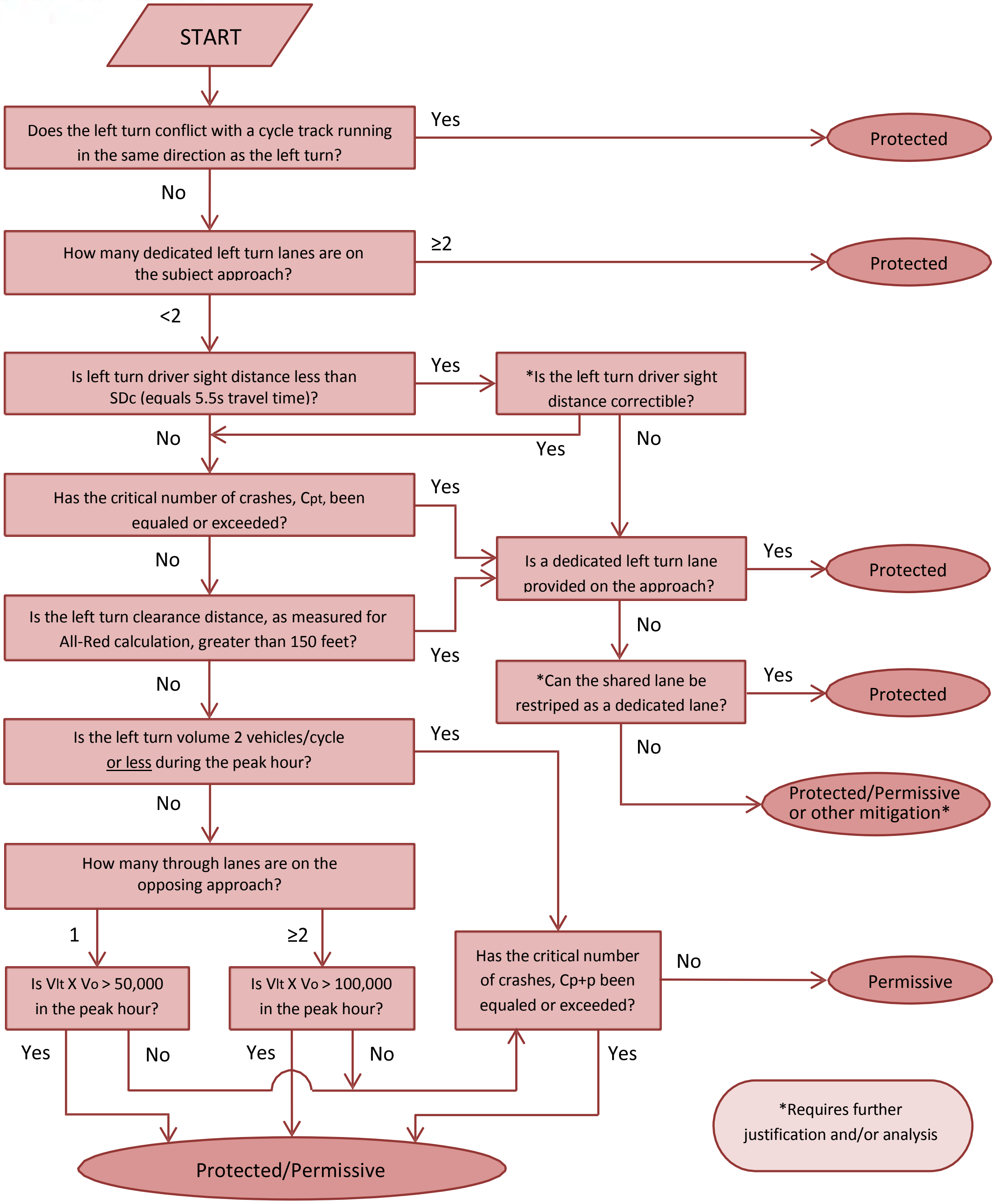


Figure 41-2 | Left Turn Phase Detection Guidelines

Table 41-1 | Left Turn Phase Selection Criteria

Period During Which Crashes are Considered (years)	Critical Left-Turn-Related Crash Count: Considering Protected-Only, C_{pt} (crashes/period)	Critical Left-Turn-Related Crash Count: Considering Prot.+Perm, C_{p+p} (crashes/period)
1	6	4
2	11	6
3	14	7

Oncoming Traffic Speed Limit (mph)	Minimum Sight Distance to Oncoming Vehicles, SD_c (ft)
25	200
30	240
35	280
40	320
45	360
50	400

Variables
V_{lt} = left turn volume on the subject approach, veh/h
V_o = through plus right-turn volume on the approach opposing the subject left turn movement, veh/h

41.5.4. Location of Controller Cabinets

Normally, the controller cabinet should be located in accordance with the following:

- It should not be vulnerable to traffic.
- Traffic movements at the intersection should be visible by a traffic signal technician standing in front of the opened cabinet front door.
- Signal Plan Schedules must indicate whether the feature is existing or proposed.
- The doors of the cabinet should open away from the curb or traveled way. The cabinet must be centered at least 3 feet from the face of the curb and situated at least 5 feet from the nearest street furniture.
- It should be possible to park a maintenance truck close to the cabinet.
- It should not be located in a drainage ditch, in an area that could be under water or where subjected to water from sprinklers.
- It should not obstruct sidewalks, wheelchair ramps or entrances.
- It should not be placed near pinch points in the sidewalk, such as near building entrances, to preserve a minimum 4-foot-wide pedestrian clear zone. In special areas of the District, wider pedestrian clear zones (minimum of 6 to 12 feet) may be required.
- It should be placed so as not to obstruct pedestrian or driver visibility.

Upon request, keys for the police panel on traffic signal controller cabinets will be furnished to the local Metropolitan Police Department district office.

The Designer should refer to the most current edition of **DDOT Standard Specification for Highways and Structures** for detailed types, functions and installation procedures of traffic controller cabinets.

41.5.5. Signal Plan Schedules

The traffic signal plans for the installation of a new signal or the major modification of an existing signal should include the following schedules:

- **Pole and Equipment Schedule.** A pole and equipment schedule shows the types of standards, mast arm lengths, type and mounting for vehicle and pedestrian signal faces, and other equipment.
- **Conductors and Conduit Schedule.** A conductor and conduit schedule shows the size of each conduit run, and the size, type and number of conductors or cables in each conduit run.

41.5.6. Preemption

At some signal locations, it is necessary to preempt the normal traffic signal operation by a railroad train, an emergency vehicle or bus/transit vehicles.

The order of priority for preemption types is:

- Railroad
- Emergency vehicles
- Bus/transit vehicles including street cars (low priority)

41.5.6.1. Railroad Preemption

While railroad preemptions are not common in the District, D.C. controllers are required to provide this feature. Railroad preemption results in a special traffic signal operation depending on the relation of the railroad tracks to the intersection, the number of phases in the traffic signal and other traffic conditions. Railroad preemption is normally controlled by the railroad grade crossing warning equipment.

- Typical circumstances where railroad preemption is required and the type of signal operations to be provided during preemption are as follows: Where a railroad grade crossing with grade warning equipment is within 300 feet of a signalized intersection, preemption of the traffic signal should use the following sequence of operation:
  - A yellow change interval and any required red clearance interval for any signal phase that is green or yellow when preemption is initiated and which will be red during the track clearance interval. The length of pedestrian clearance interval, the yellow change and red clearance intervals must not be altered by preemption. Phases that are in the green interval when preemption is initiated, and which will be green during the track clearance, must remain green. Any pedestrian walk interval in effect when preemption is initiated must

immediately be terminated, and all pedestrian signal faces must display the flashing DON'T WALK or upraised HAND display.

- A track clearance interval for the signal phase or phases controlling the approach, which crosses the railroad tracks. The signal indication for the clearance interval may be either green or flashing red.
- A yellow change interval if green signal indications were provided during the track clearance interval.
- Depending on traffic requirements and phasing of the traffic signal controller, the traffic signal may then do one of the following:
    - Go into flashing operation, with flashing red or flashing yellow indications for the approaches parallel to the railroad tracks and flashing red indications for all other approaches. Pedestrian signals must be extinguished. If flashing red is used for all approaches, an all-red or other clearance interval must be provided prior to returning to normal operation.
    - Revert to limited operation, with those signal indicators controlling through and left turn approaches toward the railroad tracks displaying steady red. Permitted pedestrian signal phases must operate normally. This operation is required only if the grade crossing warning equipment includes gates.
- The traffic signal must return to normal operation following release of preemption control.

- Where the railroad tracks run within a roadway and train speeds exceed 10 miles per hour, preemption of the traffic signals should use the following sequence of operation.
    - A yellow change interval and any required red clearance interval for all signal phases that are green or yellow when preemption is initiated and which will be red during the preemption period. The length of the yellow change and red clearance intervals must not be altered by preemption. Phases that are in the green interval when preemption is initiated and which will be green during the preemption period must remain green. Any pedestrian walk intervals in effect when preemption is initiated must be immediately terminated, and all pedestrian signal faces must display DON'T WALK or upraised HAND.
    - All signal faces controlling traffic movements parallel to the railroad tracks will display green or flashing yellow indications. All other vehicle signal faces will display red indications; pedestrian signal faces will display DON'T WALK or upraised HAND.

- Where the railroad tracks run along a roadway of a signalized intersection and train speeds do not exceed 10 miles per hour, trains may be controlled by the vehicle signal indications. This type of train control requires approval from the railroad, the Public Utilities Commission and the Director of Transportation.
- Unusual or unique track or roadway configurations may require solutions other than those described above.

41.5.6.2. Emergency Vehicle Preemption

Traffic signals may be preempted by authorized emergency vehicles. The purpose of such preemption is to give the emergency vehicle the right-of-way as soon as practical. The preemption may be controlled by one of the following means:

- By direct wire, modulated light or radio from a remote location such as a fire house
- By modulated light or radio from an emergency vehicle

Emergency vehicle preemption should use the following sequence of operation:

- A yellow change interval and any required red clearance interval for a signal phase that is green or yellow when preemption is initiated and which will be red during the preemption interval. The length of pedestrian clearance interval, the yellow change and red clearance intervals must not be altered by preemption. Phases that are in the green interval when preemption is initiated and which will be green during the preemption period must remain green. Any pedestrian walk interval in effect when preemption is initiated must be immediately terminated. The normal pedestrian clearance intervals must not be abbreviated.
- An all-red intersection preemption display is not allowed unless a special signal phasing is designed and implemented for security reason at the request of United States Capitol Police or United States Secret Service. The normal pedestrian clearance intervals may be abbreviated.
- The traffic signal must return to normal operation upon termination of the demand for preemption or the termination of the assured green interval.

At a traffic signal activated by both emergency vehicle preemption and railroad preemption, the railroad preemption will have the priority. If a demand for emergency vehicle preemption is initiated while the intersection is operating on railroad preemption, the railroad preemption sequence must continue unaffected until completion. In the event of a demand for railroad preemption during emergency vehicle preemption operation, railroad preemption must immediately assume control of the intersection.

When control of emergency vehicle preemption is by means of a radio or modulated light source, the following applies:

- The transmitter must be permanently mounted on the emergency vehicle or building and must operate at a range sufficient to permit a normal yellow change interval and any required clearance intervals to take place prior to the arrival of the emergency vehicle. The normal pedestrian clearance interval may be abbreviated.
- The preemption system may provide an indication (such as a special signal) to the driver of an emergency vehicle that preemption of the traffic signal has been effected. If a special light is used, the color must not be red, yellow or green.
- The system must be designed to prevent simultaneous preemption by two or more emergency vehicles on separate approaches to the intersection.

41.5.6.3. Bus/Transit Vehicle and Street Car Priority

This form of "low priority" signal is commonly known as Transit Signal Priority (TSP). TSP technology is used to reduce signalized delays for transit vehicles (buses or streetcars) by holding green lights longer or shortening red lights. TSP modifies the normal signal operation process to better accommodate transit vehicles, while emergency preemption interrupts the normal process for special events such as an approaching train or responding fire engine.

The TSP system consists of a bus Priority Request Generator (PRG) that communicates via secure, dedicated cellular network to a roadside PRG that manages TSP calls to the controller. Traffic management hardware and software and all roadside equipment are within DDOT's traffic management system. If the TSP system is implemented for Washington Metropolitan Area Transit Authority (WMATA) Metrobuses, the TSP equipment must be compatible with WMATA's existing Consolidated on-Board Ancillary Equipment and Fixed-end System (CoABE & FeS) for the implementation of conditional priority. WMATA buses are equipped a CoABE & FeS supplied by WMATA's vendor. This includes communications compatibility from WMATA buses to wayside equipment meeting the communications requirements agreed to between WMATA and its communications provider. The Metrobus on-board hardware, software, and firmware components must be compatible with this system. Final TSP implementation requires WMATA's fleet database update to configure intersection-specific data and also individual bus software upgrades.

41.5.7. Modification of Existing Signals

Where existing signals are to be modified, it is desirable that the construction plans include a separate plan of the existing system as well as plan showing the modifications (stage plans). It may also be necessary to include tabulation on the plan showing such appurtenances as backplates and special signal faces that may be difficult to discern on a complicated plan.

The design of any signal modification project should include adequate consideration for keeping the existing signals in operation while the modification work is being done.

41.5.8. Signals on Poles Owned by Others

Traffic signal equipment may be attached to poles owned by utility companies or other agencies when the number of poles at an intersection should be kept to a minimum. In such cases, it is necessary to enter into an agreement with the owner of the pole. The agreement should be written to hold the owner of the pole free of liability relative to operation of the traffic signal or damage to the pole, and to make the City responsible for moving the equipment in the event the pole is removed or relocated.

41.5.9. Temporary Signals for Haul Roads or One-Way Traffic in Construction Zones

General:

Temporary signals for traffic control at the intersection of a haul road, or to provide one-way traffic control through a construction zone, may be either the fixed or portable type. Such signals are normally installed by a contractor and approved by DDOT.

Requirements:

Each plan for temporary signals should include the equipment details as well as the following operating requirements:

- Temporary signals must meet the design standards described earlier in this section.
- Signal faces, detectors and control equipment are to be kept in good operating conditions at all times.
- When not in use, portable signals are to be removed from the vicinity of the highway, and fixed signals are to be placed in flashing operation, with yellow indications for the highway and red indications for the haul road.
- Timing of the signals will be determined by the DDOT traffic engineer.

- A SIGNAL AHEAD sign (and flashing beacon, if required) is to be placed on each approach of the highway in advance of the signal.
- Haul road signals must be operated using manual control or vehicle detectors. The signal will be green on the haul road only if the contractor's equipment is approaching the crossing. The haul road green interval must not exceed 10 seconds, and the highway green interval must not be less than 20 seconds, unless specific permission is given in writing. A 4-second minimum yellow change interval, and any required red clearance interval, must follow each green interval.
- One-way traffic control signals may use pre-timed or traffic-actuated controller units, or may be manually controlled. A 4-second minimum yellow change interval must follow each green interval. An all-red clearance interval must follow each yellow change interval. The all-red clearance interval must permit a vehicle to travel the length of the one-way lane before a green indication is shown to opposing traffic.
- Failure to comply with any of the above or other specified conditions will be justification for revoking the permit.

Equipment details:

- Fixed temporary traffic signals must be designed for 120-volt operation, while portable temporary signals may be battery operated.
- The vehicle signal faces must be the standard 3-section type with no less than two separate signal faces for each approach, including the haul road approaches.
- The signal faces must be mounted a minimum of 10 feet above the roadway and directed so that the indications are readily seen by traffic. The signal faces for highway traffic must be equipped with backplates.
- For one-way lane control or where conditions require sets of signals to be coordinated, the sets may be interconnected by cable or radio so they may be operated from a single manual or automatic control. The control system must be designed to prevent conflicting green indications.
- All signal displays must be fully compliant with all applicable provisions of the **MUTCD**.

41.5.10. Lane-Use Control Signals

Lane-use control signals are special overhead signals that indicate whether the use of specific lanes of a street or highway is permitted or prohibited or the impending prohibition of use.

Lane-use control signals must conform to the requirements in part IV of the **MUTCD**.

41.5.11. Ramp Metering Signals

Traffic control signals may be installed on freeway entrance ramps to control the flow of traffic entering the freeway facility.

Ramp metering control signals must conform to the requirements in part IV of the **MUTCD**. The design guidelines should be referenced to **CALTRANS Highway Design Manual** standards.

41.5.12. Signals at Movable Bridges

Signals installed at movable bridges are a special type of highway traffic signal, the purpose of which is to notify traffic to stop because of a road closure rather than alternately giving the right-of-way to conflicting traffic movements. They are operated in coordination with the opening and closing of movable bridges. Unlike traffic control signals, movable bridge signals may be operated frequently or extremely infrequently, depending on waterway traffic. Signals at movable bridges must conform to the requirements in part IV of the **MUTCD**.

41.5.13. HAWK Signals

A HAWK (High-Intensity Activated Crosswalk) signal, also known as a Pedestrian Hybrid Beacon, is a signal-beacon designed to help pedestrians safely cross busy streets. A HAWK crossing is a pedestrian-actuated traffic control device used to alert and stop motorists to permit pedestrians to cross the street safely. HAWK signal control is considered appropriate if **MUTCD** warrants are satisfied and engineering judgment confirms this to be the proper form of control. HAWK crossings are most often used near schools and other high-volume pedestrian traffic areas where a traffic signal is not warranted. In addition to crosswalk markings on the pavement, a HAWK crossing consists of traffic signal poles, street lighting, pedestrian push buttons and modified signal heads. Pedestrians activate the crossing cycle using a standard pedestrian push button or an Accessible Pedestrian Signal (APS) push button. The pedestrian movement is controlled by standard pedestrian indications that display “Don’t Walk,” “Walk” and flashing “Don’t Walk” symbols. When no pedestrians are present, the pedestrian indications display the “Don’t Walk” symbol continuously, until the crossing cycle is activated by a pedestrian. Vehicular traffic signals are active only during the crossing cycle, and go dark once the pedestrian crossing clearance period has terminated.

41.5.14. Bicycle Signals

Placement of a bicycle signal is optional and must follow the guidance provided in the **MUTCD Interim Approval for the Optional Use of Bicycle Signal Face (IA-16)** and **Interpretation Letter 9(09)-47(I)**.

41.5.15. Bus-Only Signals

Placement of bus-only signals accomplishes queue-jump operation for transit vehicles. All mountings and the LED modules must conform to the latest edition of the **DDOT Standard Specifications for Highways and Bridges**. Three-section 12-inch LED bus-only signal heads must consist of one of each of the following:

- White bar section, horizontal, masked, 120 VAC
- White triangle, masked, 120 VAC
- White bar, vertical, masked, 120 VAC

41.5.16. Streetcar Signals

Placement of streetcar signals must follow the guidance provided in the **DC Streetcar Concept of Operations** report.

41.6. Traffic Signal Operations

DDOT is responsible for the design, construction, operation and maintenance of all traffic signals.

41.6.1. Review of Traffic Signal Operations

All traffic signals in the District should be periodically reviewed for proper operation. The traffic signal operation should be observed during morning and evening peak traffic periods, as well as during off-peak periods. If an operating deficiency is observed, the reason for the deficiency should be determined. If there is a malfunction, the Transportation System Maintenance Division should be notified, and after corrective work is done, further surveillance should be conducted to be sure no deficiency remains. If it is concluded that there is a need for a design change, an analysis should be conducted to determine how to improve the design.

Improvements to consider are:

- Timing of:
  - Maximums or force offs
  - Gap interval
  - Offsets
  - Cycle length
- Time-of-day or traffic responsive settings
- Signal phasing or phase sequence (including leading pedestrian interval)

- Type of operation
- Coordination of signals
- Signs, striping and/or pavement markings
- Roadway improvements

Initial timing of traffic signals and any subsequent changes in timing is the responsibility of the Traffic Signal Team and/or its designee. Timing records must be kept and be readily available to maintenance and traffic operations staff and other agencies, where appropriate.

41.6.2. Signals at Interchanges

Signals at freeway interchanges require special considerations as to phasing and timing to minimize backup of traffic onto the freeway lanes.

In addition, signals at diamond-type interchanges require phasing and timing to allow the necessary turning movements from the cross street to and from the ramps without causing a backup of traffic between the ramps.

The decision of whether to use pre-timed or traffic-actuated operation depends not only on traffic conditions in the interchange area, but also on traffic conditions along the cross street. For example, a coordinated traffic signal system along the cross street may require that the signals at the interchange be coordinated with the cross street progression.

41.6.3. Timing of Green Intervals

The proportion of green time, or split time, allotted to each phase or combination of phases during a signal cycle should be as close as practicable to the proportion of critical lane traffic volumes on the respective approaches. In traffic-actuated operation, this proportioning is done automatically within the user-determined thresholds as a result of vehicle detector inputs to the controller unit.

Factors that may modify this proportioning are the time required for pedestrian intervals and the requirements of a coordinated system.

In the usual signal operation, predetermined splits can be selected by time-of-day or traffic-responsive equipment. In coordinated signal systems, the cycle length and the split can be verified by command from the system master controller.

41.6.4. Yellow Change Intervals

The purpose of the yellow signal is to warn approaching traffic that the green signal is ending and a red indication will be exhibited immediately thereafter.

The minimum duration of the yellow interval in the District of Columbia is 4 seconds. The duration of the yellow interval must be calculated using the ITE formula for designing the length of the yellow clearance interval.

41.6.5. Red Clearance Intervals

Red clearance intervals, which follow yellow change intervals, are not required, but should be considered where any of the following conditions exist: intersections that have had more than 5 right-angle collisions annually; intersections that are wide, offset or contain unusual geometry; intersections where the visibility of conflicting traffic is blocked or limited; intersections where the approach speeds are 55 mph or more; or where it is desirable to help clear vehicles that recurrently become queued in the intersection where there are permissive left turns. Red clearance intervals must be a minimum of 1.0 second in duration and may be increased in increments of 0.5 second.

Vehicle Clearance Interval

The vehicle clearance interval is defined as the sum of the yellow and the all red interval. The vehicle clearance interval in the District of Columbia is never less than 4.0 seconds in duration. The ITE formula for designating the length of the vehicle clearance interval must be used.

Pedestrian Clearance Interval

The pedestrian clearance interval is defined as the sum of the green plus flashing don’t walk, yellow, and all red intervals. The distance traveled by the pedestrian is the curb-to-curb distance along the center of the crosswalk. The pedestrian walking speed is defined as 3.5 feet per second.

Refer to **DDOT Guidelines for Basic Timing Parameters** for details pertaining to the calculation of minimum and maximum green, WALK, vehicular and pedestrian clearance intervals.

41.6.6. Operation of Pedestrian Signals and Countdowns

Pedestrian signal faces must display four indications: Steady WALKING PERSON, flashing upraised HAND, steady upraised HAND, and a numerical count-down display. All signalized crosswalks in Washington, DC are equipped with countdown LED modules. All pedestrian signal heads in the City must feature the upraised HAND / WALKING PERSON combination module in the top section and the countdown LED module in the bottom section.

Countdown signals should operate as follows:

- At an intersection, where all crosswalk signals activate automatically, the countdowns at the intersection may operate from the beginning of the WALK cycle. These are typically pre-timed intersections, which include intersections with no pedestrian detections and intersections with "Pedestrian Recalls" on all approaches. The only exception would be intersections with Transit Signal Priority, where the countdowns must operate from the beginning of flashing DON'T WALK intervals.
- At actuated locations, the countdowns must operate from the beginning of flashing DON'T WALK intervals, including intersections where only a crosswalk request or vehicular movement may be activated via demand.
- Intersections equipped with APS push buttons do not necessarily operate in an actuated mode of operation, and therefore the presence of push buttons should not be a determining factor regarding the mode of countdown operation.
- The operating modes for the countdown devices at a given intersection must not vary from each other.

Pedestrian timing should follow the most current edition of the **MUTCD**, specifically the chapter regarding Pedestrian Control Features. The total pedestrian crossing time consists of the WALK interval plus the pedestrian clearance time as defined in the **MUTCD**. Under normal conditions, the WALK interval should be at least 4.0 seconds. On an undivided highway, the pedestrian clearance time must never be less than the time required to walk from the curb to the opposite curb before opposing vehicles receive a green indication.

On a street with a median sufficient for a pedestrian to wait, the pedestrian clearance time should be no less than the time required to walk from the curb to the median before opposing vehicles receive a green indication.

Leading pedestrian intervals start a few seconds before the adjacent through movement phase. This allows pedestrians to establish a presence in the crosswalk and thereby reduce conflicts with turning vehicles. This option improves pedestrians' safety by increasing their visibility within the intersection and is applicable to intersections with frequent pedestrian-vehicle conflicts.

Pedestrian signal indications should normally be operated in conjunction with a vehicle phase. Pedestrian signals must be turned off during flashing operation of vehicle signal faces. Pedestrian actuation (requiring pedestrians to push a button) should be used only at actuated signals, and only when pedestrians are present at less than half of the signal cycles at the peak hour. At pre-timed signals, WALK and DON'T WALK indications should be part of every cycle.

An additional phase for the exclusive use by pedestrians is preferred at intersections with higher pedestrian volumes and relatively low cross street traffic volumes. This pedestrian-dedicated phase is configured such that no vehicular movements are served concurrently with pedestrian traffic. During this phase, pedestrians can cross any of the intersection legs and may even be allowed to cross the intersection in a diagonal path. This type of phasing, commonly known as "pedestrian scramble" has an advantage of reducing conflicts between right-turning vehicles and pedestrians, but it also decreases vehicular capacity and increases cycle lengths. The following factors should be considered before deciding to implement a "pedestrian scramble" phase:

- Pedestrian volumes and crosswalk utilization
- Pedestrian crashes
- Available sidewalk space for pedestrian accumulation
- Balance between vehicular delays and pedestrian waiting times

Refer to **DDOT Guidelines for Basic Timing Parameters** for details pertaining to the calculation of minimum and maximum green, WALK, vehicular and pedestrian clearance intervals.

41.6.7. Accessible Pedestrian Signals

APS include a variety of features that make traffic signals more accessible, particularly to pedestrians with vision impairments. The most common feature of these signals an audible tone and/or vibration to indicate the WALK interval. The signals may include a number of additional features, such as tactile arrows, tactile maps, Braille and raised print information, and an ambient noise-sensitive locator tone.

Where Are Accessible Pedestrian Signals Required?

The Americans with Disabilities Act (ADA) states that, "Municipalities should establish a plan to prioritize and make decisions about installations of APS at 'unaltered' intersections."

All designs of new and upgraded traffic signals must feature APS signals for all pedestrian crosswalks.

APS should be installed wherever pedestrian signals are installed in new construction or reconstruction projects, in accordance with the latest Public Rights-of-Way Accessibility Guidelines available at www.access-board.gov.

Where Are Accessible Pedestrian Signals Needed?

The MUTCD has guidance on the location of APS, and recommends the following:

The installation of accessible pedestrian signals at signalized intersections should be based on an engineering study, which should consider the following:

- Potential demand for accessible pedestrian signals
- A request for accessible pedestrian signals
- Traffic volumes during times when pedestrians might be present, including periods of low traffic volumes or high turn-on-red volumes
- The complexity of traffic signal phasing
- The complexity of intersection geometry
- Too little traffic is as great a problem for pedestrians who are blind as is too much traffic. In the absence of APS, blind pedestrians must be able to hear a surge of traffic parallel to their direction of travel to know when the walk interval begins.

Locations that may need APS include those with:

- Intersections with vehicular and/or pedestrian actuation
- Very wide crossings
- Major streets at intersections with minor streets having very little traffic (APS may be needed for crossing the major street)
- T- shaped intersections
- Non-rectangular or skewed crossings
- High volumes of turning vehicles
- Split-phase signal timing
- Exclusive pedestrian phasing, especially where right-turn-on-red is permitted
- A leading pedestrian interval

Where these conditions occur, it may be impossible for pedestrians who are visually impaired or blind to determine the onset of the WALK interval by listening for the onset of parallel traffic, or to obtain usable orientation and directional information about the crossing from the cues that are available.

How Should the Installation of Accessible Pedestrian Signals Be Prioritized?

Existing intersections

Prioritization information is based on existing intersections for retrofit with APS, either in response to requests or in updating an ADA transition plan.

Establishing priorities

Prioritization schemes should place only limited emphasis on factors related to frequency or likelihood of use by blind pedestrians. The information provided by APS may be necessary at any time, along any route, to residents, occasional travelers and visitors. Intersections having high pedestrian volumes are likely to have pedestrians whose vision is sufficiently impaired that they have difficulty using conventional pedestrian signals.

Of greater importance are factors related to determining whether sufficient acoustic information exists—at all times—to permit safe crossing at a particular intersection.

41.6.8. Continuity of Operation

Once a traffic signal at an intersection or pedestrian crossing has been energized, it must not be turned off unless arrangements have been made for temporary control by traffic officers, temporary stop signs, or an approved portable signal.

When a traffic signal at an intersection or pedestrian crossing is not to be in operation for a planned, extended period of time, the signal faces should be hooded, turned away from traffic or removed.

41.6.9. Flashing Operation

All new traffic signals must be operated on flash mode for a period of 7 days prior to being placed on full color operation for the first time. In this mode, the signals usually flash yellow for the main street and red for the side street, but all red flashing indications may also be used. HAWK signals do not require flash operation prior to activation.

Each traffic signal sequence of operation must feature a flash sheet describing the flash operation of the signal under emergency conditions. The engineer must determine if a RED/RED or YELLOW/RED flash is appropriate for each intersection.

Pre-timed or semi-traffic-actuated traffic signals may be operated in a flashing mode at night. Flashing yellow operation for the major street in a coordinated signal system reduces control of vehicle speed. If such speed control is desired, properly spaced signals should remain in standard full color operation.

Actuated signals at an isolated intersection should never be operated in a flashing mode except during emergencies, while a conflict monitoring device is in operation, or during railroad preemption.

The emergency mode of operation for all traffic signals must be flashing operation.

41.7. Flashing Beacons

41.7.1. Introduction

Typical applications for flashing beacons include the following:

- Signal ahead
- Other warning and regulatory signs
- Rectangle flashing beacon
- Schools
- Speed limit signs
- Intersection control
- Fire stations
- Stop signs
- Bus stops near freeway interchange
- At intersections where a more visible warning is desired

A flashing beacon consists of one or more traffic signal sections with flashing indication. Because the effectiveness of flashing beacons has not been consistent from one location to another, the decision of whether to install a flashing beacon should not be based solely on the guidelines listed in this section.

Flashing beacons to be installed must conform to the following requirements:

- Lenses should be 12 inches in diameter, except that lenses for flashing beacons at bus stops, stop sign flashing beacons, speed limit sign flashing beacons and beacons used in connection with ramp metering may be 8 inches in diameter.
- A dimming device must be used to reduce the brilliance of yellow flashing beacons during nighttime operation.
- Two-section flashing yellow beacons may be connected to flash alternately.

- A school flasher assembly must be composed of a 24-inch by 48-inch type S5-1 static metal sign flanked above and below by a 12-inch-diameter one-section traffic signal head with a solid yellow LED module wired into the housing. The bottom of the lower beacon must be 10 feet above the ground. Each beacon must be programmed to flash alternately during appropriate school crossing periods. The design must be such that the electrical cable from the beacon assembly is connected to the nearest traffic signal controller, which will provide the electrical service to operate the beacons. In addition, the controller configuration package must be specified as a Special Function for the proper operation of the school flasher.

41.7.2. Design

On divided highways where the median is 8 feet wide or greater, the installation may consist of two type 1 standards, each with a sign and a 12-inch signal face, with one standard located in the median and the other near the right shoulder.

Note that the above installation designs may result in noncompliance with the **CALTRANS Highway Design Manual** mandatory standards for horizontal clearance and shoulder width, and the advisory design standard for clear recovery zones. If such nonstandard features cannot be avoided, the Designer must obtain approval from the DDOT Traffic Signal Team.

On undivided highways or highways where the median is less than 8 feet wide, the installation may consist of a single standard located near the right shoulder as described for use on divided highways, or it may be a type 9 cantilever flashing beacon installation.

All flashing beacons must be designed and presented to DDOT in the form of an S Drawing subject to DDOT approval. A traffic signal Sequence of Operation (TS) Drawing will be required if the flashing beacons are to be time-of-day controlled through the Central Signal System.

41.7.3. Signal Ahead Flashing Beacons

Yellow flashing beacons may be used with SIGNAL AHEAD signs in advance of:

- An isolated traffic signal on either a conventional highway or on an expressway
- The first traffic signal approaching an urban area
- Any traffic signal with limited approach visibility or where approach speeds exceed 50 mph

41.7.4. Warning or Regulatory Sign Flashing Beacons

Flashing beacons should be used only to supplement an appropriate warning or regulatory sign or marker. Typical applications include:

- Obstructions in or immediately adjacent to the roadway
- Supplemental to advance warning signs
- At mid-block crosswalks
- At intersections where a warning is appropriate

The beacon should be operated only during those hours when the necessity for the warning or regulation exists.

41.7.5. Rectangular Rapid Flashing Beacons (RRFB)

RRFB implement amber LEDs that flash in an irregular pattern to supplement standard warning signs and pavement markings at unsignalized intersections and mid-block crosswalks. RRFB can be activated by pedestrians manually by a push button or passively by a pedestrian detection system for two-lane or multi-lane roadways.

The benefits of RRFB include:

- Lower-cost alternative to traffic signals and hybrid signals
- Increased driver yielding behavior at crosswalks when used with standard signs and markings

41.7.6. Flashing Beacons at School Crosswalks

Flashing beacons at school crosswalks may be installed on City streets. Flashing school beacons must be connected to the City’s Traffic Management Center through a nearby traffic signal controller so that the times of operation can be controlled through Special Functions.

41.7.7. Speed Limit Sign Flashing Beacons

A Speed Limit Sign flashing beacon may be installed on a City street in connection with a fixed or variable speed limit sign. The size and location of the circular yellow lenses are described in the MUTCD.

41.7.8. Intersection Control Flashing Beacons

An Intersection Control flashing beacon consists of one or more signal sections, with a flashing circular yellow or circular red indication in each face. Intersection Control flashing beacons must be either flashing yellow for one route (normally the major roadway) and flashing red for the remaining approaches or flashing red for all approaches.

Newly installed overhead Intersection Control flashing beacons must flash red for each approach.

A stop sign must be used on each approach with a flashing red indication.

Basic intersection lighting should be installed at intersections where an Intersection Control flashing beacon is to be installed.

41.7.9. Flashing Beacons for Fire Stations

Flashing beacons at fire station driveways or at intersections immediately adjacent to a fire station may be installed. The flashing beacons should be used only to supplement an appropriate warning or regulatory sign. The flashing beacons must be actuated from a non-illuminated condition by a switch at the fire station.

41.7.10. Stop Sign Flashing Beacons

A Stop Sign flashing beacon consists of one or two signal sections with flashing circular red indications in each section. The bottom of the Stop Sign flashing beacon housing must not be less than 12 inches nor more than 24 inches above the top of the stop sign.

41.7.11. Flashing Beacons at Bus Stops on Freeway Interchanges

At locations of approved bus stops in interchange areas, a flashing beacon may be provided near the top of a lighting standard as a flag stop.

The following design and operational requirements must be met:

- A push button must be provided on the lighting standard with a sign explaining the purpose and operation. The sign must state that if no bus has arrived within 15 minutes (or other time) after the button has been actuated it will be necessary to push it again.
- The flashing beacon must consist of a 12-inch signal section with an uncolored or white lens mounted on the lighting standard in such a position that it can be seen by an approaching bus driver on the freeway.
- The operation of the control must be such that the flashing beacon will operate for 15 minutes after the button has been actuated and then go out.

41.8. Plans, Specifications and Estimates Submittals

After the design of a traffic signal location or a number of traffic signal locations is completed for construction, a Plans, Specifications and Estimates (PS&E) package is submitted to FHWA for Construction Fund (C) and Construction Engineering Fund (CE) approval. The PS&E package features the plans, specifications and estimates for the project. The plans are the Signal Drawing and the Traffic Signal Sequence of Operation. The specifications, which must reference the most current version of the **DDOT Standard Specifications for Highways and Bridges**, include specified and contract provisions needed to perform the work. The engineer's cost estimate is based on contracting items and unit prices supplied by DDOT. All pay item descriptions and numbers must be consistent with the AASHTO Estimator Spreadsheet.

41.9. Financing

Federal funds for a specific traffic signal project are identified in the budget and the Federal Aid obligation plan before the PS&E package is formally submitted to FHWA for permission to advertise. The project is advertised for competing bids by the contract office after FHWA concurs and federal funds are formally obligated.

Normally, the cost of a new traffic signal or the modification of an existing traffic signal is to be shared by the District of Columbia and FHWA. The District may accept private funds or a portion of private funds if the signal is installed for a private use (e.g., garage entrance). DDOT will agree to install traffic signals using private funds only if the new signal can be installed without serious disruption to traffic signal coordination.

41.10. Salvaged Electrical Equipment

A construction project sometimes includes the removal of a traffic signal, lighting or other electrical equipment that will not be reused on the particular project. The determination as to whether particular electrical equipment is salvageable will be made by the authorized engineer from DDOT. The determination of whether to salvage existing equipment should be made on the basis of the economic and historical benefit to the District of Columbia.

All electrical equipment removed and determined not to be salvageable becomes the property of the Contractor and is disposed of by the Contractor. All electrical equipment determined to be salvageable is to be properly removed, packed, taped and stored by the contractor until delivery to the DDOT signal shop at a location designated by the engineer.

41.11. Permits

A traffic signal construction permit may be issued to a private developer or his contractor after the PS&E package submission is completely accepted by the DDOT Engineer. Issuance of a traffic signal permit does not preclude the requirements of other approvals or permits by other agencies.

42 Intelligent Transportation Systems (ITS)

42.1. Introduction

42.1.1. General

The purpose of this chapter is to guide designers through the steps required to complete a set of plans and specifications for DDOT ITS projects, including projects executed by DDOT or other jurisdictions in the District of Columbia. ITS projects are defined as those that apply information and communication technologies in the field of road transport, traffic and mobility management, and for interfaces with other modes of transport. As part of this guidance, this chapter includes:

- An overview of DDOT ITS and operations capabilities and objectives
- Information on the DDOT ITS design process and plan development stages
- Information on DDOT-specific ITS planning and design guidelines to bridge the gap between various DDOT ITS standards, specifications, reference manuals, and other industry practices that DDOT has elected to adopt

Designers may use this chapter as an initial point of reference to find general planning and design guidance, or to find additional information that may be available from DDOT or within the industry on specific ITS applications. Additionally, the **DDOT ITS and Communications Master Plan** (2013) is available as a resource for planning ITS and communications infrastructure in the District.

ITS designs utilize information and communications technologies available within the transportation industry to:

- Improve safety and response in incident and emergency management
- Provide advanced traveler information
- Maximize mobility and security within the transportation system

DDOT owns, operates and maintains a wide array of ITS technologies to support arterial and freeway traffic management. ITS helps DDOT identify and manage incidents and provides data used in a wide variety of applications.

This chapter includes the following sections related to ITS subsystems and communications design:

- Closed-Circuit Television (CCTV) Camera System Design
- Dynamic Message Sign (DMS) Design
- Vehicle Detection System and Count Station Design

- Roadway Weather Information System (RWIS) Design
- ITS Communications Design

To manage ITS infrastructure, DDOT has multiple transportation management centers (TMCs) that are critical to day-to-day and emergency operations of the District transportation system. TMC operations staff monitor and disseminate traffic and emergency information using the DDOT network of ITS devices. The Advanced Transportation Management System is the centralized management system at the TMCs for traffic management activities, including data collection and sharing, management of planned events, and real-time management of incidents impacting traffic in the District.

42.1.2. ITS Design and Plan Development Process Overview

All DDOT ITS projects follow the Federal Highway Administration (FHWA) Rule 940 process for systems engineering in the planning, design and implementation of ITS technologies. The development process typically begins with evaluating the project concept within the context of the regional ITS architecture in place and developing a Concept of Operations (ConOps) document for review and approval. ITS requirements are then developed from the ConOps document for review and approval before any design-related activities take place. For more information and guidance on the systems engineering process, refer to the **FHWA Systems Engineering for ITS Handbook** (http://ops.fhwa.dot.gov/publications/seitsguide/section7.htm).

Upon approval of the ConOps and system requirements documents, the ITS plan development timeline and coordination activities can proceed as presented in Figure 42-1. The flowchart depicts the general requirements expected of the ITS designer during the various stages of plan development and should be used as a reference during coordination and scheduling efforts with DDOT staff.

During the initial predesign phase, the designer is required to discuss with DDOT the proposed system needs, objectives, existing communications in area of deployment, network link selections (for example, Ethernet Internet Protocol [IP] over fiber optic cable, wireless through leased Code Division Multiple Access [CDMA], or twisted pair serial to Ethernet IP) and network structure and testing requirements to be considered for the proposed ITS project.

During this stage, the ITS designer will also coordinate with DDOT on current agency mandates regarding hardware and software cyber security, as well as the process for incorporating new devices into existing software (confirmation of licensing requirements, etc.).

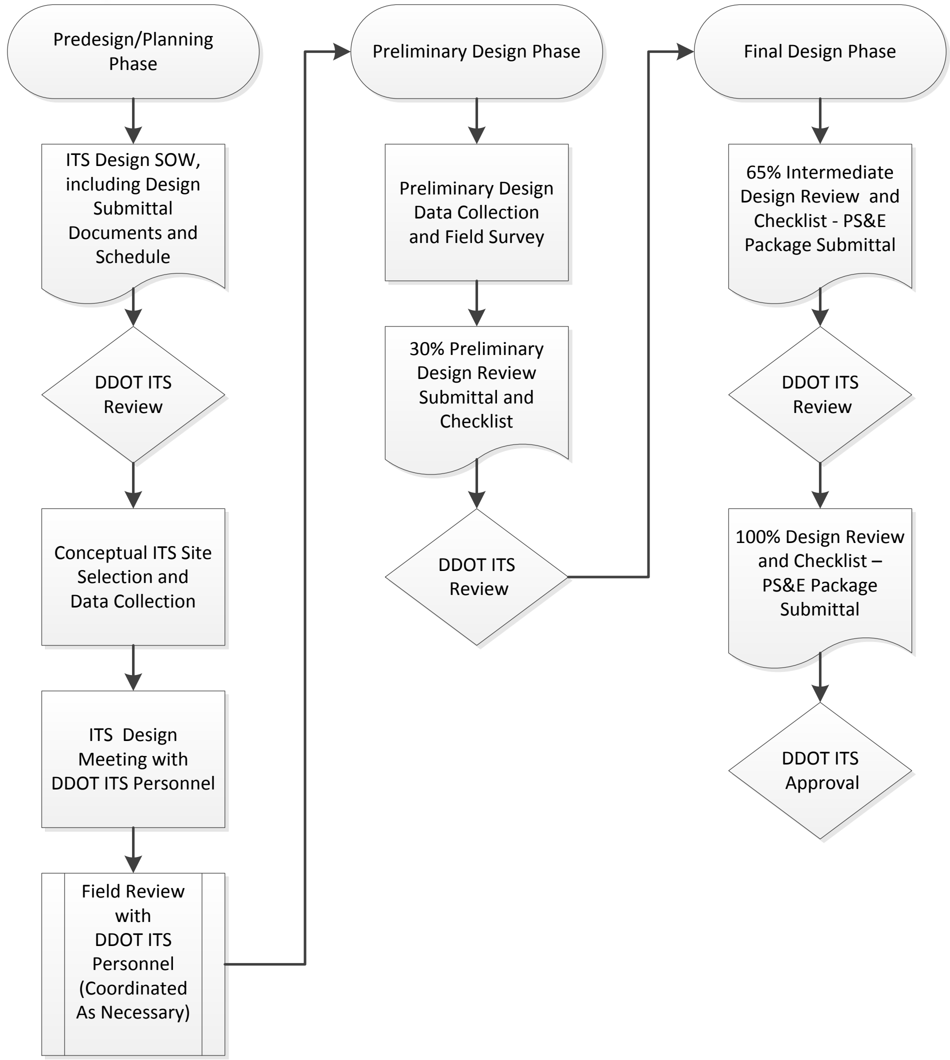


Figure 42-1 | ITS Plan Development Flowchart

The components of an ITS project Plans, Specifications and Estimates (PS&E) package may include the following elements:

- ITS Site Index Plan including overview maps of proposed deployment locations
- ITS Site Plans
- ITS Communication Plans including system block diagrams and communications one-line schematics detailing device-to-TMC communications
- ITS Electrical Plans including service details and electrical one-line schematics
- ITS Device Details
- ITS Structure Plans
- Erosion and Sediment Control Plans

- Maintenance of Traffic Plans
- ITS Special Provisions
- ITS Contract Estimate
- ITS Design-Supporting Calculations

42.1.3. 30%, 65% and 100% Design Submittal Checklists

Design submittal checklists are located at the end of this chapter. The checklists illustrate DDOT expectations at each level of submittal, including such content as system-level requirements, field-level confirmations, and other information for verification during ITS hardware and software deployment.

The designer representative is to complete and sign each design submittal checklist and provide it with the applicable level of submission.

42.2. CCTV Camera Design

The purpose of this section is to summarize the DDOT CCTV camera system features and requirements, and describe standard practices and procedures related to the design of CCTV camera deployments in the District.

42.2.1. System Overview

CCTV cameras are placed at intersections and strategic locations around the District to provide situational awareness, and allow traffic monitoring, surveillance, and operation of the transportation system.

The existing CCTV camera system in the District provides surveillance that DDOT Operations staff uses for system-wide situational awareness monitoring and a number of valuable incident detection, verification, and response activities that assist emergency responders.

CCTV camera deployments can be generally categorized into two types:

- **Portable CCTV Camera Systems.** Portable trailer-mount CCTV systems are used primarily in temporary circumstances such as to monitor traffic and incidents in a work zone during a construction project.
- **Permanent CCTV Camera Systems.** CCTV systems mounted on permanent infrastructure are deployed as part of the **DDOT ITS and Communications Master Plan**. Deployments on standalone CCTV poles and traffic signal poles are the most common types in the District.

CCTV cameras are designed and installed in accordance with the **DDOT Standard Specifications for Highways and Structures** and the **DDOT Standard Drawings,** with all components designed to be compatible with DDOT's existing traffic camera system. Several industry standards related to CCTV camera design are listed below.

- National Transportation Communications for ITS Protocol (NTCIP) 1205 – NTCIP Objects for CCTV Camera Control
- ONVIF Network Interface Specification Set, Current Version
- American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Signs
- National Electrical Manufacturers Association (NEMA) TS 4 standards

42.2.2. CCTV Camera Placement

The ITS designer is responsible for selecting conceptual CCTV camera device sites in coordination with DDOT ITS personnel and subsequently conducting initial field verification of those sites. The following is a list of factors to be considered when selecting a camera location:

- **CCTV Camera Purpose.** CCTV cameras may be used to monitor roadways at critical or congested intersections, interchanges of limited-access roadways, DMSs or other critical ITS infrastructure.
- CCTV Camera Placement:
    - **Intersection CCTV cameras**:
        - Provide coverage for all directions of approach to the intersection (at critical intersections, multiple cameras may be required to obtain optimal visibility)
    - **Limited-access corridor CCTV cameras**:
        - Provide 100% visual coverage (no occlusions from sign structures or overpasses) of the entire roadway with some overlap in coverage areas of adjacent cameras
        - Space no more than 1 mile apart
        - Locate on outside of roadway curve
        - Locate at higher elevations when possible for viewing distance (consider maintenance access)
        - Locate at interchanges to capture intersecting arterials and ramps
    - **CCTV cameras at DMS locations**: Place a CCTV camera in a location that can be used for DMS message confirmation.

  - **Visual obstructions**: If it is determined that sightline obstructions exist (trees, structures, roadway curvature, etc.), use a bucket truck when required by DDOT to validate CCTV camera footage and determine the appropriate location and height for the CCTV camera. Digital video and/or digital pictures of views from all directions at the proposed camera location and mounting height must be provided to DDOT ITS personnel for review and comment.

- **ITS Device Collocation.** CCTV cameras can be collocated with other ITS infrastructure efficiently in situations where power and communications facilities are readily available.

42.2.3. CCTV Camera Type

CCTV cameras used by the District are pan/tilt/zoom (PTZ) dome cameras. Refer to **DDOT Standard Specification** for details on current qualified products and use of approved equivalents.

42.2.4. CCTV Camera Mounting

CCTV cameras are typically installed as top-pole mounts on either standalone CCTV poles or traffic signal poles for intersection deployments. Taller camera pole structures (for example, poles exceeding 40 feet in height) are not permissible in most areas of the District and are planned and designed on a project-specific basis. Where applicable, camera lowering devices should be installed on tall camera poles for maintenance access.

When approved by the District, in some design situations, cameras may be located on existing infrastructure using an appropriate mounting bracket (for example, an existing sign structure, bridge, or tunnel). When planning CCTV camera locations and mountings, the designer should consider image stability and industry-supported solutions.

Refer to the **DDOT Standard Drawings** for typical pole-mounted CCTV camera installation details.

42.2.5. CCTV Camera Structures

For cameras mounted on traffic signal poles, refer to the **DDOT Standard Specifications for Highways and Structures** for traffic signal pole structural and foundation requirements and the **DDOT Standard Drawings**. Foundations for larger camera structures are designed on a project-specific basis.

42.2.6. CCTV Camera Control Cabinet

CCTV camera cabinet layouts are to be designed in accordance with the **DDOT Standard Specifications for Highways and Structures**.

CCTV camera control cabinets may be pole- or ground-mounted enclosures, depending on the application or collocation with additional ITS devices. Enclosures should be oriented so that field personnel face the roadway while performing routine maintenance at the cabinet location.

42.2.7. CCTV Communications System Configuration

CCTV cameras are to be designed to communicate with the DDOT TMC over the existing or proposed communications network identified for use in the ITS project. The designer will work with DDOT to determine the best method for conveying field data from the device to the TMC. Three types of field-to-center communications may be used, depending on the location of the CCTV:

- The existing DDOT traffic signal controllers communications network is a twisted pair copper cable network used to communicate with the citywide signal system and ITS device subsystems
- Fiber optic cable network (particularly for freeway device locations where fiber optic communications networks are available or proposed)
- Wireless cellular service link via digital cellular modem

Refer to the **DDOT Standard Drawings** for typical CCTV camera system communications configuration details for the existing DDOT network.

42.3. DMS Design

The purpose of this section is to describe the DDOT DMS system along with standard practices and procedures related to the design of DMS deployments in the District.

42.3.1. System Overview

DMSs are placed at strategic permanent locations to inform travelers in the District; they are often used at critical messaging locations for DDOT traffic operations, emergency evacuation, and incident management. All DMSs are remotely managed, monitored and controlled by DDOT operators at the Traffic Management Center.

DMS messaging uses include emergency operations, incident management, traffic management (including construction or maintenance activities), weather conditions, special events, AMBER alerts, safety messages and travel time displays.

Travel time messaging is used at DMS locations during normal operations to display distance and present travel times to key destinations. Travel times are updated at regular intervals using real-time data collected at detection locations.

DMSs are designed in accordance with the **DDOT Standard Specifications for Highways and Structures** and the industry standards listed below.

- Manual on Uniform Traffic Control Devices (MUTCD)
- NTCIP 1101, 1201, 1203, 2104, 2202, and 2301
- AASHTO Standard Specifications for Structural Supports for Highway Signs
- NEMA TS 4 standards

42.3.2. DMS Placement

The designer is responsible for selecting conceptual DMS sites in coordination with DDOT ITS personnel and subsequently conducting initial field verification of those sites. In selecting a DMS location, the existing roadway corridor signing plan must be reviewed to determine the sign positioning in relation to other roadway signage in accordance with **MUTCD** guidelines. The following is a list of factors to be considered by the designer:

- **DMS Purpose.** DMSs are placed before decision points and alternate routes on a roadway corridor (for example, major interchanges and established detour routes).

  In the District, DMSs are primarily located along freeway segments or at tunnel portals and approaches. A conceptual DMS messaging plan and its intended use should be taken into consideration during location selection. Some proposed DMS locations are already identified in the **DDOT ITS and Communications Master Plan**.

- DMS Placement:
  - **Visibility**. Verify DMS location has at least 1000 feet of sign visibility and a minimum of 800 feet of legibility distance for drivers to read and process messaging effectively.
  - **Clarity**. Maintain a minimum of 800 feet of separation between the DMS and roadway guide signs.
  - **Viewing time**. Verify the motorist has a minimum of 9 seconds to clearly view the DMS message under driving conditions.
  - **CCTV coverage of DMS**. Verify sign is visible by a CCTV camera located upstream of the sign location for message confirmations.
  - **Travel time messaging**. Evaluate distances to proposed data collectors and travel time destinations.
  - **Alternate or diversion routes**. Locate DMS 1 to 4 miles in advance (no closer than 1 mile) of an alternate route or major decision point.

  - **Proximity to intersections**. DMSs should not be placed close to a signalized intersection.
  - **Viewing angle and rotation**. Evaluate position with respect to the roadway alignment during design.
  - **Vertical or horizontal curves**. Curves affecting sight distance to the DMS should be evaluated during design.
  - **Visual obstructions**. Obstructions to signage sightlines should be evaluated during site data collection (tree limbs, structures, roadway curvature, etc.). Location of the DMS relative to the position of the sunrise/sunset under daytime conditions can also be confirmed to check for sun glare potential.

- **ITS Device Collocation.** Other ITS devices (CCTV, vehicle detection) can be collocated with DMS efficiently in situations where power and communications facilities are readily available, or where vehicular data collection may be required.

42.3.3. DMS Type

Per **DDOT Standard Specifications for Highways and Structures**, DMSs are designed as full-matrix LED signs of the following types:

- **Type I.** Walk-in access housing DMS installed on major freeways and arterials as overhead or pedestal sign structures. Type I signs should be used when the DMS is in a limited access roadway corridor.
- **Type II.** Front access housing DMS installed on city streets as cantilever or pedestal sign structures. Type II signs should be used when the DMS is on a small arterial or city street.

42.3.4. DMS Structures

Refer to the **DDOT Standard Specifications for Highways and Structures** for sign structure and foundation requirements. Depending on the sign application, DMSs may be installed on overhead, cantilever or pedestal-mount sign structures. Design criteria for each type of DMS used in the District (for example, sign types, maximum dimensions and weight) can be found in **DDOT Standard Specifications for Highways and Structures**.

42.3.5. DMS Controller Cabinet

DMS controller cabinets are to contain 19-inch rack-mount layouts designed in accordance with the **DDOT Standard Specifications for Highways and Structures**.

DMS controller cabinets may be structure- or ground-mounted enclosures, depending on the application or collocation with additional ITS devices. Enclosures should be oriented so that the maintainer is facing the roadway while performing maintenance at the cabinet location.

42.3.6. DMS System Configuration

Communications System. For DMS controller communications interface requirements, refer to requirements and NTCIP sections of **DDOT Standard Specifications for Highways and Structures**.

All DMS are to be designed to communicate with DDOT TMCs via the following three types of field-to-center communications (depending on the sign location):

- 900 MHz wireless link and twisted pair cable combination
- Wireless cellular service link via digital cellular modem
- Fiber optic cable network (particularly for locations where fiber optic communications networks are available or proposed)

Electrical System. All DMS are to be designed to include an uninterruptible power supply (UPS) battery backup system according to **DDOT Standard Specifications for Highways and Structures**.

42.4. Vehicle Detection System and Count Station Design

The purpose of this section is to describe typical DDOT vehicle detection sites and standard practices and procedures related to the design of vehicle detection system deployments in the District. Detection options are also discussed in **Chapter 41** of this manual.

42.4.1. System Overview

Vehicle detection systems are standalone devices deployed to detect the presence of vehicles and provide real-time data on vehicle presence, speed, volume and occupancy, as well as vehicle classification to a limited extent. Vehicle gaps, travel times, and incident occurrence can be detected using automated data analysis techniques applied to the data gathered from vehicle detection systems. These data systems are also used extensively in TMC operations activities involving traffic monitoring/management and emergency management.

Vehicle detection systems and permanent count stations allow the collection of historical and real-time traffic data, which DDOT uses to evaluate system performance and when considering future decisions and planning.

DDOT has deployed different technologies at vehicle detection sites to collect traffic data, including in-pavement wireless magnetometer sensors and permanent traffic count stations utilizing inductive loops and acoustic, microwave, infrared and video-based detectors.

Vehicle detection systems are designed in accordance with the **DDOT Standard Specifications for Highways and Structures** and the industry standards listed below.

- NTCIP 1203
- NEMA TS 4 standards

42.4.2. Vehicle Detector Data

For vehicle detection system deployments, the system requirements and data needs must first be defined (as part of a ConOps or System Requirements document) to identify how collective deployments will meet data precision and quality requirements. Designers should verify that detection coverage and spacing will be sufficient as part of the design process.

Permanent vehicle detection systems are required to measure the following data:

- Vehicle speed
- Vehicle volume
- Vehicle presence or lane occupancy

On-ramp and off-ramp vehicle detection is typically designed for mainline corridor detection systems.

Permanent continuous vehicle count stations are installed at critical locations across the District as part of citywide data collection efforts.

42.4.3. Detector Placement

- **Detector Purpose.** Vehicle detectors are typically deployed for either data collection or incident detection
- **Detector Placement.** Detectors should be placed to achieve the following:
    - Provide sufficient data on density of traffic to detect incidents and congestion levels, as well as calculate accurate travel times throughout the area of deployment
    - Space 1/2 mile to 1 mile apart for urban or regularly congested sections
        - Coordinate spacing criteria with DDOT ITS personnel during the scoping stage of the project

- Avoid obstructions to detection zone (for example, adjacent structures or an undesirable offset to roadway barrier sections may result in decreased accuracy at microwave detection locations)

- **ITS Device Collocation.** Vehicle detection systems can be collocated with other ITS infrastructure efficiently in situations where power and communications facilities are readily available

42.4.4. Vehicle Detector Type

Vehicle detector technologies (both intrusive and non-intrusive) may include the following:

- Inductive loops may be used at continuous vehicle count station locations
- In-pavement wireless detection systems send data through a wireless connection to a roadside access and/or repeater point
- Microwave radar traffic flow detection systems are side-fire non-invasive roadside detectors
- Video image traffic flow detection systems are non-invasive roadside detectors capable of limited vehicle axle classification
- Mainline corridor detection systems use microwave radar or non-intrusive detection systems
- Permanent continuous vehicle count stations can use inductive loops, microwave or video-based detectors, depending on the application

42.4.5. Vehicle Detector Structures

Vehicle detection systems may be designed for mounting on standalone pole installations or collocated on other ITS device structures or infrastructure.

Refer to the **DDOT Standard Specifications for Highways and Structures** for pole structure and foundation requirements.

42.4.6. Vehicle Detection Cabinets

Vehicle detection cabinet layouts are to be designed in accordance with the **DDOT Standard Specifications for Highways and Structures**.

Vehicle detection cabinets may be pole- or ground-mounted enclosures depending on the application, or collocated with other ITS devices. Enclosures should be oriented so that the maintainer is facing the roadway while performing maintenance at the cabinet.

42.4.7. Vehicle Detection Communications System Configuration

Vehicle detection devices are connected to a digital subscriber line (DSL) modem in the detection cabinet that transmits data over the existing or proposed communications network pathway back to a DDOT TMC. Detector systems are to be designed for integration with DDOT CapTOP software. Three types of field-to-TMC communications may be used, depending on the location of the detector:

- The existing DDOT traffic signal controllers communications network is a twisted pair copper cable network used to communicate with the citywide signal system and ITS device subsystems
- Fiber optic cable network (particularly for freeway device locations where fiber optic communications networks are available or proposed)
- Wireless cellular service link via digital cellular modem

42.5. RWIS Design

The purpose of this section is to describe the DDOT RWIS system and standard practices and procedures related to the design of RWIS deployments in the District.

42.5.1. System Overview

DDOT deploys RWIS as an advanced planning tool to detect adverse weather conditions so that DDOT personnel can implement weather management strategies involving traffic advisories, traffic control and roadway treatment. Maintenance and operations personnel use RWIS information to assess the nature and magnitude of weather conditions, make staffing decisions, plan treatment strategies, minimize costs (including labor, equipment and materials) and assess the effectiveness of treatment activities.

RWIS equipment collects weather data on present status roadway surface conditions, measuring water, ice and snow on the roadway and actively monitoring roadway temperature on site. Additionally, atmospheric or meteorological conditions are monitored, including air temperature, relative humidity, dew point, precipitation classification, visibility, barometric pressure, and wind and speed direction.

Data from the RWIS sensors in the field is collected by a Remote Processing Unit in the RWIS control cabinet. Weather information collected by RWIS is displayed and archived on the DDOT RWIS server system so DDOT can access present and historical weather information at site locations.

RWISs are designed in accordance with **DDOT Standard Specifications for Highways and Structures** and the industry standards listed below.

- NTCIP 1204 – Object Definitions for Environmental Sensor Stations
- NEMA TS 4 standards

42.5.2. RWIS Placement

RWIS locations are strategically located for citywide real-time weather condition data and are proposed in the **DDOT ITS and Communications Master Plan** according to District of Columbia ITS Architecture regional objectives. The following should be considered by the designer in RWIS placement and site design:

- **RWIS Purpose.** A weather station may be deployed in various areas, including areas with winter maintenance concerns or areas with a historically high number of accidents in inclement weather. These locations could include bridge decks and approaches, horizontal or vertical curves, areas that are ice-prone due to flooding from nearby water bodies, or sections of roadway prone to fog and low visibility conditions.
- RWIS Placement:
    - **RWIS site topography**. RWIS locations require a flat area suitable for the station foundation and grounding installation.
    - **Maintenance considerations**. Because RWIS measurement devices are sensitive, frequent maintenance and calibration is to be expected and should be considered in site placement.
    - **RWIS sensor placement**. DDOT uses non-intrusive roadway sensors to monitor roadway surface conditions. RWIS sensors should be positioned away from potential roadside splashing and snowplow removal operations to prevent sensors from becoming dirty or disabled.
- **ITS Device Collocation.** RWIS sites contain a PTZ CCTV camera that is collocated on the tower structure for verifying traffic and weather conditions in conjunction with the weather data collected.

42.5.3. RWIS Type and Instrumentation

An RWIS station includes a tower structure that supports all sensors and equipment listed in **DDOT Standard Specifications for Highways and Structures**.

42.5.4. RWIS Structures

RWIS tower structure design is typically the responsibility of the vendor, designated through project submittals signed by a Professional Engineer registered in the District of Columbia. The ITS designer should perform an adequacy check to mitigate any obstacles to the vendor designing and supplying a reasonable structure and support at the locations identified on the proposed site plan.

Refer to the **DDOT Standard Specifications for Highways and Structures** for structural and foundation requirements.

42.5.5. RWIS Control Cabinet

Cabinet layouts are to be designed in accordance with the **DDOT Standard Specifications for Highways and Structures**.

42.5.6. RWIS Communications System Configuration

RWIS locations transmit real-time environmental data from the RWIS controller cabinet over the existing or proposed communications network pathway back to the DDOT TMC, where data is collected, archived and displayed on the RWIS server system. Types of field-to-center communications for RWIS locations include:

- The existing DDOT traffic signal controllers communications network is a twisted pair copper cable network used to communicate with the citywide signal system and ITS device subsystems
- Fiber optic cable network (particularly for freeway device locations where fiber optic communications networks are available or proposed)

42.6. ITS Communications Design

The DDOT communications network provides service for field-to-TMC connections with ITS devices District-wide. The communications network is a critical component of the District's freeway management system, citywide signal system, and emergency management system. The data carried across the communications network enables DDOT to efficiently operate and monitor many elements of the transportation system. The communications network is the primary service network for the traffic signal system and CCTV video surveillance system. DDOT's center-to-center (TMC-to-TMC) high-bandwidth connections are located on a broadband network provided by DC-Net, the telecommunications provider of the District Office of the Chief Technology Officer.

This section describes the basic design principles associated with the existing and proposed communications networks used for ITS deployment.

42.6.1. Existing and Proposed Communications Networks Overview

42.6.1.1. Existing Systems

For current designs, DDOT is shifting to a predominately Ethernet IP-based backbone network, where ITS communications will use an Internet Service Provider's network to transmit to DDOT's TMC-to-TMC network (see Figure 42-2). A small percentage of ITS equipment communications links will remain as point-to-point connections, and no future design is anticipated to involve twisted pair point-to-point links. Fiber optic cable trunk line deployment is also planned for future ITS communications.

Before the shift to the IP-based network, the physical infrastructure of the ITS and traffic management system largely consisted of twisted pair copper cable contained in underground duct bank and conduit systems. This twisted pair network was augmented with wireless links, cellular links and General Packet Radio System communications, some of which remain in operation.

42.6.1.2. Proposed Communications Network Design

As described in the ITS Design and Plan Development Process section, during the initial predesign phase the ITS designer is required to meet and discuss with DDOT the proposed system needs, objectives, communications available in area of deployment, network link selections (for example, Ethernet IP over fiber optic cable, wireless through leased CDMA, or twisted pair serial to Ethernet IP), network structure (for example, incorporating physical redundancy), and network testing requirements to be considered for the proposed ITS project.

Several networking options are available for connecting ITS field devices to existing and proposed networks. Types of communications typically used for each device are listed in previous sections where each device type is discussed. Networking options at a given location may include Ethernet IP network, fiber optic network, wireless cellular links, DSL, and other leased data line options.

In some cases, network field hub locations may be required to be designed and constructed as part of the proposed expansion of the Ethernet network for ITS project communications.

ITS designers must evaluate and document the device communications pathway with respect to being able to use DDOT's existing network for servicing a proposed new location. Network hub locations, proposed cable pathway, and communications system configuration for each device location must be included in system-level diagrams and cable assignments in the prepared ITS plans.

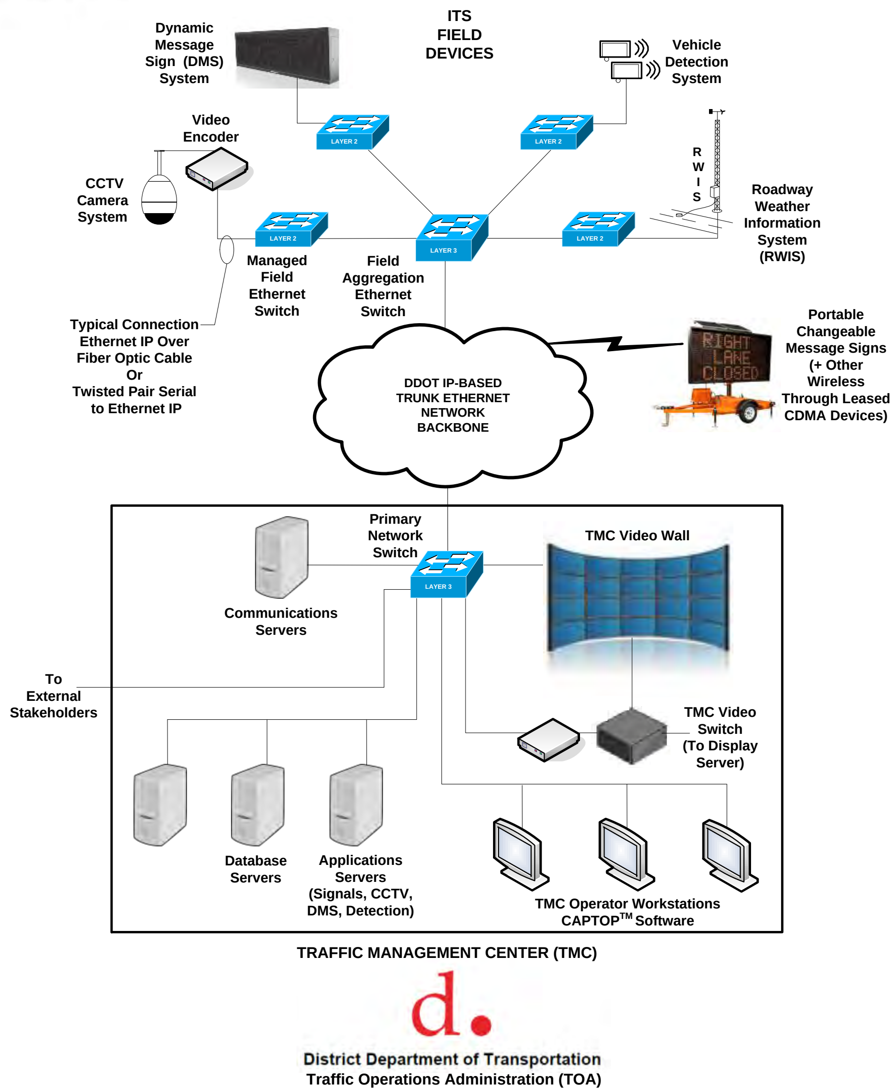


Figure 42-2 | ITS System-Level Diagram and Network Design

Several Departmental and industry standards related to communications infrastructure design are listed below.

- DDOT 1000 Series Intelligent Transportation Systems Standard Specifications
- Building Industry Consulting Service International Telecommunications Distribution Methods Manual and Information Transport Systems Installation
- National Fire Protection Association (NFPA) National Electric Code (NEC)
- United States Department of Agriculture Construction of Direct Buried Plant Manual
- Insulated Cable Engineers Association, Inc. ANSI/ICEA S-89-648, Standard for Aerial Service Wire

42.6.2. ITS Communications Cable Design

Cable infrastructure design involves both the design of conduit pathway and the selection of communications cable applicable for the ITS design. Junction box locations, cable splice points and cable length estimates (including cable slack) are all site considerations that are part of the design. Conduit fill calculations supporting NFPA NEC requirements for proposed conduit use should be submitted as part of design.

ITS site plans must specify the number of underground communications cables and their routes. A minimum of two conduits must be used for all underground communications cable routes. A minimum of two conduits will also be used for all directional drill installations beneath roadways, railroad rights-of-way or streams or that run longitudinally beneath a sidewalk.

Communications Cable for Urban Freeways

On urban freeways, fiber optic trunk cables are installed as proposed ITS communications backbone cables, and are connected to the network path leading back to the TMC according to the system design. Junction box spacing is not to exceed 1500 feet in any underground conduit route that conveys communications cable. A junction box of adequate size to house a drop cable splice is required at each ITS device location.

Communications Cable for Urban Arterial Streets and Highways

On urban arterials and highways, communications cable pathway must be designed according to **DDOT Standard Specifications for Highways and Structures** and located underneath the centerline of roadway pavement.

For aerial cable installations, feasibility should be reviewed with the DDOT Utilities Section early in the design process to confirm with the service providers that the project is possible and determine the scope of work for the service connection.

42.6.3. Communications Network Design Considerations

Field-to-TMC communications systems for ITS deployments should include the following design considerations:

- **Device Bandwidth Calculations**. Determine bandwidth requirements of the planned devices in relation to allowable bandwidth of a communications network from field-to-TMC. With the exception of CCTV cameras, a typical communications session between an ITS device controller and the TMC usually involves a small amount of data (3 kilobits or less) and can be easily supported using low-bandwidth communications (9.6 kbps to 56 kbps). A full T-1 (1.54 mbps) service is typically used for video transmission to the TMC.

- **Network Availability.** In coordination with DDOT personnel, during design confirm with local service providers that the intended service is available at the proposed access locations. Assess signal strength for sites positioned for cellular wireless communications as part of site data collection efforts.
- **Cost/Benefit Analysis.** Compare costs and benefits of design alternatives, particularly for services requiring monthly user fees over the life-cycle of the deployed ITS (for example, communications over wireless via leased CDMA).
- **Network Security.** Consider the network security and firewall design for the field-to-TMC network within the system block diagram design. Coordinate with DDOT on current agency mandates on cyber security requirements for hardware and software, as well as the process for incorporating new devices into existing software (for example, confirmation of licensing requirements).

District Department of Transportation

ITS DESIGN PHASE CHECKLISTS

District Department of Transportation

30% DESIGN ITS CHECKLIST

Contract/Project: ____

Note to Engineer: Complete, sign, and include this checklist with the 30% submittal to DDOT.

ITS Infrastructure and Hardware Design

- ☐ Technical memoranda provided for evaluation of current ITS technologies, if required.
- ☐ Recommended types and quantities of ITS elements listed.
- ☐ Rationale for choosing locations provided.
- ☐ Anticipated cost for proposed ITS device installations included.
- ☐ Statement addressing interface with existing ITS elements (e.g., availability of network/communications, conflicts with systems, opportunities for the addition of other ITS devices) provided.
- ☐ Anticipated modifications to existing ITS sites or other DDOT facilities included.
- ☐ List of existing ITS devices located within the defined project limits included.
- ☐ Layout of all existing and proposed ITS elements provided.
- ☐ Analysis of existing ITS elements and impact on the elements during construction provided.
- ☐ Statement on the need to remove and relocate ITS elements affected by construction and maintenance of traffic included.
- ☐ Statement on the need for temporary ITS elements during construction included.
- ☐ Recommendation for maintenance of all ITS elements within the limits of the contract included.
- ☐ Impact of implementing a Smart Work Zone when major construction warrants it included.
- ☐ Inter-department and/or interagency coordination requirements documented.
- ☐ Utility coordination requirements for electrical service to ITS devices identified.
- ☐ Summary of the overall ITS project scope of work and explanation of any deviations provided.
- ☐ Site-specific information for each ITS device location included.
- ☐ Statement on whether guiderail analysis is required included.
- ☐ A project-level roll plot (or sheets for individual sites) of the roadway plan and a profile

illustrating all existing and proposed relocated or new ITS elements, utilizing the appropriate plan symbology included.

ITS Communications Network Design

- ☐ Existing communications facilities within the project limits identified.
- ☐ Project system block diagram including all proposed ITS subsystems identified.
- ☐ Location of existing communications cable and how it will or will not be affected by this contract, including maintenance of traffic staging, identified and discussed.
- ☐ Best project communications method for the project identified.
- ☐ Deviations from ITS or communications master plan (or other pre-concept design information provided by DDOT) documented.
- ☐ Coordination with DDOT for system-level redundancy requirements for the proposed network connections documented.

ITS Software Design

- ☐ Current process for incorporating new ITS devices into CapTOP and other existing software platforms identified.
- ☐ All software requirements for each proposed ITS subsystem (confirmation of licensing requirements, etc.) identified.
- ☐ Coordination with DDOT on current mandates on cyber security requirements for ITS hardware and software documented.

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Designer of Record
Name and Company

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Designer of Record
Phone and Email

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Designer of Record
Signature (Date)

65% DESIGN ITS CHECKLIST

Contract/Project: ____

Note to Engineer: Complete, sign, and include this checklist with the 65% submittal to DDOT.

ITS Infrastructure and Hardware Design

- ☐ Preliminary index of drawings included.
- ☐ ITS plan sheets with details included and numbered consecutively.
- ☐ ITS overview sheet(s) included.
- ☐ List of standards and general notes specific to the ITS drawings included.
- ☐ List of ITS items and special provisions included.
- ☐ All device locations with coordinates (latitude, longitude, and elevation) included.
- ☐ Obstructions or other important features identified.
- ☐ When interior components are to be installed as part of an ITS project, drawings including building floor plans and elevation views provided.
- ☐ If building floor plans and elevation views are unavailable, schematic drawings depicting general layouts, proposed equipment location and routing of conduit and cable provided.
- ☐ Symbol, device name, stationing and milepost of existing and proposed ITS element locations.
- ☐ ITS element names (in accordance with DDOT convention) provided.
- ☐ Field site checks to determine accurate location of ITS elements completed.
- ☐ Exhibits of the roadway profiles illustrating visibility and occlusions of ITS elements included. The exhibits should include overhead obstructions such as bridges, sign structures, and overhead utilities.
- ☐ Conduit and cable sized and labeled on the design drawings. Includes all electrical and fiber optic cables used in the design.
- ☐ ITS elements and junction boxes shown and stationed or dimensioned with milepost location.
- ☐ Power service points and interior equipment/infrastructure installation locations (e.g., within toll plaza buildings) identified and shown.
- ☐ Voltage drop calculations and power consumption (watts) for each ITS element completed and provided.

- ☐ Copies of correspondence with utility providers for new or relocated points of service included.
- ☐ All details and standards included.
- ☐ Temporary ITS elements included.
- ☐ All work for relocating existing ITS element identified in plans and special provisions provided.
- ☐ Cross section drawings illustrating ITS element elevations in relation to the roadway and maintenance accessibility provided.
- ☐ Most current available special provisions and drawings for applicability to specific project and site conditions included.
- ☐ Conduit trenching details included.
- ☐ Details on conduit attachments to structures included.
- ☐ In-ground and/or structure-mounted junction box details included.
- ☐ ITS element draft test plans and traceability matrix (as required) in special provisions included.
- ☐ Schedule constraints related to ITS work provided.
- ☐ Interim milestones needed for ITS elements included.

ITS Communications Network Design

- ☐ A wireless path analysis, if required, completed and documented as an engineering calculation.
- ☐ Preliminary communications layout, cable identification (including fiber strands as applicable), communications tie-ins, and signal strength test analysis provided.
- ☐ Communications service points and interior equipment/infrastructure installation locations (e.g., within toll plaza buildings) identified and shown.
- ☐ Redundant pathway design provided (as coordinated with DDOT).

ITS Software Design

- ☐ Coordination with ITS manufacturers/vendors for verifications on any off-the-shelf software platforms, including costs, licensing, and any other data or system performance requirements, documented.

☐ Coordination with existing DDOT software vendors for incorporating new ITS devices into CapTOP and other existing software platforms documented.

☐ Cyber security specifications for meeting previously identified requirements for ITS hardware and software (as applicable) submitted.

Designer of Record

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Designer of Record
Name and Company

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Designer of Record
Phone and Email

____
Designer of Record
Signature (Date)

100% DESIGN ITS CHECKLIST

Contract/Project: ____

Note to Engineer: Complete, sign, and include this checklist with the 100% submittal to DDOT.

Final 100% Design Submittal Checklist

- ☐ All plan elements listed in DDOT DEM Section 42.1.1 that are relevant to the design included in final plan set.
- ☐ Locations of all ITS elements finalized and verified.
- ☐ ITS construction details not specified in the DDOT standard drawings included.
- ☐ Final detailed communications layout plans included.
- ☐ Cross section at each ITS structure site included.
- ☐ Distance of each new or relocated ITS pole from the edge of the traveled lane or an offset distance from construction baseline or centerline verified and listed.
- ☐ Interim ITS milestone and liquidated damages special provisions completed and included if required.
- ☐ Detailed Bill of Materials on specific detailed drawings verified.
- ☐ Overhead support structures identified and included.
- ☐ Concrete pads for ITS cabinets detailed.
- ☐ Submittal checklist to be used during the construction phase for verifying presence and completeness of all items required for submittal included.
- ☐ Individual checklists for ITS element pay items included.
- ☐ Final conduit and wiring for existing and proposed ITS elements provided.
- ☐ Cabinet wiring diagrams completed, updated to the project and included.
- ☐ Temporary ITS elements identified and detailed.
- ☐ ITS site guide drawings updated for the project and included.
- ☐ Final quantities and project estimate completed and included.
- ☐ All ITS special provisions detailing technical specifications of items to be furnished and installed reviewed, tailored to the project and included.

☐ Designer's internal QA/QC completed and documented. DDOT ISO-required supporting documentation provided.

Designer of Record

____
Designer of Record
Name and Company

____
Designer of Record
Phone and Email

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Designer of Record
Signature (Date)

SAMPLE ITS DESIGN FIELD REVIEW WORKSHEET

PROJECT ____ DATE ______________________

ENGINEER _________________________________ ORGANIZATION___________________

HIGHWAY __________________________ DIRECTION: ______N ______S ______E _____W

MILE MARKER_______________ GPS COORDINATES ______________________________

DEVICES ____

GUIDERAIL OR BARRIER REQUIRED? ____

POWER: _______________________________ (AC/DC/SOLAR)

POWER POINT OF SERVICE LOCATION FOR SITE ____

____

COMMUNICATIONS (NOTE AS EXISTING OR PROPOSED):

_______________ TWISTED PAIR SERIAL TO ETHERNET IP

________________ETHERNET IP OVER FIBER OPTIC CABLE

________________WIRELESS CELLULAR THROUGH LEASED CDMA

________________OTHER

UPSTREAM COMMUNICATIONS POINT ____

DOWNSTREAM COMMUNICATIONS POINT ____

BUCKET TRUCK SURVEY REQUIRED FOR CCTV? ____

WIRELESS PATH ANALYSIS REQUIRED? ____

DEVICE LOCATION SKETCH:

43 Street Lighting

43.1. Street and Alley Lighting

This section of the manual is intended to guide the planning and design of a highway/street lighting system that conforms to DDOT policy. It should promote uniformity in the design and plan preparation of highway lighting systems. Complying with all of the design criteria is sometimes difficult and requires some judgment on the part of the Designer to attain the necessary balance. However, the criteria should be followed as closely as possible to achieve uniformity of design in highway/street lighting systems.

In April 2004, DDOT undertook a comprehensive study to develop a uniform streetlight policy throughout the City. This study was developed with the assistance of an advisory committee that included representatives from various agencies, communities, historic preservation groups and other citizens. The study examined pole placement and color, light distribution and color, and options for different poles based on street function, among other things. These standards were incorporated into this chapter of the Design and Engineering Manual.

Periodically DDOT updates the **District of Columbia Streetlight Policy and Design Guidelines (DDOT SLP&DG**) document. Information in the DDOT SLP&DG document is not included in this chapter of the Design and Engineering Manual to reduce conflicting and outdated information. Therefore, designers should consider and apply information from both documents. The DDOT SLP&DG can be obtained at ddot.dc.gov.

DDOT recognizes that situations will occur where good engineering judgment dictates deviation from this policy. Any such deviation must be detailed in writing and submitted for DDOT approval. It is not the intent of this chapter to reproduce all the information that is adequately covered by textbooks and other readily available publications. This chapter, when used in conjunction with engineering knowledge of highway lighting design and good judgment, should enable designers to perform their jobs more efficiently.

The terminology used in this manual, unless stated otherwise, is as defined in the current American Association of State Highway and Transportation Officials **(AASHTO) Roadway Lighting Design Guide**.

The Program Manager/Project Manager must confer with the DDOT Streetlights Operations Branch for their streetlight requirements. Warrants for lighting are outlined in the **AASHTO Roadway Lighting Design Guide** and **Section 43.5** of this manual.

The Designer must develop street lighting analysis for both existing and proposed conditions for DDOT electrical/light engineers' approval before initiating a design. The design must follow the **DC Streetlight Policy and Design Guidelines** and other DDOT requirements.

Coordination with the utility company is necessary to ensure proposed materials are compatible with utility inventories. The power source locations should be designated by and negotiated with the utility company in order to supply the power. In special lighting situations (e.g., ornamental or decorative lighting), the District and federal share of costs must not substantially exceed the estimated cost of conventional highway lighting, unless such special lighting is within the scope of the project (e.g., enhancement projects) or is otherwise justified by the public interest or historical areas.

The following information should be shown on the lighting plan:

- Circuit type, voltage and location of power source
- Luminaire type, lumens and locations
- Light standard type, mounting height, bracket arm type and length, and foundation details
- Size and location of electrical conduit, conductor size, location of direct burial cable, and locations of pull boxes and junction boxes

The design and streetlight plan should be prepared based on approved lighting analysis and DDOT streetlight and plan, or Downtown Streetscape Regulation if it applies.

43.1.1. Regulations and Guidelines

Uniform lighting must be used on new roadway projects. The lighting must be developed in accordance with the most current edition of the below references and guidelines, and the most recent supplemental revisions or guidelines approved by the District.

- District of Columbia Streetlight Policy and Design Guidelines
- AASHTO Guide to Development of Bicycle Facilities (for trail lighting)
- AASHTO Roadway Lighting Design Guide
- Federal Highway Administration (FHWA) Roadway Lighting Handbook
- FHWA Manual on Uniform Traffic Control Devices (MUTCD)
- Illuminating Engineering Society (IES) Lighting Handbook

NOTE: All publications are to be the latest edition.

All fixtures, poles, and designs will be reviewed and approved by the DDOT Electrical Engineer. Refer to the District's **Downtown Streetscape Regulations** for the streetlight design within the downtown streetscape boundary and Business Improvement Districts (BIDs).

The purpose of streetlights is to illuminate publicly traveled ways to a level that allows the safe passage of public traffic, both vehicle and pedestrian. Street lighting of public streets and alleys in the District must be designed and installed in accordance with these standards and DDOT's standard specifications for street lighting. All street lighting designs must be coordinated with the affected community. The Designer must choose from the current streetlight standards and lighting fixtures used in the District unless a unique lighting system is required due to special situations or requirements. The streetlight design must be coordinated by the Designer with the traffic signal design and utility company work.

In historic districts designated by the State Historic Preservation Office (SHPO), the Designer must conform to SHPO requirements and obtain the necessary information prior to beginning the design. Lighting poles, arms and luminaires mounted on top of bridge parapets may be special types. The Designer must coordinate work performed in the vicinity of historic districts with the National Park Service and Architect of the Capitol.

During the preliminary design review meeting, the applicant or developer must provide photometric calculations. The calculations must analyze the existing conditions of street lighting around the development for all existing and proposed lights. In the event the lighting is inadequate or the distance between light poles is more than 60 feet, the applicant will be responsible for installing new light pole(s). All existing light fixtures must be upgraded to LED, and all lighting systems in public space must be underground. New lights must be installed for all new construction in public space.

For any new third-party construction or new development, the applicant must upgrade the existing lights around the new development or provide a new streetlight plan.

43.1.2. Residential Areas

All lighting in residential areas must be installed to minimize light shining on or negatively affecting the neighboring residents. Fixtures must be located in such a manner that dark voids and excessive glare in windows are eliminated. The pole spacing must be close enough to obtain the necessary illumination levels and must not exceed 150 feet, and the streetlight mounting height for Acorn (Washington globe) fixtures should not exceed 15 feet and 1 inch in residential areas. Minimum spacing should be 60 feet.

Luminaire glare shields may be used to minimize the glare of a conventional lighting system. DDOT may consider exceptions to the policy to reduce lighting requirements on a case-by-case basis. Street lighting should be installed as listed in the **DDOT SLP&DG**.

43.1.3. Underground Service

Street lighting must be installed with underground electric service on all new subdivision developments and reconstruction on public streets in the District.

43.1.4. Streetlight Standard Color

Refer to the District's downtown streetscape regulation and the Memorandum of Understanding (MOU) between the District and the BIDs for the streetlights in the downtown and BID areas. The District's standard streetlight color is D.C. Gray, Federal Chip No. 16099, unless directed otherwise. When a black pole is approved, the color must be Federal Chip No. 27038. The poles and arms must be painted with either a two-part epoxy paint system or powder-coated color with the area design scheme. Obtain Green Chip and Red Chip numbers for the Chinese Lantern Streetlights from DDOT Streetlights Operations Branch.

43.2. Layout Criteria

Lighting standard spacing and offsets should be as uniform as possible. If it is necessary to vary the spacing or offset, it should be done gradually, keeping in mind that the minimum spacing must be 60 feet and the maximum must be 150 feet. In general, lighting must be located as follows:

43.2.1. Streets

43.2.1.1. Signalized Intersection

Signalized intersections will be lighted using pendant arm and combined streetlights and signal poles. Mounting of signals will be perpendicular to the flow line. Light poles or traffic signal poles at intersections with curb ramps must be at least 2 feet longitudinally from the edge of the ramp flare.

43.2.1.2. Railroad Crossing Lighting

Railroad crossing lighting must conform to the **Railroad-Highway Grade Crossing Handbook** (FHWA).

43.2.1.3. Sidewalks without Continuous Tree Space

Install streetlights 3 feet from the face of the curb to the centerline of the support pole. If a pedestrian clear space of 4 feet cannot be maintained behind the light pole, the pole may be located at the back side of the sidewalk. In all cases, 4 feet of pedestrian clear space must be maintained. In no case may a streetlight be installed in front of a building door or sidewalk lead. A 15-foot clearance must be maintained between a tree and the proposed streetlight.

43.2.1.4. Sidewalks with Continuous Tree Space

Install streetlights in the center of the tree buffer space but no less than 2 feet and no more than 4 feet from the face of the curb. In no case may a streetlight be installed in front of a building door or sidewalk lead. A 15-foot clearance must be maintained between a tree and the proposed streetlight.

43.2.1.5. Fire Hydrant Conflicts

When locating proposed lighting, avoid possible conflicts with fire hydrants. Install lighting at least 6 feet from fire hydrants.

43.2.1.6. Underpass Lighting

All bridge underpasses where vehicles, pedestrians, bicyclists, or equestrians may be present require lighting. Lighting can be provided from adjacent pole-mounted luminaires for short underpasses; otherwise luminaires must be mounted to the underpass walls.

43.2.2. Main Line Highways

Lighting on main line highways must be placed along outside lanes spaced opposite or staggered to suit the geometry and provide the best lighting uniformity.

43.2.3. Ramps

To facilitate maintenance and relamping, it is desirable to locate the lighting standard along the inside radius; a minimum setback of 5 feet 6 inches is recommended.

43.2.4. Gore Area

It is desirable for a lighting standard to be located in the vicinity of an exit gore area. In no instance may a lighting standard be located in a roadside recovery area.

43.2.5. Adjacent to Overpasses

Care must be taken to avoid glare from mainline lighting affecting traffic on overpasses. Luminaire shields may be used to minimize the glare, if necessary. For typical (normal vertical clearance) overpass structures, luminaires must not be located closer than 35 feet from the face of parapets.

43.3. Lighting Systems

The Designer must refer to the DDOT standard specifications for approved luminaire types. Lighting poles mounted at grade must be the Department's standard poles. The arm may be a special type, but must be capable of being mounted on a standard pole. The support arms must be reinforced with a bracket for streetlights on bridges and freeways. Care must be taken to avoid having a lighting bracket arm and mounted luminaire obstruct drivers' view of signs.

DDOT is currently developing a streetlight monitoring program. The Designer must coordinate with the appropriate DDOT personnel regarding the current standards until the program is completed.

43.3.1. Refractor Style Cobra (Pendant Arm)

The refractor style cobra with a Type-3 cutoff distribution pattern mounted on poles is the standard construction for freeway installations. Poles located on "Special Streets" as defined in the **DDOT SLP&DG** must be outfitted in a decorative teardrop style. Refer to the **DDOT SLP&DG** for pole-type placements in historic, non-historic with aboveground wiring, non-historic with belowground wiring and Special Street areas.

For underpasses, lighting can be provided from adjacent pole-mounted luminaires for short underpasses; otherwise luminaires must be mounted to the underpass walls.

43.3.2. Ornamental Streetlights on Historic Bridges

In-kind ornamental streetlights with unique fixtures and light poles must be installed on the District's historic bridges, including special bridges as directed by DDOT. Streetlights on these bridges must be replaced in-kind when upgrading the bridges or streetlights.

43.3.3. Fixtures Attached to PEPCO Poles

The Designer may choose appropriate luminaires and design them based on the spacing of PEPCO poles and pole attachment befitting the existing situation. The Designer may use additional poles if necessary.

43.3.4. Tunnel and Miscellaneous Fixtures

Special fixtures will be used in tunnels, under decks, on sign structures and in special situations. Wall-mounted luminaires are preferred in tunnels and under decks. The luminaires must be located to facilitate maintenance and relamping.

43.4. Lighting at Intersections

All signalized intersections are to be illuminated. At signalized intersections, lighting must be installed on traffic signal standards wherever possible. In general, the nighttime visibility of a pedestrian or hazardous object within an intersection is enhanced by increased contrast between the object and the surrounding street area. The optimum contrast (and hence safety) is achieved when the streetlights are situated to silhouette (or backlight) objects in the intersection. Therefore, streetlights at intersections are required to be placed on the downstream side of the intersecting street, as viewed by a motorist approaching the intersection in the lane directly beneath the luminaire. Refer to Table 43-1 for a summary of the positioning of light standards at intersecting streets.

Table 43-1 | Intersection Light Locations

Major Collectors/Arterials	4 lights, one on each corner
Arterials/Arterials	4 lights, one on each corner
Arterials/Collector	2 lights, one on opposite corners
Collector/Collector	2 lights, one on opposite corners
Local/Collector	2 lights, one on opposite corners
Local/Local	1 light on one corner

43.5. Warrants for Highway Lighting

This section summarizes the process for determining if highway lighting is warranted. Refer to current **AASHTO, Roadway Lighting Design Guide** for more detailed information.

43.5.1. Step 1

All highways in the District of Columbia warrant the installation of streetlights; to demonstrate this need, AASHTO has developed a system of warrants. The Designer must check the AASHTO warrants prior to starting the design for any special conditions, and AASHTO warrants must be investigated before a final determination is reached. If highway lighting is warranted based on the following (except for under-deck/tunnel lighting), then the Designer will proceed to Step 2.

43.5.1.1. Continuous Lighting (Freeway) (CFL)

One of the following AASHTO warrants must be met to consider continuous lighting:

- CFL-3
- CFL-4
- Special considerations

43.5.1.2. Complete Interchange Lighting (CIL)

One of the following AASHTO warrants must be met to consider complete interchange lighting:

- CIL-1 plus CIL-2
- CIL-3
- CIL-4
- Special considerations

43.5.1.3. Partial Interchange Lighting (PIL)

One of the following AASHTO warrants must be met to consider partial interchange lighting:

- PIL-1 plus PIL-2
- PIL-3
- Special considerations

43.5.1.4. Under–Deck Lighting or Tunnel Lighting

AASHTO warrants must be met to consider under-deck and/or tunnel lighting. If lighting is warranted, the Designer must prepare the design and skip Step 2.

43.5.1.5. Additional Design Considerations

Additional lighting must be considered warranted for ramps, mainlines or acceleration lanes for any of the following reasons.

- Ramps
    - Inside radius of entrance or exit ramp is less than 150 feet
    - Accident data in the ramp area indicates a problem exists
- Acceleration Lanes
    - Vehicles need to stop before the acceleration lane
    - Grade and/or curvature present a visibility problem that cannot be corrected through other means
    - Sidewalks exist to permit pedestrians to cross at the entrance or terminal of a ramp
- Mainline

- The Designer must obtain the accident data of the location to determine the night-to-day accident ratio. The ratio could weigh heavily in the determination of whether highway lighting is required.

  - Grade and/or curvature present a visibility problem that cannot be corrected through other means
  - There are one or more bridges without shoulders

43.5.2. Step 2

If lighting is warranted based on AASHTO, then the need for lighting on a particular highway or interchange must be considered using the appropriate evaluation.

43.6. Street Lighting Design

DDOT's approved luminaire and supporting poles and arms must be used for all streetlight designs in the District. The environmental impact of each system, especially on residences, must be investigated. Luminaire shields may be used to minimize the glare of a conventional lighting system. Upon approval, the Designer must then address, analyze and compare such determining factors as initial installation cost, maintenance costs and energy consumption costs of the remaining system(s). All illumination and electrical design must meet the criteria specified below. Before work commences on the lighting design, the Designer must request the Electrical Engineer's approval of all design parameters.

- The Designer must be prepared to present, explain and defend his/her lighting system choice and design at any public or other meetings, as required.
- The Designer must prepare 20-foot scale drawings of all systems to be included with the report, and based on investigations and analyses, must make a recommendation to DDOT of the system best suited to the project.
- Photometric layout should be provided.
- The Designer must not intermix a DDOT lighting system with a utility company wood pole transmission system.
- The Designer is responsible for locating and identifying the horizontal and vertical clearances of the utility company's primary (750 volts or more) and secondary power lines.
- The Designer must coordinate the electrical design work with the present and future plans of the utility companies. All overhead and underground utilities must be shown on the plans. There must be no conflicts with the lighting installation.

- When utility poles must be relocated and wood poles are the sole source of illumination for a section of highway, the Designer must work with the affected utility to space and position utility poles, through the utility agreement in conformance with utility standards, to produce suitable illumination. However, if needed to achieve a quality design, the Designer should call for the installation of additional District-owned wood poles outside of the utility company's pole transmission system.

43.6.1. Basis for Lighting Calculation

43.6.1.1. Common Criteria

The following are common for all types of highway lighting systems.

Photometric Data

The photometric data used in all calculations must be the latest data available.

Streetlight Luminaires

LED luminaires must be used for all new projects. Data for luminaire photometric calculations must be obtained from manufacturers defined in the list of approved LED luminaires in the **DDOT Standard Specification for Highways and Structures** manual.

Maintenance Factors

All lighting systems depreciate with time. The design values must consider appropriate reduction in initial illumination values. The maintenance factor is about 0.75 and 0.68 for ambient areas considered dirty. The values to be used in the photometric calculation also depend on the type of fixture, and the Designer should use a value based on engineering judgment.

43.6.2. Other Considerations

The following considerations are to be incorporated into all lighting calculations (in addition to the width of highway pavement, including shoulders, and excluding medians where they exist):

- The size of luminaires that would accommodate the level and uniformity of illumination.
- The length of bracket arms that would provide maximum efficiency and uniformity in lighting. It should be noted that in some areas the use of two different lengths of bracket arms may meet the above requirements, but may also produce an objectionable appearance with regard to the luminaire alignment.

- Where the geometry or the uniformity ratio requirements necessitate adjustments in the calculated lighting standard spacing, closer spacing may be used.
- Contributions from all luminaires that have an effect on the area considered must be taken into account to obtain the lux values.
- When adjacent to sign structures, it is desirable to locate lighting standards equidistant from sign structures. The lighting standards must not be located within 50 feet of the structure. Care must be taken to avoid having a lighting bracket arm and luminaire mounted at 26 feet, obstructing drivers' view of the sign legend.
- When locating lighting poles near overhead sign structures, the pole must be located so as not to affect drivers' view of the sign message. Any adverse glare will be handled by the use of luminaire shields.

43.6.3. Lighting Calculations

43.6.3.1. Methods of Calculation

For the preliminary design, the average point method must be used. The lighting will be designed using a District-approved lighting design program, which currently includes Lighting Analysts' AGi32. Other lighting design software may be approved, but the Designer would be responsible for providing a registered copy of the software and training at no cost to DDOT. Special design software for tunnels must be used when designing tunnel lighting. The photometric data to be used in the calculations will be provided by DDOT upon written request.

43.6.3.2. Calculation Guidelines

When performing the calculations:

- When a portion or section of the highway is under analysis, it must be analyzed as a self-contained area (main area). Sub-division (sub-area) within the main area is not permitted.
- The self-contained area (main area) of analysis must correspond to the highway geometry under investigation.
- The point-to-point interval must be 5 feet longitudinally and transversely.
- The entire section of highway that is being illuminated must be analyzed completely (it can be analyzed with many main areas).

The following information must be included with each analysis:

- Project identification

- Plan sheet number involved in calculations
- A station-to-station identification of the area being analyzed
- The identification of each contributing luminaire being analyzed

When the analysis is completed, submit copies of all the project files in AGi32 format and pdf for review.

43.6.4. Power Source

43.6.4.1. Incoming Service

The secondary service obtainable from the local utility company's pole or manhole must be used to service the complete installation in each area. Information on the payee of the energy charge must be provided in the electrical service request. For all streetlight and alley light designs, the Designer must supply the utility with a complete set of drawing for review and approval of the locations of all connections. Where an electrical service is required for an underpass or tunnel, the Designer must request a class of service from the utility company. The form to make the request will be obtained from the utility company and completed in full. The Designer must supply a copy of the request to DDOT. Standard services available from the utility company are as follows:

- Single Phase: 3 Wire: 120/240 V and 240/480 V – 120/240 volt service is preferred for all street and alley lighting. However, in areas where that class of service is not available, then the use of a 240 volt circuit is allowed.
- Two Phase: 3 Wire: 120/240 V and 240/480 V – the latter is preferred. The utility company provides this special secondary voltage to the Department exclusively. Utilized voltage must be 240 volts.
- Three Phase: 4 Wire: 265/460 V and 277/480 V – dependent on the utility company. Utilized voltage must be 265 or 277 volts.

When service is obtained from a manhole, the Designer must consult with the utility company for the size, location, material and termination of the service conduit. The utility company usually furnishes the service wires; however, this must be verified.

43.6.4.2. Load Center Designations

Obtain the designation from the Electrical Engineer when a load center is added to the street/highway lighting system.

43.6.4.3. Circuitry and Other Considerations

In most cases, where the wire fill will permit, all cables for two or more lighting circuits may be installed in the same conduit. Nominal size of cable used in highway lighting circuits must be according to the National Electrical Code (NEC); however, no cable smaller than #10 AWG 600 volt may be used. Other sizes may be used if approved by the Electrical Engineer. It is recommended that variations in cable sizes be avoided if possible. All street and alley lights must be controlled by a photocell mounted on each fixture or luminaire.

The Designer must utilize both phases of a circuit and connect the lighting so that no two consecutive lights are connected to the same phase in case of a loss of a single phase. The use of fused connector kits for each luminaire is not permitted.

Lighting circuits, including future lighting extensions where required, must be designed for a maximum 5 percent voltage drop at the terminal point of each circuit. The voltage drop must be calculated between the phase and neutral.

43.6.4.4. Balanced Lighting Circuits

All lighting circuits must be balanced. Lighting circuits must be arranged so that if one of the circuits fails, it can be rerouted with minimal work. To accomplish this flexibility in the circuitry, an empty conduit must be provided to connect the conduit systems of adjacent load centers where feasible.

All conduit duct banks must provide spare ducts for future use. On all highways where widening is imminent or is being contemplated, the locations of the lighting system must be outside the limits of the future widening. The system must be designed so that the permanent lighting installations are complete and in operation when a new highway is opened to traffic. If this cannot be accomplished, temporary lighting must be provided.

43.6.5. Under-Deck and Tunnel Lighting

43.6.5.1. Under-Deck Lighting

The purpose of under-deck lighting is to provide a continuous level of illuminance and uniform lighting beneath structures. Therefore, under-deck lighting is only required where this level of illuminance, due to structural limitations such as the width, skews, and minimum clearance, cannot be accomplished by means of other lighting standards.

Wall-mounted under-deck luminaires must be installed on pier faces or abutments at a minimum mounting height of 15 feet unless AASHTO requires a higher vertical clearance for the particular roadway classification. The pier faces or the abutment must be parallel to the highway and must be within 10 feet from the curb or edge of the highway. Otherwise the luminaires must be fastened to adapter plates installed between the bridge girders. Wall-mounted under-deck luminaires installed at a mounting height of more than 15 feet yield better efficiency and uniformity.

Pendant type luminaires must be mounted from the structural steel. The luminaires must be located to facilitate maintenance and relamping. If the highway width permits, the luminaires should be located over the shoulder. When a luminaire is suspended from a bridge structure over the traveling lane, the bottom of the luminaire must not be lower than the bridge girder. A special detail may be necessary to accommodate the conduit layout under the structure. For calculation purposes, the following data must be used:

- Mounting Height: As required (15 feet nominal)
- Luminaires: Designer must use LED luminaires, and engineering judgment should be used to determine the appropriate wattage
- Uniformity Ratio

On highways that are not illuminated, under-deck lighting must be provided for underpasses having pedestrian traffic. The average maintained illuminance must be 0.8 foot-candle.

43.6.5.2. Vehicular Tunnels

A structure of any type that surrounds a vehicular roadway and is longer than an underpass is recognized by AASHTO as a tunnel. Tunnels normally require supplementary day lighting to provide adequate roadway visibility for safe and efficient traffic operation.

Entrance Portal Lighting

The most critical portion of a tunnel that affects visibility is at the portal. Visibility of this first entrance zone, while still outside the tunnel, is essential to the motorist in identifying and safely reacting to the presence of vehicles and objects that may be present on the tunnel roadways. This is accomplished by lighting the entrance zone in proper proportion to the outside ambient luminance to which the motorists' eyes are adapted.

Two- and three-lane one-way tunnels having favorable alignments of the approaches and tunnel structure, and which are of relatively short length, have been adequately lighted with relatively low artificial lighting levels. The optimization of portal entrance conditions, in some cases, has produced adequate entrance visibility at artificial luminance levels in the range of about 100 to 200 candelas per square meter reflected from an in-service roadway surface. Entrance zone lighting levels should be designed to accommodate the brightest ambient luminance expected at the location.

Lighting Beyond the Entrance Zone

If the tunnel is classified as a short tunnel, the entrance zone lighting level applies throughout its entire length. However, in long tunnels, lighting beyond the minimum stopping sight distance should be reduced progressively until an established minimum level is reached. It is recommended that beginning at the end of the entrance zone, lighting levels be reduced in steps to a level not less than 5 horizontal foot-candles (54 lux) or 5 candelas per square meter on the roadways. Each stepped zone should have a length at least equal to the minimum stopping sight distance.

Nighttime Tunnel Lighting

Nighttime lighting should make use of a portion of the daytime lighting system rather than be a separate system. Nighttime levels in a tunnel should be somewhat higher, but not exceeding three times that of the lighting requirements for the roadways adjacent to the tunnel. Uniformity of lighting should closely match that of the requirements for the adjacent roadways.

Tunnel Lighting Control Systems

Lighting levels for the entrance zone may be adjusted to match the ambient conditions due to varying light levels from season to season and during cloudy or inclement weather. If such system variances are determined to be economical and feasible, lighting levels in subsequent tunnel zones should vary in the same proportion. Lighting systems for tunnels should be designed as failsafe as practical to reduce the possibility of a total tunnel outage in the event of a circuit failure or other malfunction.

43.6.6. Overhead Sign Lighting

The following guidelines will be used to determine if sign lighting is to be provided for overhead signs:

- The tangent sight distance is less than 1200 feet due to horizontal or vertical curve or other sight obstruction.
- Geographic and/or geometric conditions may warrant sign lighting for the following situations, and an evaluation will be made:
  - Diagrammatic signs
  - “Exit Only” lane drops
  - High volume interchanges (interstate to interstate)

- Areas with high concentration of dew or frost
- Sheeting material retroreflectivity characteristics

When it is determined that overhead sign lighting is to be provided, the lighting level must conform to AASHTO and **MUTCD** guidelines. LED luminaires equivalent to 100 W high-pressure sodium vapor luminaires should be used for lighting overhead signs if they meet the illuminance requirements. If not, higher wattages may be used to meet the requirements. The Designer must coordinate the electrical details and the details of the sign structure. A minimum of two luminaires must be provided for each sign panel. LED sign lighting fixtures will be used in place of high pressure sodium (HPS) fixtures. The advantages are long life (50,000 hours), white color, 30% lumen depreciation at 50,000 hours and improved light control. Where sign lighting is not required, walkways and luminaire supports are not to be provided, but the design of the sign structure must allow the future installation of walkways and luminaire supports.

Shown in Table 43-2 are illuminance and luminance levels for sign lighting recommendations as per AASHTO, depending on the ambient lighting conditions of the surrounding areas.

Table 43-2 | Illuminance and Luminance Levels for Sign Lighting

	Sign Illuminance		Sign Luminance*	
Ambient Luminance	**Foot-candles**	**Lux**	**Candelas per Square Meter**	**Candelas per Square Foot**
Low	10–20	100–200	22–44	2.2–4.4
Medium	20–40	200–400	44–89	4.4–8.9
High	40–80	400–800	89–178	8.9–17.8

Source: The IESNA Lighting Handbook, Reference & Application, 9th Edition, Illuminating Engineering Society of North America.
***Based on a maintained reflectance of 70 percent for white sign letters.**

Overhead guide signs should be provided based on AASHTO and **MUTCD** guidelines as presented below.

- Sign lighting should be placed on a track system mounted on the bottom of the sign that allows all of the lights to be serviced from the side of the road.
- An underground 4 feet by 4 feet by 4 feet manhole should be provided close to the overhead sign.
- A 1-inch rigid galvanized steel conduit should be used to route all cables.
- The minimum clearance from bottom of the sign to the highest point of roadway or paved shoulder should be 20 feet 9 inches.

- The minimum clearance from bottom of the luminaire to the highest point of roadway or paved shoulder should be 17 feet 9 inches.

43.6.7. "Welcome to Washington" (Gateway) Signs

"Welcome to Washington" signs are placed on significant entry points to Washington at the DC line and are known as Gateway Signs. The sign lighting design should follow the following general guidelines:

- The sign lighting system must be serviced by a new 120/240 V metered electrical service cabinet on a concrete base with PEPCO power feed to the service pedestal. PEPCO should be contacted for service connection verification.
- A 4-inch electrical conduit should run from the power tap to the service pedestal with three #4/0 cables and one #2 Ground cable. If the power source is overhead, a riser will be used protect the cables running along the pole, and a conduit will run for the underground portion to the service pedestal. For underground power feeds, the electrical conduit should run from the PEPCO manhole wall to the service pedestal.
- A 2-inch conduit and two #10 and one #8 Ground cable will run from the service pedestal to the sign.
- Signage lights will be photoelectric cell controlled.
- The total lamp wattage must not be more than 400 watts per circuit.

43.6.8. High Mast Lighting Systems

The lighting calculations to determine the required illumination must be based on the following definitions and criteria:

- Area
    - Only the traveled highway and ramps, including shoulders, must be considered in the calculations.
- High Mast Lighting Standard Assembly Setback
    - Minimum 30 feet measured from the face of curb or edge of pavement to centerline of high mast lighting standard. A lesser setback may be used. Should a lesser setback be approved, appropriate protection must be provided.
- Luminaires

- High mast type 250W, 400W or 1000W high-pressure luminaires must produce a symmetric, long and narrow or asymmetric distribution. A maximum of eight luminaires of the same or different distribution must be clustered to provide the required pattern of light distribution from the high mast lighting assembly.

- Mounting Height
  - The tower must not be more than 100 feet. The actual highway elevations must be used in the calculations.

43.6.9. Existing Highway Lighting System

When an existing lighting system is being affected by construction and the light source is other than high-pressure sodium, it must be converted to high-pressure sodium unless special situations govern. The existing series circuits must be converted into parallel circuits for all City street and highway lights.

43.6.10. Temporary Lighting

All roadway construction projects in the District where the existing lighting system cannot be maintained during construction must use temporary lighting. This lighting can be a mixture of existing poles, temporary poles for construction or new parts for the system being installed. In no case will the illumination levels be less than the existing illumination levels entering and exiting the project limits.

The Designer should specify temporary lighting during the streetlight upgrade construction. During the construction, the lighting contractor must install temporary lights according to DDOT requirements and maintain all streetlights and circuits in the project area. The light must not produce any dark spots on the roadways and pedestrian facilities, nor may it produce glare that affects motorists or house windows. If there is no electric power or if the power is cut off, the lighting contractor must arrange a temporary power source or restore power so that there is no blackout time between dusk and dawn. Pendant poles with a temporary base or wood poles may be used for temporary lighting.

43.6.10.1. Designing the Temporary Lighting

Temporary lighting design is concerned with providing the proper illuminance for the proper duration and in the proper location to increase safety in the construction areas with minimum expenditure. The Designer must design a simple yet safe temporary lighting system that conforms to the NEC as a minimum. The Designer should consider the following options:

- Investigate the possibility of installing certain proposed lighting assemblies, including underground facilities, in the early stage of construction and using them as the temporary lighting
- Use pendant poles with temporary bases or wood poles

Regardless of the type of temporary lighting used, the contractor must maintain the installations, until they are no longer required, and then remove the portions that are not part of the permanent lighting system.

43.6.11. Conduit

Conduit used for roadway and alley lighting projects must be sized accordingly:

- 1-2 inch between manhole/junction box and light pole
- 1-2 and 1-4 inch between manhole and all light poles installed at an intersection
- 2-4 inch between PEPCO feed point and DC manhole/junction box
- 1-4, 2-4, 4-4 and 6-4 inch between DC manholes for mainline runs

Conduit must be installed so that the top of the duct bank is 3 feet below sidewalks and tree planting space to allow the required soil volume.

The minimum allowable distance for trenching for conduits from a tree box is 8 feet.

43.6.12. Utility Clearance

43.6.12.1. Underground Utilities

Per the National Electrical Safety Code (NESC), the following minimum clearances between the proposed underground conduit facility and the existing utility facility must be met:

- A horizontal clearance of 12 inches must be maintained between utility facilities
- A vertical clearance of 12 inches must be maintained between utility facilities

43.6.12.2. Overhead Utilities

The overhead clearance requirements should follow NESC guidelines. The minimum clearances between streetlight structures and overhead utility cables are presented in Table 43-3. Furthermore, the minimum clearances between streetlight overhead cables and other utility cables are presented in Table 43-4.

Table 43-3 | Vertical Clearance between Streetlight Structures and Overhead Utility Cables

Separation of Streetlight Structure from the Following Cable Type	Vertical Clearance (Feet)
Utility Cable (< 750 V)	2
Utility Cable (Over 750 V to 2.2 KV)	4.5
Utility Cable (Over 2.2 KV to < 5.5 KV)	5.5
Utility Cable (Over 5.5 KV)	10

Table 43-4 | Vertical Clearance between Streetlight Overhead Cables and Other Utility Cables

Separation of Streetlight Overhead Cables from the Following Cable Type	Vertical Clearance (Feet)
Utility Cable (< 750 V)	2
Utility Cable (Over 750 V to 4 KV)	4
Utility Cable (Over < 4 KV)	10

Rigid Nonmetallic Conduit

All conduit installed underground by trenching for street and alley lighting must be gray PVC Schedule 40 and encased in concrete. Conduit installed by directional boring must be high-density polyethylene (HDPE) and manufactured to be installed by this method.

Fiberglass or Metallic Conduit

Fiberglass or rigid metallic conduit must be used for all conduit installed on structures. Proper expansion and deflection fittings must be used to allow movement. A 5-foot section of metallic conduit must extend outside of each wing wall and be connected to a manhole or junction box as required. Fiberglass or rigid metallic conduit must be installed on exposed locations, such as hanging under bridge decks or mounted on the surface of walls.

NOTE: A ground wire must be installed in all DDOT conduit where required by the NEC.

43.6.13. Cables and Wire

All cables and wire used in District roadway and alley lighting projects must be in compliance with DDOT's standard specifications. All cable used will be color coded in compliance with the NEC. In areas where more than one lighting circuit is installed together, the cables and wires must be tagged and marked with the circuit information for easy identification and maintenance.

43.6.14. Breakaway and Steel Transformer Bases (T-Bases)

T-bases should be designed in accordance with the latest AASHTO standards and specifications for structural supports for highway signs, luminaires and traffic signals.

Breakaway T-bases can be used on high-speed roadways (freeways) with little or no pedestrian activity. Non-breakaway T-bases should be used at all other locations and locations with pedestrian/bicycle activity. The Designer must weigh the relative risks involved in the situations before selecting an appropriate design. Non-breakaway T-bases can be used at locations protected by guiderails.

AASHTO standards and specifications should be followed in selecting proper materials for breakaway luminaire support. Breakaway luminaire supports are typically frangible bases (cast aluminum transformer bases).

43.7. Manholes and Handholes

Manholes and handholes must be designed as part of a complete lighting system. All manholes must be concrete and be pre-cast or cast-in-place; junction boxes must be polymer concrete. Spacing must not be greater than 250 feet between manholes and/or junction boxes. Drainage will be provided in all manholes/junction boxes by the use of gravel. All manholes will have PVC racks installed so that cables can be racked on the walls.

As part of its paving and reconstruction projects, the District is installing conduit duct banks and manholes to construct a streetlight distribution system separate from PEPCO’s. The only connection to PEPCO is through two 4-inch conduits built from the District manhole to the distribution manhole identified by PEPCO as a feed point. On major streets, the District’s system is made up of six 4-inch conduits and manholes. In neighborhoods and in all alleys, the system consists of two 4-inch conduits and manholes. In all cases, one manhole will connect three to four streetlights and be located no farther than 250 feet apart.

43.8. Voltage Drop Calculation Method

Voltage drop will be calculated on all electrical and lighting circuits. The method used and all of the calculations will be furnished to the District by the Designer as part of the design documents. The voltage drop must not exceed 3 percent on any circuit.

43.9. Navigation Lighting

43.9.1. Design Requirements

Highway structures over navigable waterways require waterway obstruction warning luminaires in accordance with the Code of Federal Regulations (CFR) Title 33, Part 118 and U.S. Coast Guard (USCG) Publication, **A Guide to Bridge Lighting**. DDOT will coordinate with the USCG. Design of navigation lighting is subject to USCG approval. Once approval of the lighting system is obtained, modifications cannot be made without additional Coast Guard review.

For fixed bridges required to have navigation lighting, the edge of channel through the superstructure should be marked by a red channel margin light, which must show through a horizontal arc of 180 degrees. The center of channel will be marked by a green navigation light showing through a horizontal arc of 360 degrees. Navigation lights are not considered an encroachment on vertical clearances and should be placed over actual channel limits whenever possible. Project-specific designs are required for structures supporting green center channel and red channel margin lights. Include the height of green center channel and red channel margin lights when establishing superstructure heights to comply with vertical clearance requirements.

43.9.2. Plan Content Requirements

Show fully detailed, project-specific designs of structures supporting green center channel and red channel margin lights. Specify requirements for automatic lock positions for service and operation. Specify light and service chain mounting locations. Prepare supplemental designs as required showing locations and details of conduit runs, manholes, power sources and other electrical components and incidental items. Provide a separate circuit for navigation lights.

43.10. Fountain/Underwater Art Structures

These requirements cover luminaires for installation below the surface of the water in fountains and art structures per NEC:

- Provided the criteria set forth in Article 356 of the NEC are satisfied liquid-tight flexible nonmetallic conduit should be used.
- Lamp-holders installed in wet or damp locations must be listed for use in wet locations. Lamp-holders installed in damp locations must be listed for damp locations or must be listed for wet locations as described in Section 430.96 of the NEC.

- Luminaires installed in recessed cavities in walls or ceilings, including suspended ceilings, associated with Fountain/Underwater Art Structure Lighting must comply with Sections 430.115 through 430.122 of the NEC.
- All wiring, conduit, cabling, grounding and all associated electrical equipment for the Fountain/Underwater Art Structure Lighting must be in accordance with Article 680 of the NEC.

43.11. Uplighting for Trees

These requirements cover installation of luminaires for tree uplighting per NEC:

- Any receptacles, connectors and attachment plugs necessary for uplighting of trees must be of a listed grounding type rated 15 or 20 amperes.
- Any adjustable luminaires associated with uplighting for trees that require adjusting or aiming after installation are not required to be equipped with an attachment plug or cord connector, provided the exposed cord is of the hard-usage or extra hard-usage type and is not longer than required for the maximum possible adjustment. The cord must not be subject to strain or physical damage.
- Luminaires installed in recessed cavities associated with tree uplighting must comply with provisions set forth in the NEC in Sections 410.115 through 410.122.
- Luminaires for recessed uplighting must be marked to indicate the maximum allowable wattage of lamps. The markings must be permanently installed in letters at least 1/4 inch high, and must be located where visible during re-lamping.

43.12. Vibration/Wind Considerations for Bridge Light Poles and Conduit

The light poles' primary function is to resist the combinations of luminaire weight, ice and wind forces that poles may encounter over their expected life. Along with the foundation system, the primary force a light pole must withstand is from wind. Light poles are particularly susceptible to these forces on bridges. The Effective Protected Area (EPA) is equal to the area "visible" by the wind at a particular angle. All poles have maximum weight and EPA capacities. To calculate the EPA of a particular fixture configuration, simply add the EPA values of the fixture(s) and mounting bracket(s) to be mounted.

Light poles can be described as vertical cantilever structures. As with all structures, they will vibrate under the right conditions in different modes and at different frequencies. Several types of outside forces may excite the pole and start vibration; the most common of these is wind. For example, poles mounted on a bridge may be subject to vibration due to wind blasts from passing trailer trucks or receive traffic-induced vibrations from the movement of the deck. Vibration in different structures decays at different rates, called the dampening coefficient. Some poles have low dampening coefficients and vibrate with less force and for a longer time after the force has stopped. Slender, flexible poles that have low dampening characteristics vibrate more readily and longer than stiffer poles. Thus, the lighting designer must consider the EPA capacities and vibrations when choosing an appropriate pole for a bridge.

Supporting conduit typically runs on bridge members because the suspension of conduit support systems from bridges through welding, clamping, drilling or bolting requires considerable engineering and design data. For hanger conduit designs, the hangers should have a minimum support surface width of 2 inches for adequate load bearing capability. Bridge structures are subject to the transmission of vibrations from the road surfaces to the conduit runs. Adequate provisions must be made in the use of threaded sealants to ensure the hanger’s integrity. These provisions will reduce costly maintenance and avoid hazardous situations over the life of the installation.

44 Guidelines for Pavement Markings and Signage

44.1. Introduction

This work consists of establishing the location of existing pavement markings and installing proposed pavement markings, pavement markers, and reflective material on specified pavements in accordance with these specifications and the **Manual on Uniform Traffic Control Devices (MUTCD)** (current edition).

Permanent pavement markings consist of hot thermoplastic markings (white and yellow) for asphalt concrete surfaces, and plastic markings with a black border for Portland Cement Concrete surfaces. For temporary work, the Contractor may use reflective tape (white and yellow) or paint. In no case will the use of temporary lane markings require destructive measures, such as grinding, for removal from permanent roadway surfaces.

Roadways must not be opened to traffic before pavement markings and signage are properly installed.

44.2. General

- **Type and Location of Pavement Markings.** The DDOT Chief Engineer or Infrastructure Project Management Administration traffic engineer makes the final determination regarding the type and location of pavement markings within the right-of-way (ROW) during review of the project pavement marking and signage plans.
- **Opening of Roadway.** The roadway must have permanent pavement markings in place prior to the opening of any lanes, unless provisions have been made on the Traffic Control Plan and approved by DDOT.

44.3. Pavement Markings

For a new roadway design, the final pavement marking plans with proper geometries should be submitted for 30 percent review. Whenever pavement markings are shown on any type of drawing plan sheet, the plan sheet must have a legend of pavement markings. The entire legend must be shown in full. (NOTE: The legend may be modified only with the approval of the Infrastructure Project Management Administration traffic engineer.)

44.3.1. Special Pavement Marking Areas

- Pennsylvania Avenue, NW (the Presidential inauguration street) between 3rd Street and 15th Street must have ALL WHITE PAVEMENT MARKINGS, including double white lines.
- All crosswalks must have a minimum 20-foot width whenever possible in the Downtown Central Business District (CBD), including the Downtown Streetscapes Area. This area is currently

bounded on the east by 3rd Street, NW, on the south by Independence Avenue, SW, on the west by 23rd Street, NW and on the north by Massachusetts Avenue, NW, and includes the full width of the boundary streets. The Contractor should always contact the DDOT Transportation Policy and Planning Administration for CBD limits, because the CBD limits are occasionally modified.

- Throughout the rest of the city, crosswalks must be 10 feet wide on local streets, 15 feet wide on collector streets, and 20 feet wide on major arterials, unless otherwise noted.
- Restricted lane diamond symbols must be white and spaced 120 feet apart.
- For reversible lane markings, the center yellow double dash lines are 35 feet long with 5-foot skip spacing; the peak hour lines on each side are 10 feet long with 30-foot skip spaces.

44.4. Stop Lines

- Stop lines are white and 12 inches wide.
- Stop lines are to be parallel to the crosswalk.
- There must be a minimum 4-foot clear space between the back edge of the crosswalk line and the stop line.
- Stop lines at unmarked crosswalks should be placed at the desired stopping or yielding point. The stop line should be a minimum of 4 feet and a maximum of 30 feet from the nearest edge of the intersecting roadway.
- Stop lines are required at all signalized intersections unless otherwise indicated. The Designer must have a valid reason for not including stop lines at any signalized intersection lacking them.
- Stop lines are required at all stop signs. Stop lines should align with the stop signs if possible.
- Stop lines can be installed at other locations as specified by the DDOT traffic engineers.
- When bike boxes are used, stop lines should be installed 8 to 10 feet behind the crosswalk.
- Advance stop lines should be installed 20 to 50 feet before an uncontrolled crosswalk on streets with multiple lanes approaching the crosswalk, and should be accompanied by appropriate signage.

44.5. Lane Lines

- **Dash Lines.** Dash lines must be 4 inches wide and 10 feet long, with 30-foot skip spaces in between. However, the last dash line of each block will vary in length. If it is shorter than 10 feet, then it must be connected to the next-to-last skip line. All dash lines must stop 1 foot before the back edge line of a crosswalk.
- **Intersection Traffic Guidelines.** Intersection traffic guidelines must be one of two types: (1) white lines that are 4 inches wide, 2 feet long with 4-foot long skip spaces, or (2) double yellow

lines that are 4 inches wide, 2 feet long with 4-foot long skip spaces. All guide lines must stop 6 feet before the back edge line of the crosswalk. If no stop line is present, the double yellow lines should stop in the same place as if a crosswalk and stop line were present.

- **Centerline Striping.** All centerline striping must be double yellow, 4 inches wide, with a 4-inch minimum gap in between. Centerline striping will be placed on roadways less than 34 feet wide only if the centerline is offset.
- **Approach Lane Lines.** Solid white approach lane lines to a signalized intersection are 6 inches wide. They begin adjacent to the stop line and continue away from the stop line for a distance of 90 feet. If there are three or more approach lines, then measure the 90-foot length for the shortest lane line and align all other approach lines with this 90-foot line on a 90-degree angle.
- **Broken Line.** All broken lines must be white and 4 inches wide.
- **Reversal Lane Lines.** Reversal lane lines are always striped with double yellow lines for all reversible unbalanced traffic lanes during peak rush hours. The existing double yellow lines are 35 feet long with 5-foot spacing. The adjoining reversible lane line is double yellow, 10 feet long, and must align with all affected intersection approaches as well as with the beginning of the 35-foot double yellow line.
- **Turn Bay Lines.** Turn bay lines must be created with an 8-inch-wide dotted line. If a turn bay occurs on a horizontal curve, it must be marked with short 8-inch-wide dotted lines (2 feet long with 4-foot gaps).
- **Parallel Curb-Parking Lanes.** All parallel curb-parking lanes must be 8 feet wide with 6-inch-wide lines separating it from the adjacent 11-foot-wide travel lane.
- **Parking Stalls and Angle Parking.** All striping for parking must be white and 4 inches wide. All lines marking edges of parking areas must also be white and a minimum of 4 inches wide. See **Section 44.8.1** for further detail on striping of Americans with Disabilities Act (ADA)-accessible parking.
- **Bike Lanes.** The stripe nearest the curb or parked car must be 4 inches wide. The stripe dividing the bike lane from the travel lane must be 6 inches wide. Striping designs must comply with American Association of State Highway and Transportation Officials (AASHTO) standards, federal standards (such as the standards laid out in the **MUTCD**), and DDOT standards, as approved by the DDOT Bicycle Coordinator with the Transportation Policy and Planning Administration. Bicycle lane symbols and directional arrows are spaced 6 feet apart within the 5-foot-wide bike lane.
- The width of the bike lane must be 5 to 6 feet, or 4 feet where the distance between the curb and inside stripe is 12 feet including parking.

- **Signalized Intersections**. At signalized intersections, starting from the stop line, all approach lane lines must be at a minimum of 90 feet long. At the end of the 90-foot line, align all other approach lane lines so they are all normal to the roadway. From this point, begin 30-foot skip spaces and 10-foot lane lines. At the end of each block, the last skip line must not be less than 10 feet long. If it is less than 10 feet in length, it must be connected to the next to last dash line. When one dash line is shorter, match all of the other adjoining dash lines to make a uniform appearance.
- Refer to **DDOT Standard Drawings** for size and dimension details.

44.6. Double Yellow Center Lines

- Double yellow centerlines are two 4-inch-wide yellow lines separated by 4-inch-wide spacing.
- Double yellow center lines are to be marked on all roadways that have sufficient width to allow two 10-foot travel lanes and two 7-foot parallel curb-parking lanes, with a minimum street width of 34 feet.
- Undivided roadways where four or more lanes are available for moving traffic at all times must have double yellow lines.
- Double yellow centerlines will be placed on roadways less than 34 feet in width only if the centerline is offset.
- On two-way roadways that are 32 feet wide or less, a 20-foot section of the double yellow center line must be marked, from the stop bar back, when the roadway approaches a controlled intersection.
- The double yellow centerline should be brought up to the stop line, or to where such a line would be if there is no stop line, unless otherwise noted.

44.7. Crosswalks

- Crosswalks must be 10 feet wide on local streets, 15 feet wide on collector streets, and 20 feet wide on major arterials with high pedestrian volumes.
- Standard parallel crosswalk lines (low visibility) must be white and 6 inches wide.
- High-visibility crosswalks consist of 2-foot-wide longitudinal stripes parallel to the curb line and spaced every 2 feet with 2-foot-wide white stripes. Edge lines are to be 6 inches wide within crosswalks.
- All curb ramps must be located within the marked crosswalk, not including side flares of the ramps. All curb ramps must be installed perpendicular (90 degrees) to the gutter pan angle, with the back side of the flare aligned as closely as possible to the back edge line of the crosswalk.

Crosswalks are to be marked at the following locations:[1]

- Intersections or mid-block locations controlled by vehicular and/or pedestrian traffic signals or all-way stop signs.
- High-visibility crosswalks are required at all uncontrolled crosswalks and all crosswalks (including signalized or stop-controlled crosswalks) leading to a block with a school, within a designated school zone area, along a designated school walking route, on blocks adjacent to a Metro station, in areas with moderate to high pedestrian volumes, and in locations with high frequencies of conflicts with pedestrians and turning vehicles.
- In general, high-visibility crosswalk markings are strongly preferred over decorative markings because they are easier for motorists to see. Crosswalks constructed of decorative materials should include 12-inch-wide reflective white strips along the boundary of the crosswalk to maximize visibility. The decorative surface must be firm, stable and slip resistant; vertical displacement must not exceed 1/4 inch, and horizontal gaps must not exceed 1/2 inch per ADA requirements.
- At the nearest intersection of all bus stops.
- ADA ramps must be included at all crosswalks, whether at a corner or mid-block. ADA ramps must be installed in pairs of two, one for each pedestrian travel direction.

The potential for motor vehicle-pedestrian crashes increases significantly where crosswalk markings alone are used at uncontrolled crossing locations (1) along multi-lane streets with no raised medians on which traffic volumes exceed approximately 12,000 vehicles per day, and (2) along multi-lane streets with raised medians that could serve as crossing islands and whose traffic exceeds 15,000 vehicles per day. Crosswalk enhancements should therefore be considered to provide safer crossings at these locations.

44.7.1. Types of Crosswalk Markings

Parallel crosswalk markings are two 6-inch lines placed at either edge of the crosswalk. The stripes are perpendicular to the roadway centerline except in the case of skewed intersections.

High-visibility crosswalk markings add longitudinal markings in addition to the 6-inch edge lines. The edge lines are perpendicular to the roadway centerline except in the case of skewed intersections.

[1]Exceptions to these rules are possible when a crosswalk is omitted because of a dangerous situation for pedestrians. All exceptions must be approved by the DDOT Chief Engineer and a dedicated DDOT traffic engineer.

Decorative crosswalk markings are crosswalks marked with brick, stamped concrete or other special materials. Any decorative crosswalk markings must be in accordance with the latest version of the **MUTCD**.

44.8. Parking Lines

- A parking "L" should be marked to indicate the beginning and ending limit for on-street parking.
- A parking area, if drawn adjacent to curbs, should have a width of 7 feet (including the gutter) measured from the face of curb.
- A parking "L" and parking spaces should be drawn with 4-inch-wide white lines.
- If there are restrictions limiting where parking is allowed, one of the following signs should be posted to limit the distance to and from each intersection where parking will be allowed: NO STANDING OR PARKING ANYTIME, NO PARKING ANYTIME, NO STANDING OR PARKING: METRO BUS ZONE, and NO PARKING OR STANDING with (RUSH HOUR/TIME LIMIT RESTRICTIONS).
- Refer to **Chapter 45** of this manual for detailed parking regulations.

44.8.1. Accessible Parking

Accessible parking must be marked and signed in accordance with the **Americans with Disabilities Act Accessibility Guidelines**. Additionally, the aisle adjacent to an accessible off-street parking space must use 1-foot-wide stripes spaced 2 feet apart, on a 45-degree angle. Refer to **Chapter 45** of this manual for detailed information on accessible parking.

44.9. Diagonal Lines

Diagonal lines are to be used to call attention to areas not intended for vehicular use. The following is a partial list of these areas:

- Gore areas
- Painted channeling island
- Obstruction markings
- Paved shoulders, where necessary

On urban arterials, diagonal lines are to be 12 inches wide spaced 5 feet on center; on expressways and interstates, 24-inch lines spaced 10 feet apart are used. They are to be placed at a 45-degree angle to the line forming the perimeter of the area.

44.10.Pavement Marking Messages (Symbols, Arrows and Words)

- Arrow or "ONLY" markings are spaced 32 feet apart unless otherwise noted.

- When approaching an intersection, all turn lane messages must begin with an arrow, followed by the word “ONLY” and end with an arrow. This entire message usually fits within the 90-foot solid lane limit.
- For longer turn lanes, the message must be arrow, “ONLY”, arrow, “ONLY” arrow. This message always has the word “ONLY” twice, and an arrow symbol at the beginning, in the middle between the “ONLY” and at the end.
- When combing markings, e.g., left and through arrows in one lane and an arrow and word message in an adjacent lane, all arrows of each lane should align with each other.
- Preformed thermoplastic must be used for all pavement markings such as arrows, crosswalks, railroad crossings, school crossings, stop bars and bike symbols.
- Preformed thermoplastic pavement marking must be used for asphalt pavement, and preformed high-contrast tape pavement markings must be used for Portland Cement Concrete (PCC) pavements. Prefabricated legends and symbols must conform to the applicable shapes and sizes as outlined in the **MUTCD**.

44.11.Permanent Striping

Thermoplastic pavement markings must be placed on all asphalt concrete surfaces, and high-contrast tape pavement markings must be used for PCC surfaces as directed. Unless there is an emergency, striping is not to be placed when the ambient temperature is below 50 degrees Fahrenheit.

44.12.Temporary Striping

Before re-opening a roadway for travel where pavement or permanent striping cannot be completed due to construction staging, weather or time constraints, when approved, temporary striping is required.

All pre-markings must be of the same general color as the pavement markings being pre-marked. When tape is used as pre-marking, pre-marking must be 4-inch by 4-inch or smaller squares or 4-inch diameter or smaller circles spaced at 25-foot minimum intervals. At locations where the pavement marking colors will change, e.g., gore marking, the ends of the markings may be pre-marked regardless of the spacing.

Pre-markings must not be installed when the ambient temperature is below 50 degrees Fahrenheit, and in no case will the removal of temporary lane markings require destructive measures, such as burring or grinding from permanent roadway surfaces.

Any existing striping that conflicts with the proposed temporary markings must be eradicated when temporary striping is utilized. Once the traffic has been restored to its final alignment, the permanent striping must be restored and the temporary striping eradicated.

44.13. Traffic Signs

44.13.1. General

- **Type and Location of Signs.** The DDOT project traffic engineer makes the final determination regarding the type and location of controls to be placed within the ROW. The controls include traffic control signs, street name signs, delineators and permanent barricades.
- No sign of any type can be mounted in a tree box.
- Signs should not be mounted on wood poles being used by the telephone company or PEPCO unless owned by the District of Columbia.
- **Design.** All design must be in accordance with this manual and the latest revision of the **MUTCD** and the Federal Highway Administration's **Standard Highway Signs** manual.
- **Sign Posts, Supports and Mountings.** Sign posts and their foundations and sign mountings must be constructed to hold signs in a proper and permanent position, to resist swaying in the wind or displacement by vandalism. See **Chapter 35** of this manual for the design of ground-mounted sign supports.
- **Breakaway Post System.** Posts must be of appropriate length to comply with **MUTCD** specifications for the location and must conform to the federal breakaway standards.
- **Sign Reflectivity.** All traffic control signs must be fabricated with reflective materials. All regulation signs, such as stop signs and one-way signs, must use Diamond Grade sheeting. For all other signs, High-Intensity Grade sheeting must be used. Engineer Grade sheeting may be used only if authorized by DDOT for signs of less importance. Sheeting for all School Zone (S1-1) crossing signs and sheeting for all mid-block Pedestrian and Advanced Pedestrian crossing (W11-2) signs must be Fluorescent High-Performance Lime Green – Diamond Grade.
- **Backing Plates.** Thickness of aluminum traffic signs must be 0.125 gauge. For all other message signs, such as neighborhood watch signs, a lesser gauge may be used.

44.13.2. Traffic Control Signs

- **Design and Size.** Sign specifications and diagrams are detailed in the latest revision of the **MUTCD**. This publication is available from the U.S. Department of Transportation, Federal Highway Administration. Acceptable sign sizes are listed in the "standard" column of the table printed with each diagram. Expressway and construction signs must be a minimum of 36 inches.

- **Mounting.** Signs should be mounted on existing streetlight and power poles, with new posts being used only if necessary. Streetlight locations should be checked for potential sign installation during the design process and shown on the signage and striping plan sheets. Using stainless steel banding to mount signs is acceptable for fiberglass and steel poles.
- Regulatory
    - **Sheeting Materials.** All signs must be fabricated with only sheeting material, including letters. No silk-screened signs will be permitted.
    - **Stop Signs.** Stop signs must be a minimum of 30 inches tall.
    - **Yield Signs.** For minor intersections only, a yield sign may be used in lieu of a stop sign, at the discretion of DDOT and according to **MUTCD**.
    - **Speed Limit Signs.** All collectors and arterials should have speed limit signs in accordance with the **MUTCD,** latest edition.
    - **Parking/No Parking Signs.** Designated parking and no parking zones must have signs in accordance with **MUTCD**.
    - **Truck Routing Signs/Truck Restriction Signs.** Restricted routes must have signs in accordance with the District Freight Signage Plan**.**

44.13.3. Roundabouts

Signage is required in advance of roundabouts. Use “Yield at Roundabout” (W3-2a, 36 inches by 36 inches or R1-2, 36 inches by 36 inches), “Roundabout Advisory Sign” (RB-1, 24 inches by 24 inches) and “Reduced Speed Ahead” (R2-5a, 24 inches by 30 inches). The “Yield” sign (R1-2, 36 inches by 36 inches) must be located at each entry to the roundabouts. An arrow sign designating direction of travel in the traffic circle must be located on the central island.

NOTE: If any pedestrian crossings are provided at these roundabouts, pedestrian signs (symbolic pedestrian, without crosswalk lines) are required before all approaches to the intersections. Place the signs a minimum of 150 feet before the crosswalks and another pedestrian sign at the crosswalk (with crosswalk lines on sign).

44.13.4. Bus Stop Signage

The Metrobus stop sign should be located at the beginning of the bus stop after the 50-foot taper. These signs will be installed by the Washington Metropolitan Area Transit Authority (WMATA).

“No Standing or Parking – Metrobus Zone” signs should be posted at both ends of the bus stop. These signs will be installed by DDOT.

45 Parking

This chapter defines the parking criteria for on-street parking, Central Business District (CBD) parking, and other special requirement areas. This chapter also establishes the dimensional requirements for off-street parking. Parking must meet DDOT requirements, **District of Columbia Municipal Regulations (DCMR) 18 Chapter 24**, and **Americans with Disabilities Act Accessibility Guidelines**.

45.1. On-Street Parking

Depending on the roadway classification, certain roadways have on-street parking designated by an "L" shaped pavement marking or "parking space" signs. The functional classification of roadways adopted by DDOT is presented in **Chapter 30** of this manual.

To accommodate on-street parking in the District and to minimize potential accidents and conflicts between moving and parking vehicles, the dimensional requirements of Table 45-1 must be used.

Table 45-1 | On-Street Parking Space Dimensional Requirements

DEGREES	STALL WIDTH	STALL DEPTH	ADJACENT LANE WIDTH	SKEW WIDTH
90	9'-0"	18'-0"	24'-0" Min	None
60	9'-0"	19'-0"	14'-6" Min	9'-3"
45	9'-0"	17'-8"	12'-8" Min	12'-9"
0 (Parallel)	8'-0"	20' to 22'	N/A	None
0 (Parallel)	7'-0"	20' to 22'	N/A	None

All on-street parking areas must be striped as designated in Table 45-1 to provide sufficient depth and width for vehicles. For streets where parking is limited or not allowed, "No Parking" street signs are required in accordance with the Federal Highway Administration's **Manual on Uniform Traffic Control Devices**.

45.1.1. Non-Parallel Parking

In the CBD and other special designation areas, the District permits perpendicular or diagonal parking. All on-street parking areas must be approved by the Public Parking Program Manager and meet the requirements of Table 45-1. The parking spaces must be striped. Diagonal parking may be approved at an angle of 45 or 60 degrees, and any angled parking on a public street must be pre-approved by DDOT. Vehicles must enter angled parking spaces only by reversing.

Parking spaces for family vehicles must be a minimum of 9 feet wide for all angled parking spaces.

45.1.2. On-Street Parking for People with Disabilities

On-street disability parking in front of DC government buildings and other places needs approval from DDOT. The parking area must be appropriately marked.

DDOT has several commercial and residential programs intended to ensure on-street parking is accessible to people with disabilities. Accessible Parking Meter standards need to be followed by designating ADA-accessible meters at ADA-accessible parking spaces. The DDOT ADA Coordinator should be contacted to ensure compliance.

Language on meters is dictated by the meter industry, location of the project and type of meter. Contact the DDOT Transportation Operations Administration (TOA) for additional information.

Only the TOA can approve installation of on-street parking spaces for people with disabilities.

45.1.3. Driveway Clearance

Sight distance is a major factor when exiting mid-block parking lots. Therefore, on-street vehicle parking spaces must have a minimum clearance of 5 feet on each side from the edge of a driveway unless special sight distance problems exist. The DDOT Chief Engineer will make the final determination of the clearance required for the driveway.

45.1.4. Intersection Clearance

No parking is allowed within an intersection.

To allow drivers to maneuver into parking spaces without encroaching on the crosswalk, and to provide space for a vehicle to wait while another vehicle is reversing into the parking space, the parking spaces must be designed with a minimum clearance of 40 feet upstream and 25 feet downstream of an intersection (measured from the intersecting roadway’s nearest face-of-curb line). If a crosswalk is present, parking spaces must be designed with a minimum clearance of 25 feet from the crosswalk. Depending on traffic conditions, parking orientation, intersection geometry and sight distance, the District may require larger clearances.

Non-parallel on-street parking must be designed with a minimum clearance of 20 feet (or 40 feet measured for an intersecting roadway's nearest face-of-curb line, whichever is greater) between the first parking space before an intersection and the stop line.

45.1.5. Fire Hydrants

No parking is allowed in front of a fire hydrant or within 10 feet in either direction from the centerline of the fire hydrant.

45.1.6. Parking in Alleys

Parking is allowed in public alleys that are at least 30 feet wide if DDOT issues a regulation permitting parking; otherwise parking is not allowed in public alleys. Parking is allowed in front of or behind private property within the alley system provided a driveway is installed. These spaces must be pre-approved by DDOT.

For parallel parking on private property and on commercial property adjacent to public alleys, there must be a minimum of 5 feet of clearance space between the parking space and the edge line of the alley. For parking at a 90-degree angle to an alley, there must be a minimum of 3 feet of space between the end and front of the parking space and the edge line of the alley.

45.2. Off-Street Parking

Parking is not allowed in the public space area between the curb of the street and the property line without a permit from the Public Space Permit Office. The regulations authorizing permits for parking in this area are provided in **DCMR Title 24**. All applications for such use must be submitted to the DDOT Public Space Committee and include payment of annual rent. For more information on this type of permit, please contact the Public Space Committee Coordinator at PublicSpace.Committee@DC.gov or via telephone at (202) 442-4960.

45.2.1. Off-Street Accessible Parking Spaces for People with Disabilities

Off-street accessible parking spaces should use a 90-degree universal parking space design. Accessible parking spaces should ideally be 11 feet wide with a 5-foot-wide aisle. This aisle may be shared between two accessible parking spaces. A 5-foot aisle must also be placed between an accessible parking space and a regular parking space. The 5-foot space must be striped in accordance with **Section 44.8.1** of this manual. The usable stall depth for accessible parking spaces is 19 feet.

Concrete curb stops should be provided for each parking space. A minimum 5-foot area must be provided in front of each parking space and must connect to an accessible route leading to a building or facility entrance.

45.2.2. Loading Zones

Loading zone spaces are to be 30 to 40 feet in length. Larger sizes must have pre-approval from the Infrastructure Project Management Administration.

45.3. Bicycle Parking

Comply with **DCMR Title 11, Chapter 21** and DDOT **Bicycle Facility Design Guide**, for off-street bicycle parking.

Refer to DDOT **Bicycle Facility Design Guide** for on-street bicycle parking.

45.4. Parking Space Sizes for Typical Family Vehicles

The Family Vehicle Classification includes the following vehicles: sub-compact, compact, standard car, large car, station wagons, 7-seat passenger vans, SUVs (4-5 passengers only), and large pick-up trucks (excluding second seats and extended cabs). Table 45-2 shows typical family vehicle classifications and Table 45-1 shows the on-street parking dimensional requirements. As the parking stall width narrows, the adjacent aisle width must be made wider to compensate for the extra maneuvering required for a vehicle to enter and exit a parking space.

- A typical family in the United States uses at least one of these vehicles.
- The average car door opening is 3 feet 8 inches.
- Table 45-1 shows the minimum required dimensions for parking space widths and angles when parking these vehicles.
- The DC Regulations require an 8 foot-wide standard for parallel parking spaces to a curb and a 9-foot standard for all angled parking spaces.

Table 45-2 | Family Vehicle Classifications

Vehicle Type	Length	Width	Height	Rear Overhang
Subcompacts	11’-7” – 14’-8”	5’-1” – 5’-8”	4’-2” – 4’-7”	3’-9”
Compacts	13’-10”– 15’-4”	5’-7” – 5’-8”	4’-4” – 4’-8”	4’-3”
Mid-Size Cars, Station Wagons	15’-0” – 16’-8”	5’-7” – 6’-0”	4’-2” – 4’-9”	4’-4”
Large Cars, 7-Seat Passenger Vans, SUV’s (small)	15’-2” – 18’-5”	5’-8” – 6’-0”	4’-7” – 5’-0”	4’-5”
Large Pick-up Trucks	15’-10”– 20’-2”	6’-5” – 6’-9”	5’-9” – 6’-4”	4’-4”

District Department of Transportation

APPENDICES

Appendix A: **Definitions**

Access for Land Uses - This access is the physical location where a legal Traversable Path may be constructed for vehicular movement between a parcel of land and the public right-of-way.

Access Management - The concept of a public agency controlling the location of access points in order to achieve the dual purposes of providing access to individual land uses and limiting access on higher order streets to facilitate the smooth flow of traffic while limiting impedance.

Addendum - Change in Contract Documents issued in writing prior to opening of bids.

Advertisement - A public announcement, as required by law, inviting bids for work to be performed, materials to be furnished, or proposals to be developed. Such advertisements will indicate with reasonable accuracy the quantity and location of the work to be done or the character and quantity of the material to be furnished and the time and place of the opening of proposals.

Alley - Public passageway for vehicles, pedestrians, drainage purposes, or any combination thereof, which connects with a street and which usually affords a means of access to the rear of properties abutting streets or highways.

Applicant - The person or designated agent providing pertinent information for preparation of permit. This is often the Developer.

Approach Taper - An approach taper is from the point where all approaching traffic must shift laterally, to the point of the beginning bay taper.

Arterial - An Arterial is that part of the roadway system serving as the principal network for through traffic flow. The routes connect primary areas of traffic generation and important rural highways entering urban areas. Arterials may contain two, four, or six through lanes.

Attached Sidewalk - Sidewalk that is adjacent to the curb.

Award - The decision of the Contracting Officer to accept the proposal of the lowest responsible bidder for the work, subject to the execution and approval of a satisfactory contract and bond to secure the performance of the work, and other conditions as may be specified or required by law.

Base Course - The layer or layers of a specified or selected material of designated thickness placed on a subbase or subgrade and used as a foundation to support an intermediate and/or surface course.

Bay Taper - Bay taper is from the edge of the adjacent through traffic lane to the beginning of the full width of the turn lane storage.

Bicycle Facilities - A general term denoting improvements and provisions made by public agencies to accommodate or encourage bicycling, including parking facilities, mapping of all Bikeways, and Shared Roadways not specifically designated for bicycle use.

Bicycle Lane (Bike Lane) - The portion of the shoulder or roadway designated by striping, signing and pavement markings for the preferential or exclusive use of bicyclists.

Bicycle Path (Bike Path) - A Bikeway physically separated from motorized vehicular traffic by open space or barriers and within either the District right-of-way or an easement.

Bicycle Route (Bike Route) - A segment of a bicycle system, designated by the District. Bicycle routes have appropriate directional or informational markers, with or without specific bicycle route numbers.

Bid Bond - A guarantee by a Surety company that the Contractor who submitted a bid on a project will not withdraw his bid for a specified period.

Bidder - Any individual, firm, partnership, corporation or joint venture submitting a proposal for the Work contemplated, acting directly or through a duly authorized representative.

Bikeway - Any road or path designed for bicycle or pedestrian traffic, but not necessarily for their exclusive use.

Bridge - A single- or multiple-span structure, including supports, erected over a depression or an obstacle such as water, highway or railway, and having a passageway for carrying traffic or other moving loads and having an opening measured along the center of the passageway of more than 20 feet.

Bridge Length - The greater dimension of a structure as measured along the center of the roadway between the backs of abutment backwalls or between ends of the bridge deck.

Bridge Roadway Width - The clear width of the superstructure measured at right angles to the center of the roadway between the bottom of curbs or, if curbs are not used, between the inner faces of parapet or railing.

Certified Minority Business Enterprise - A business enterprise that has been issued a certification of registration by the District of Columbia, Minority Business Opportunity Commission qualifying it to perform certain categories of work.

Change Order - A written order issued by the Contracting Officer to the Contractor covering changes in the contract.

Chicanes - Offset curb extensions that change the path of vehicular travel from straight to curvilinear.

Chief Engineer - Chief Engineer of the Department acting directly, or through and within authority of an authorized representative.

Code - The latest official adopted ordinances, policies, codes and regulations.

Collector - A street that provides both land access service and traffic circulation within residential neighborhoods and commercial and industrial areas. The primary purpose is to collect traffic from local streets and properties and channel it into the arterial system.

Commercial - A business area where ordinarily there are many pedestrians during day or night hours. This definition applies to densely developed business areas outside, as well as within, the central section of the District.

Completion Date - The date on which the Contract is specified to be completed.

Connective Access Between Public Streets - The physical location where one public street in one development connects to a public street in another development.

Construction Completion Time - The number of days, stated either in calendar days or as a completion date, allowed for completion of the contract, including authorized time extensions.

Construction Costs - Construction costs generally include all rights-of-way, earthwork, paving, drainage, structures, signing and striping, traffic control, lighting, landscaping, curb and gutter, sidewalk, and utility relocation work necessary to complete the required improvements.

Construction Plans - Detailed and working plans including plan and profile, details, notes and any other information necessary for complete construction of the required improvements.

Consultant Engineer - A Professional Engineer licensed in the District, working on behalf of the Developer.

Contract - The binding agreement between the District of Columbia and another party or parties.

Contract Documents - Addenda, Contract Form, General Provisions, Labor Provision, Performance and Payment Bonds, Specifications, Special Provisions, Contract Drawings, approved written Change Orders, and Agreements required to acceptably complete the Contract, including authorized extensions thereof.

Contract Drawings - All drawings, often referenced as Drawings or Plans (i.e., project drawings, Office Manual Drawings and other standard drawings), including reproductions of revisions thereof but exclusive of shop and Working Drawings and reference drawings, which show the location, character and dimensions of the prescribed work, including layouts, profiles, cross sections and other details.

Contracting Officer - The Department representative authorized to execute and administer the Contract on behalf of the District, including his or her daily appointed successor and authorized representative.

Contract Price - The price stated in the Schedule of Prices.

Contract Time - The number of calendar days allotted in the Contract Documents for the duration of the project.

Contractor - The individual, firm, partnership, corporation or joint venture under Contract with the District for execution of prescribed work, acting directly or through a duly authorized representative.

Corner Clearance - At an intersecting street, the distance along the curb line from the projection of the intersecting street flow-line to the nearest edge of the curb opening.

Corner Sight Distance - The distance necessary for the driver of a motor vehicle stopped at a stop sign on a minor street or driveway to see approaching vehicles, pedestrians and bicyclists along the intersecting major street and have sufficient space to make any allowed move to cross the major street or merge with traffic on the major street without causing vehicles, pedestrians or bicyclists traveling at or near the design speed on the major street to slow down. The controlling distance for design is the longest distance, generally the distance necessary to merge with traffic.

Cross Slope - Slope of the pavement surface, excluding gutter perpendicular to the street centerline.

Culvert - A Structure other than a bridge that provides an opening under a Roadway for drainage or other uses.

Current - As used in reference to specifications or test methods, those in effect at the time of advertisement for bids.

Days - Intended as Calendar Days and not Working Days unless stipulated as Working Days.

Department - The Department of Transportation, District of Columbia.

Departure Taper - Departure taper of a left turn bay is from the point where through traffic beyond the intersection begins a lateral shift to the left to the point where the through lane is adjacent and parallel to the centerline.

Design Coordination Meeting - A meeting between the Department, utility companies, the Consultant Engineer, the Developer, and other required attendees pre-design and during design before beginning construction of public improvements.

Design Exception - A documented decision to design a project element to design criteria that do not meet minimum values or ranges established. For projects on the National Highway System, any deviation from Federal Highway Administration (FHWA)-approved design standards, including FHWA's 13 controlling criteria, require FHWA approval.

Design Speed - The speed determined for design that takes into account the physical features of a street influencing vehicle operation; the maximum safe speed maintainable on a specified section of street when conditions permit design features to govern. Design speed is 5 to 10 mph higher than the posted speed limit to provide a factor of safety and allow for other conditions or uses of the street that may affect vehicle operation.

Design Waiver - Any deviation from design standards and standard details for local projects and those off the National Highway System.

Designer - The person or persons responsible for the creation and submission of contract documents or construction plans for the purpose of one-time construction of a facility. This person must be a licensed Professional Engineer registered in the District.

Detached Sidewalk - Sidewalk that is offset from the curb.

Developer - The private party or parties desiring to construct a Public or Private Improvement within the District or easements, securing all required approvals and permits from the District, and assuming full and complete responsibility for the Project.

Development - Construction of improvements on land that is essentially vacant.

Development Agreement - The contract between the District and the Developer, which defines Public Improvement requirements, costs, and all other related Public Improvement issues.

Director - The executive officer of the Department of Transportation.

Distance Between Double Driveways - The distance measured along the curb line between the inside edges of two adjacent curb openings.

District - The District of Columbia, a municipal corporation.

Driveway - A private access from a public or private roadway.

Driveway Approach - The portion of the driveway lying in the public right-of-way or public access easement between the street gutter lip or roadway of a public street and the right-of-way or public access easement line, for the full width of the access, including both apron and side slopes.

Earth - The word "earth," wherever used as the name of the excavated material or material to be excavated, means all kinds of material other than rock as defined herein.

Easement - The right of the District to use lands owned by a private party for the purposes of maintenance, access, drainage or other use, as specified on a plat or deed of dedication.

Edge Clearance - The distance measured along the curb line from the nearest edge of the curb opening to a point where the property line extended intersects the curb line.

Elevation - The figures given on the Drawings or in the other Contract Documents after the word "elevation" or abbreviation of it means the distance in feet above the standard datum used by the District.

Embankment - A raised structure of soil, soil aggregates, or rock below the subgrade.

Engineer - The Chief Engineer or authorized designated representative.

Estimated Cost (Cost Estimate) - Unit costs based on those approved by the Department and assigned to materials and related quantities. The Opinion of Cost must be broken down by Phase, when applicable, for each Project, and must be submitted by the Designer at the time of first plan review by the Department.

Expressway - A divided major roadway for through traffic with partial control of access and usually with interchanges at major crossroads.

Eyebrow - A bulb or semi-circular extension of a curb on the outside edge of a street or at an "L" turn to provide more street frontage for adjacent lots.

Fees - Monetary charges that compensate the District for services rendered.

Fence - An artificially constructed barrier of wood, masonry, stone, wire, metal or other manufactured material, or combination of materials, erected to enclose, partition, beautify, mark or screen areas of real property.

FHWA - Federal Highway Administration of the United States Department of Transportation.

Field Order - A written notice given by the Inspector to the Designer or Contractor detailing a change, request, mandate or corrective action necessary to conform to these Standards, approved Plans, or other applicable District Codes.

Final Acceptance - The satisfaction of all conditions with respect to the Work and completion of all aspects of the Contract as set forth in the Standard Specifications.

Final Acceptance Certificate - The letter issued by the Department in accordance with the Standard Specifications evidencing the Department's determination that Final Acceptance has occurred.

Final Acceptance Date - The date on which Final Acceptance is achieved, as indicated on the Final Acceptance Certificate.

Franchise Agreement - An agreement between the District and certain private utility companies, specifying terms and conditions for use of the District's public rights-of-way or other publicly owned land.

Freeway - A divided major roadway with full control of access and with no crossings at grade.

Frontage - The distance along the street right-of-way line of a single property or development within the property lines. A corner property at an intersection would have a separate frontage along each street.

Green Infrastructure - The living network that includes Low Impact Development (LID) techniques and connects landscape areas, natural areas and waterways.

High Volume Driveways - Private access from a public roadway designed to service 250 or more vehicle trips per day.

Highway, Street or Road - The entire right-of-way reserved for use in constructing or maintaining the roadway and its appurtenances.

Holidays - The following days are recognized as legal holidays*:

New Year's Day	Labor Day
Martin Luther King Jr. Day	Columbus Day
Washington's Birthday	Veterans Day
DC Emancipation Day	Thanksgiving Day
Memorial Day	Christmas Day
Independence Day	Inauguration Day**

*Confirm with Department of Human Resources calendar **(when applicable)

Any day declared a holiday by the District will be observed. When a holiday falls on a Sunday, the following Monday will be observed as a holiday. When a holiday falls on a Saturday, the preceding Friday will be observed.

Improvement Agreement - The Subdivision Improvements Agreement, Public Improvements Agreement or Development Agreement, which are written documents of terms and conditions related to a one-time development of a specific Project within the District's jurisdiction. Such agreements are made between the District and Developer to outline responsibilities and duties of each party

Improvements - Include public or private improvements within District rights-of-way or easements.

Industrial/Warehouse - Any establishment that manufactures or stores an article or product.

Inspector - The Engineer's authorized representative assigned to inspect any work performed and materials furnished.

Intersection nose - The radius or distance from the end of the storage bay to the near edge of the cross-route exit lane for a left turning vehicle. For left turn bays, the cross-route exit reference is normally the centerline of an un-channelized two-way street or the far edge of the median in a channelized street.

Intersection Sight Distance - See Corner Sight Distance.

Invitation for Bids - See Advertisement.

"Issued for Construction" Plans - Design plans that conform to these Standards and are signed and stamped by the Designer and signed by the appropriate Department staff and ready for distribution to the Contractor for construction.

Laboratory - The established testing laboratory or other testing laboratories that may be designated by the Engineer for the performance of tests.

Landscape - Materials including, without limitation: grass, ground cover, shrubs, vines, trees and non-living materials, commonly used in landscape development, as well as attendant irrigation systems.

Lane Width - The width of a travel lane measured from the centerline of the lane striping to the centerline of the parallel lane stripe, to the face of the curb, or lip of gutter (edge of pavement), whichever is applicable.

Lift - The maximum specified thickness of material that may be placed at one time.

Lip - Defines the outermost edge of the gutter pan, where the gutter pan meets the roadway.

Liquidated Damages - The amount to be deducted from monies due the Contractor for failure to complete the Work in the specified time.

Local Streets - All facilities that are not in one of the higher systems. Their primary purpose is to provide direct access to abutting lands and connections to the higher classification streets.

Low Impact Development (LID) - Stormwater management practices that mimic site hydrology under natural conditions by using design techniques in construction and development that store, infiltrate, evaporate, detain, or reuse and recycle runoff.

Main Member - Any member designed to carry the loads applied to the structure.

Major Streets - These streets include all major collector and arterial streets and are typically designated on the Master Street Plan or Transportation Master Plan.

Manager/Administrator - The highest level of staff authority within the Department.

May - A permissive condition.

Mayor - The elected head of the District of Columbia as set forth in Public Law 93-198, dated December 24, 1973, Title 4, Part B, Section 422(1).

Memorandum of Agreement - An agreement between DDOT and a non-District agency.

Memorandum of Understanding - An agreement between District agencies involving an exchange of materials, supplies, equipment, work or services of any kind.

Minor Street - These streets include local or minor collector streets.

Must - A mandatory condition.

Neckdowns - A narrowing of the roadway for traffic calming at intersections or mid- block.

Neighborhood - A residential or commercial area defined by ordinance.

Notice to Proceed - A written notice to the Contractor from the Contracting Officer stating the date on which the Contractor will begin executing the work or a phase of work under a Contract.

Official - A person appointed by the District to administer these Standards.

Ordinance - A law established by the District Council.

Original Cost of Design and Construction - The Original Cost of Design and Construction means the cost of financing, engineering, construction and any other costs actually and reasonably incurred that are directly attributable to the improvements.

Overall Development Plan - The Initial Plan showing Preliminary Improvements.

Parkway - A broad, landscaped highway thoroughfare.

Pavement Structure - The combination of base courses, intermediate courses and surface course placed on a subgrade to support the traffic load and distribute it to the roadbed.

Pay Item (Bid Item, Item) - An item of work specifically described and for which a price, either unit or lump sum, is provided.

Pay Item Schedule (Schedule of Prices) - A schedule showing the Pay Item number, the approximate quantity of each Pay Item, the price bid by the Contractor to be paid for each item of work performed under the Contract, the total cost of each item and the total amount bid by the Contractor.

Pedestrian Walkway - A public facility for pedestrian traffic not necessarily within the right-of-way of the vehicular traffic roadway but within public easements (e.g., public tunnels).

Performance and Payment Bond - A guarantee by a Surety company that the Contractor will be responsible for the performance and fulfillment of the Contract and will pay all bills and accounts for materials and labor used in the work.

Permittee - The holder of a valid permit from the District issued in accordance with these Standards or other District-related process.

Phasing Plan - This plan defines improvements to be completed in specified parts over a defined sequence.

Plans - The Contract Drawings that show the location, character and dimensions of the prescribed work, including layouts, profiles, cross sections and other details.

Plant - All physical resources, facilities, machinery, equipment, staging, forms, tools, work and storage space other than provided by the Contract, together with subsidiary essentials and necessary maintenance for proper construction and acceptable completion of the project.

Pre-Construction Meeting - A meeting between the Engineer and assigned agents and the Inspector to review proposed work necessary to construct the project, prior to proceeding with the work. A meeting may be required for each project at the Inspector's discretion.

Private Improvements - Those improvements similar to Public Improvements, but which are installed within private easements and requiring a Development Construction Permit.

Private Street - Contained in private easements but must be designed and constructed to these Standards.

Professional Engineer (P.E.) - See Registered Professional Engineer.

Project - All work to be completed under the contract.

Project Manager or Supervisor - The person appointed by the Contractor for management and control of work on the project as performed by the Contractor and Subcontractors.

Proposal - The offer of a bidder on the prescribed form to perform stated construction work at the prices quoted.

Proposal Form - The prescribed form on which a bidder submits an offer.

Proposal Guaranty - The security furnished with a bid assuring that the bidder will enter into the contract if his offer is accepted.

Proposed Roadway Improvements - The roadway improvements deemed necessary due to the project development.

Public Improvements – Development in public-type facilities such as pavement, curb, and gutter, sidewalk, pedestrian/bike/equestrian paths, storm drain facilities with related appurtenances, culverts, channels, bridges, water distribution, or transmission facilities with related appurtenances, sanitary sewer collection facilities with related appurtenances, water and wastewater treatment facilities, pavement markings, signage and striping, streetlights, traffic signals and related appurtenances, landscape, erosion control and right-of-way grading, or earth excavation processes integral to construction of other public improvements listed herein.

Public Improvements Acceptance, Final - The written notification from the District, after the District Engineer finds the Warranty Period satisfactorily completed, that all public improvements are free of defects and the District releases the Developer from future maintenance obligations.

Public Improvements Conveyance and Acceptance - The document and process that initially accepts for ownership, maintenance and warranty the public improvements identified by a developer in the approved Plans and Improvement Agreement for a specific project.

Public Space - All publicly owned property between property lines on a street, such as the roadway, tree spaces, sidewalks, and alleys.

Punch List, Initial or Final - A written list of work items, compiled by the Inspector, that do not conform to these Standards or other District codes that govern the project.

Raised Crosswalk - A roadway crossing that elevates the pedestrian crossing above the roadway surface. This improvement is a Traffic Calming device.

Record Drawings (As-Built Drawing) - Original design drawings updated by a Professional Engineer depicting all modifications from the design that occurred during construction.

Redevelopment - Removal or modification of existing improvements and construction of new improvements or substantial remodeling.

Registered Professional Engineer - Professional Engineer in the fields of civil, structural, mechanical or electrical engineering, who is registered with the District's Board of Registration for Professional Engineers.

Report - A professionally bound document, the contents of which may contain certain necessary analyses, surveys, tests, exhibits, and other pertinent data supporting the subject matter.

Resident Engineer - The authorized representative of the Engineer in charge of one or more construction contracts.

Right-of-Way (ROW). Also "Public ROW" - Land, property or interest therein acquired for or devoted to the District's highway purposes.

Roadbed - Graded portions of highway upon which soils base, pavement or base, surface, shoulder, sidewalk, and median are constructed.

Roadway - The portion of the highway, arterial, collector or local street right-of-way intended for vehicular and/or bicycle use.

Rock - "Rock," wherever used as the name of an excavated material, means only boulders and pieces of concrete or masonry exceeding one cubic yard in volume, and solid ledge rock whose removal, in the Engineer's opinion, requires drilling and blasting, wedging, sledging, barring or breaking up with power-operated tools. No soft or disintegrated rock that can be removed with a hand pick or power-operated excavator or shovel, or loose, or previously blasted rock or broken stone in rock fillings or elsewhere, and no rock exterior to the maximum limits of measurement allowed that may fall into the excavation, will be measured or allowed as rock.

Roundabout - A circular street intersection used as a traffic control device in lieu of a multi-way stop or traffic signal.

ROW Permit - A document, with or without conditions specified by the District, which allows a Developer to construct any public or private improvements within an improved right-of-way or easement.

Scoping Meeting - This conference is a required meeting for the Applicant and Applicant's traffic engineer to review all requirements for a project.

Secondary Member - Member not designed to carry primary loads.

Setback - The lateral distance measured perpendicular to the street and extending from the right-of-way line, or other specific feature, to the closest point of a structure.

Shared Roadway - Any roadway upon which a bicycle lane is not designated and that may be legally used by bicyclists regardless of whether such facility is specifically designated as a bikeway.

Sheltered Market - Designated projects procured in accordance with the provisions of DC Law 1-95 (Minority Contracting Act of 1976) and on which only bids from minority business enterprises pre-qualified by the District of Columbia Minority Business Opportunity Commission will be accepted.

Shop Drawings - Drawings prepared by the fabricator or supplier showing the layout and details of components fabricated in a shop, such as structural steel, reinforcing steel or railing, for inclusion in the permanent facility.

Should - An advisory condition, recommended, but not required.

Shoulder - The portion of the roadway contiguous with the traveled way for accommodation of stopped vehicles for emergency use, and for lateral support of base and surface courses.

Sidewalks - The portions of the right-of-way intended for pedestrian use.

Site - The area upon or in which the Contractor's operations are carried out and such other areas adjacent thereto as may be designated by the Engineer.

Special Provisions (Designated as S.P.) - Special directions and requirements peculiar to a project not otherwise thoroughly set forth in Standard Contract Provisions and Standard Specifications.

Specifications - All directions, provisions and requirements contained in the Standard Specifications, Supplemental Specifications, and Special provisions which are necessary for the proper performance of the contract.

Specified Completion Date - The date on which the contract work is specified to be completed.

Speed Hump - A paved hump in the street roadway. The geometrics of the speed hump determine how fast it can be navigated.

Standard Contract Provisions - Standard Instructions to Bidders, General Provisions, Labor Provisions, Bid and Contract Forms as amended for use with District of Columbia construction projects.

Standard Drawings - Drawings detailing the Department's current engineering standards.

Standard Specifications - The Department's current specifications and provisions.

Standards - "District Standards" inclusive of all secondary/supplemental codes and any subsequent amendments.

Stop Work Order (SWO) - A written instruction/notice from the Department revoking the Contractor's Construction Permit and subsequent rights to continue work on the project due to nonconformance with these Standards.

Stopping Sight Distance - This distance is measured from the driver's eye 3.5 feet above the pavement to the top of an object 6 inches high on the pavement anywhere on the roadway. It is the distance required by the driver of a vehicle traveling at the design speed to bring the vehicle to a stop after an object on the road becomes visible.

Storage Length - The distance from the end of the bay taper to the intersection nose or stop line.

Street - A public highway as shown on the records of the District, whether designated as a street, alley, avenue, freeway, road, drive, lane, place, boulevard, parkway, circle, or by some other term.

Streetscape - Pedestrian and landscape improvements in the right-of-way generally occurring between the curb and the right-of-way line. Streetscape generally includes sidewalks, street trees, pedestrian lighting, fencing, furnishings, and landscaped areas including medians and irrigation.

Structures - Bridges, culverts, catch basins, drop inlets, retaining wall, cribbing, end walls, buildings, sign supports, and appurtenant features encountered in the work and not otherwise classed herein.

Subcontractor - Any individual, partnership, firm, corporation or any acceptable combination thereof, or joint venture, to which the Contractor, with the consent of the Department, sublets part of the Contract.

Subgrade - The top surface of a roadbed upon which the pavement structure and appurtenances are constructed.

Substantial Completion - The satisfaction of the criteria for completion of construction of the project set forth in the Standard Specifications, and as defined by the Department, and as and when confirmed by the Department's issuance of the Substantial Completion Certificate.

Substantial Completion Certificate - The letter issued by the Department in accordance with the Standard Specifications evidencing the Department's determination that Substantial Completion has occurred.

Substantial Completion Date - The date on which Substantial Completion is achieved, as indicated on the Substantial Completion Certificate.

Substructure - All of that part of a bridge below the bearings of simple or continuous spans, skewbacks of arches and tops of footings of rigid frames, including backwalls.

Superintendent - The Contractor's authorized representative in responsible charge of the work.

Supplemental Specifications - Approved additions and revisions to the Standard Specifications.

Surety - The corporation, partnership or individual, other than the Contractor, executing a bond furnished by the Contractor.

Surface Course - The top layer of a pavement structure; also referred to as the "wearing course" or "top course."

Traffic Control Plan - A formal plan prepared by the Department or the Contractor indicating how traffic is to be managed during a construction project. The Traffic Control Plan (TCP) must comply with the current edition of **Manual on Uniform Traffic Control Devices**.

Trail - Any path used by pedestrians or bicyclists within a public right-of-way or easement. This would include concrete, gravel or natural surfaces.

Traversable Barriers - A barrier placed across any portion of a street and is traversable by bicyclists, pedestrians, inline skaters and emergency vehicles only.

Traversable Path - Consists of a curved curb transition, a curb cut or a drive-over curb, along with a paved driveway width.

Tree Lawn - Area of right-of-way between the curb and the sidewalk.

Tree Space - The portion of the public right-of-way used or reserved for trees.

Variance - That which differs from the standards set forth in these Standard Specifications.

Warranty Period - The period of time that the Contractor is responsible for material and workmanship defects in the work, until written notification by the District of Final Acceptance of the Public Improvements.

Wheel Path - The 3-foot wide wheel traveled portion located on both sides of the roadway and starting 2 feet from the center of the roadway.

Width of Curb Opening (W) - The width of curb opening measured at the curb line, excluding the curb transitions or curb returns.

Work - The furnishing of all labor, materials, equipment and incidentals necessary or convenient to the successful completion of the project and the carrying out of the duties and obligations imposed by the Contract.

Working Drawings - Drawings furnished by the Contractor showing the layout and details of temporary construction, procedures and methods of construction, and data for construction equipment that will be employed in the construction of the permanent facility (e.g., form drawings, erection drawings, load test pile procedures, pile hammer data, catalog cuts, performance data).

Xeriscape - A total design concept in which sound horticultural and landscaping principles are applied to reduce water usage and maintenance in the landscape. It is not meant to reduce water needs to a minimum, nor is it meant to eliminate irrigation.

Appendix B: Definitions of Acronyms

ACRONYM:	DEFINITION:
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
ADAAG	Americans with Disabilities Act Accessibility Guidelines
ADT	Average Daily Traffic
AGC	Associated General Contractors of America
AGR	annual growth rate
AOC	Architect of the Capitol
APS	Accessible Pedestrian Signal
AREMA	American Railway Engineering and Maintenance-of-Way Association
ARTBA	American Road and Transportation Builders Association
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing Materials
ATSSA	American Traffic Safety Services Association
AWDZ	Anacostia Waterfront Development Zone
AWG	American Wire Gauge
AWS	American Welding Society
AWT	Average Weekday Traffic
BID	Business Improvement District
BMP	Best Management Practice
CAD	computer-aided design
CALTRANS	California Department of Transportation
CBD	Central Business District
CBL	Construction Baseline
CBR	California Bearing Ratio
CCTV	Closed-Circuit Television
CDMA	Code Division Multiple Access
CE	Categorical Exclusion
CEQ	Council on Environmental Quality
CFA	Commission of Fine Arts
CFL	Continuous Freeway Lighting

ACRONYM:	DEFINITION:
CFR	Code of Federal Regulations
cfs	cubic feet per second
CIL	Complete Interchange Lighting
CLRP	Constrained Long-Range Plan
CoABE & FeS	Consolidated on-Board Ancillary Equipment and Fixed-end System
COG	Council of Governments
ConOps	Concept of Operations
CSE	copper sulfate half-cell electrode
CSS	Context Sensitive Solutions
CTR	Comprehensive Transportation Review
CVN	Charpy V-Notch test
DC SHPO	District of Columbia State Historic Preservation Office
DC Water	District of Columbia Water and Sewer Authority
DCEPA	District of Columbia Environmental Policy Act
DCMR	District of Columbia Municipal Regulations
DCRA	DC Department of Consumer and Regulatory Affairs
DDOT	District of Columbia Department of Transportation
DDOT SLP&DG	District of Columbia Streetlight Policy and Design Guidelines
DEM	Design and Engineering Manual
DMS	Dynamic Message Sign
DOEE	District Department of Energy and the Environment
DSL	digital subscriber line
EA	Environmental Assessment
EIS	Environmental Impact Statement
EISF	Environmental Impact Screening Form
EPA	Effective Protected Area
EPA	Environmental Protection Agency
EPB	Environmental Program Branch
EPS	Expanded Polystyrene
ESAL	Equivalent Single-Axle Load
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations

ACRONYM:	DEFINITION:
FCM	fracture critical member or member component
FGER	Final Geotechnical Engineering Report
FHWA	Federal Highway Administration
FMIS	Financial Management Information System
FONSI	Finding of No Significant Impact
FTA	Federal Transit Administration
GDR	geotechnical data report
GER	geotechnical engineering report
GI	Green Infrastructure
GPR	ground penetrating radar
HAWK	High-Intensity Activated Crosswalk
HCM	Highway Capacity Manual
HDPE	high-density polyethylene
HEC	Hydraulic Engineering Circular
HLMR	high-load multi-rotational
HMA	Hot Mix Asphalt
HPO	DC Historic Preservation Office
HPS	High Performance Steel
HPS	High Pressure Sodium
HSA	hollow-stem auger
IES	Illuminating Engineering Society
IP	Internet Protocol
iph	inches per hour
IPMA	Infrastructure Project Management Administration
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ksf	kips per square foot
ksi	kips per square inch
LCCA	Life Cycle Cost Analysis
LED	light emitting diode
LEP	Limited English Proficient
LFR	Load Factor Rating

ACRONYM:	DEFINITION:
LID	Low Impact Development
LOD	limit of disturbance
L.O.N.	Length of Need
LOS	level of service
LRFD	Load and Resistance Factor Design
LRFR	Load and Resistance Factor Rating
LRTP	Long Range Transportation Plan
MARC	Maryland Area Regional Commuter
MASH	Manual for Assessing Safety Hardware
MEP	Maximum Extent Practicable
MOA	Memorandum of Agreement
MOE	Measure of Effectiveness
MOE	Method of Evaluation
MOT	Maintenance of Traffic
MOU	Memorandum of Understanding
MPD	Metropolitan Police Department
mph	miles per hour
MSA	Moment of Sign Area
MSE	Mechanically Stabilized Earth
MUTCD	Manual on Uniform Traffic Control Devices
NACTO	National Association of City Transportation Officials
NAVD	North American Vertical Datum
NBIS	National Bridge Inspection Standards
NCHRP	National Cooperative Highway Research Program
NDT	nondestructive testing
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NEP	Non-English Proficient
NEPA	National Environmental Policy Act of 1969
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
NHS	National Highway System

ACRONYM:	DEFINITION:
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRL	Notional Rating Load
NSBA	National Steel Bridge Alliance
NSRS	National Spatial Reference System
NTCIP	National Transportation Communications for ITS Protocol
OGC	Office of the General Counsel
OMB	Office of Management and Budget
OP	Office of Planning (District of Columbia)
PA	Programmatic Agreement
PC	Point of Curvature
PCC	Portland Cement Concrete
pci	pounds per square inch per inch
PCI	Precast/Prestressed Concrete Institute
PEPCO	Potomac Electric Power Company
PDRM	preliminary design review meeting
PGA	Peak Ground Acceleration
PGER	Preliminary Geotechnical Engineering Report
PGL	Proposed Grade Line
PIL	Partial Interchange Lighting
PIP	Public Involvement Plan
PPSA	Policy, Planning, and Sustainability Administration
PRG	Priority Request Generator
PROWAG	Public Rights-of-Way Accessibility Guidelines
PS&E	Plans, Specifications and Estimates
psi	pounds per square inch
PSSR	preliminary soil survey report
P.T.	Point of Tangency
PTFE	polytetrafluoroethylene
PTI	Post-Tensioning Institute

ACRONYM:	DEFINITION:
PTZ	pan/tilt/zoom
PVC	polyvinyl chloride
PVI	point of vertical intersection
QA/QC	Quality Assurance / Quality Control
RF	Radio frequency
RNMC	Rigid Non-Metallic Conduit
ROD	Record of Decision
ROW	right-of-way
RQD	rock quality designation
RRFB	Rectangular Rapid Flashing Beacon
RWIS	Roadway Weather Information System
SBSS	Sand-Based Structural Soil
SESC	soil erosion and sediment control
SHPO	State Historic Preservation Office
SHV	Specialized Hauling Vehicle
SLP&DG	Streetlight Policy and Design Guidelines
SMM	stormwater management map
SPT	Standard Penetration Test
STIP	State Transportation Improvement Program
SUE	Subsurface Utility Engineering
Sv	storage volume
SWMP	Stormwater Management Plan
SWRv	Stormwater Retention Volume
TCP	Traffic Control Plan
TDM	Transportation Demand Management
TIA	Traffic Impact Analysis
TIP	Transportation Improvement Program
TIS	Traffic Impact Study
TMC	transportation management center
TOA	Transportation Operations Administration
TPPA	Transportation Policy and Planning Administration
TR	Transportation Report

ACRONYM:	DEFINITION:
TRB	Transportation Research Board
TCRP	Transit Cooperative Research Program
TS&L	Type, Size and Location
TSP	Transit Signal Priority
UFA	Urban Forestry Administration
UPS	Uninterruptable Power Supply
U.S.C.	U.S. Code
USCG	U.S. Coast Guard
USCS	Unified Soil Classification System
USGS	United States Geological Survey
v/c	volume-to-capacity ratio
VAC	Volts Alternating Current
VE	Value Engineering
VECP	Value Engineering Change Proposal
VI	Value Index
vpd	vehicles per day
vph	vehicles per hour
VRE	Virginia Railway Express
WASA	Water and Sewer Authority
WMATA	Washington Metropolitan Area Transit Authority

Appendix C: Project Owners and Stakeholders

C.1 Office of the Director (OD)

Infrastructure Project Management Administration (IPMA):

Design & Project Management Division (Ward Teams)

Asset Management Analysis Division

Safety, Standards & Quality Control Division

Anacostia Waterfront Initiative/Special Projects Division

C.2 Progressive Transit Services Administration (PTSA)

Policy, Planning, and Sustainability Administration (PPSA):

Policy Development Division

Strategic Transportation Planning Division

Plan Review and Compliance Division

Traffic Operation Administration (TOA)

Transportation System Maintenance Division

City-wide Program Support Division

System Inspection and Oversight Division

Urban Forestry Administration (UFA):

Program Operations Division

Field Operations Division

Project Development Shareholders:

Project Manager

Consulting Engineer

DC Water Utility Engineer

Budget Office

Commission on Fine Arts

State Historic Preservation Office

Federal Highway Administration

Federal Emergency Management Agency

U.S. Army Corps of Engineers

U.S. Fish and Wildlife

Department of Public Health, Air Quality Division

Department of the Environment

Architect of the Capitol

Project Structural Engineer

District Materials Engineer

Geotechnical Engineer

District Surveyor

District ROW Manager

Chief Engineer

National Park Service

Railroad Company

Public and Private Utilities

Federal Aviation Administration

Federal Transit Administration

Washington Metropolitan Area Transit Authority

District Corporation Counsel

Procurement Office

District Americans with Disabilities Act Coordinator

District Equal Employment Opportunity/Civil Rights

Advisory Neighborhood Commissions

Business Improvement Districts (BID)

Neighborhood Services Coordinators

National Crime Prevention Council (NCPC)

District Department of Transportation

Appendix D: DC Department of Transportation (DDOT) Project Checklist

<table>
<tr><td>DDOT Project No.</td><td>Federal-Aid Project No.</td><td>Project Location</td></tr>
<tr><td colspan="2">Beginning Limit</td><td>Ending Limit</td></tr>
<tr><td>Ward No.</td><td>Program Manager</td><td>Federal-Aid Project: [ ]

Non-Federal-Aid Project: [ ]</td></tr>
<tr><td colspan="3">Proposed improvements/scope of work</td></tr>
</table>

Step 1: Project development is managed by the Office of Planning and becomes part of the 5-year Capital Improvement Program. The initial scope of work, cost estimate and community issues are identified and coordinated with the Team Program Manager.

Step 2: The DDOT Team Program Manager reviews the initial scope of work in coordination with Office of Planning, Infrastructure Project Management Administration ROW Administration and Urban Forestry Administration. The Program Manager visits the project site to determine all issues for scope of work. Upgrade the design and construction cost estimates.

Step 3: Team Program Manager manages and reviews the in-house designs and the designs performed by consultants.

Instructions:

10. This checklist is to be used in conjunction with the **Right of Way Policies and Procedures Manual**.

The checklist is intended to aid DDOT project managers, consultant project managers and private developers engaged in designing projects for construction in the District.

X Denotes action is required of the project manager at these stages of the project.

Check (✓**)** the Clearance box when an item is completed and approval of clearance is obtained from the authorizing department, agency or administration.

All Federal-Aid Projects require coordination and approvals from the District division of the Federal Highway Administration (FHWA).

The following tables summarize the project development procedures, the anticipated activities and the agencies involved.

Section 1: General	Step 1 Project Development 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
Estimated Construction Cost	$	$	$	Project Manager	
Project Budget & Program Actions for Obligation	X	X	X	Chief Financial Officer (DDOT Budget Office)	
Public Involvement	X	X	X	Advisory Neighborhood Commissions (ANCs)	
Maintenance Input	X	X	X	ROW Administration, Traffic Operation Administration, Urban Forestry Administration	
Utility Input	X	X	X	ROW Administration & Utility Companies	
Water/Sewer (DC Water) Input	X	X	X	DC Water	
Trees & Landscaping	X	X	X	Urban Forestry Administration	
L'Enfant Landmark Location	X	X	X	National Capital Planning Commission	
Capitol Hill Location	X	X	X	Architect of the Capitol	
Historic District/Historic Bridge or on Historic Property	X	X	@ 65%	State Historic Preservation Office (SHPO), Commission of Fine Arts	
Business Improvement District & Streetscape Enhancement				DDOT Streetscape Committee, National Capital Planning Commission	
Traffic Issues	X	X	X	Infrastructure Project Management Administration (IPMA) Office of Mass Transit	
Bike/Pedestrian Improvements	X	X	X	Transportation Policy and Planning Administration	
Rehabilitation or Reconstruction	X	X	X	IPMA	

Section 1: General	Step 1 Project Development 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From	
				Department/ Administration	✓
Horizontal Control (Maryland Coordinate) and Benchmarks			X	DC Surveyor's Office	
Vertical Control (DC Datum) and Benchmarks			X	DC Surveyor's Office	
Federal Lands Affected	X	X	X	Office of Planning, General Services Administration, Federal Highway Administration, Affected Agency	
Design Data (Form 02002)		X		Project Manager	
Design Exception (02003)			@ 65%	IPMA	

Section 2: Environmental	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
Route Location Approval Major Certification (EIS) Minor Compliance (EA) Categorical Exclusion	X	X		Office of Planning	
Section 4(f)	X	X	@ 30%	National Park Service (NPS)	
Section 6(f)		X	@ 100%	DC Parks & Recreation Dept.	
ROW Acquisition	X			DC Office of Property Management	
Archaeology (Effects Determination)	X	X		DC Health	
Paleontology (Effects Determination)	X	X		DC Health	
Floodplains	X	X		DC Health, Corps of Engineers	
404 Permit	X	X	@ 65%	Corps of Engineers, Department of Energy and the Environment (DOEE)	
Wetlands	X	X		DC Health, Corps of Engineers	
Wetlands Mitigation		X	X	DC Health, Corps of Engineers	
Unite States Fish and Wildlife Service, DOEE Fisheries and Wildlife Division		X	X		
Threatened and Endangered Species	X	X	X	DC Health, DOEE	
Hazardous Waste and Materials, Contaminated soils	X	X	X	DC Health, EPA	

Section 2: Environmental	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
Noise Control - Variance	X	X	@ 30%	DC Health	
Air Quality	X	X	@ 65%	DC Health	
401 Certification	X	X	@ 65%		
402 Permit	X	X			
National Pollutant Discharge Elimination System (NPDES) Permit	X	X			
Water Quality	X	X	@ 65%	DC Health, DC Water	
Erosion Control		X	@ 65%	DC Health	
National Park Lands Permit (Work on NPS Land for Surveying and Construction)		X	Prior to 30% for Surveying @ 100% for Construction	NPS	

Section 3: Traffic	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From	
				Department/ Administration	✓
Traffic Design Data (For Year of Construction)		X		Infrastructure Project Management Administration (IPMA)	
Traffic Accident Analysis	X	X		IPMA	
Turning Movements		X		IPMA	
Signal Warrants	X	X		IPMA	
Intersection Layout/Design	X	X	X	Office of Planning, IPMA	
Interchange Layout/Design	X	X	X	Office of Planning, IPMA	
Construction/ Modification of Circles and Other Landmarks	X	X	@30%	National Capital Planning Commission	
Traffic Calming	X	X	X	IPMA	
Traffic Signal	X	X	X	IPMA	
Streetlight	X	X	X	IPMA	
Permanent Signing and Pavement Marking		X	X	IPMA	
Construction Traffic Control Plans (Signing, Signals and Pavement Marking)		X	X	IPMA	

Section 4: Structures	Step 1 Project Develop -ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
Structure – Tunnel	X	X	X	IPMA (Infrastructure Project Management Administration)	
Structure – Bridge	X	X	X	IPMA	
Structure – Culvert	X	X	X	IPMA, DC Water	
Architectural/ Aesthetic Bridge Rail	X	X	X	IPMA	
Pedestrian Overpass/Underpass	X	X	X	IPMA	
Architectural/Aesthetic Treatment of Structure		X	X	Infrastructure Project IPMA, State Historic Preservation Office (SHPO) for Historic Structures	
Foundation Investigation and Recommendation		X		IPMA (QA/QC Materials Div.)	
Structure Condition Report		X		Project Manager	
Retaining Walls, Aesthetic Treatment		X	X	Project Manager	
Noise Barrier Walls	X	X	X	DC Health	
Crashworthy Bridge Rail		X	X	Project Manager	
Vertical & Horizontal Clearance		X	X	IPMA	
Proposed Section		X	X	Project Manager	

Section 5: Pavement	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
ROW Distribution for City Streets (Width of Roadway, Sidewalks, Tree Space & ROW, etc.)		X	X	District Surveyor's Office, ROW Administration (Database)	
Distress Pavement Justification Report	X	X		Infrastructure Project Management Administration (IPMA)	
Geotechnical Studies and Pavement Analysis Investigation, Selection of Materials		X		IPMA (QA/QC Materials Div.)	
Curb Cuts, Crosswalk Layouts & ADA Requirements		X	X	Policy, Planning, and Sustainability Administration & IPMA	
Sidewalks, Curbs & Gutters and Special Treatments		X	X	IPMA	
Selection of Pavement		X	X	IPMA	
Alternative Pavement Design (Life Cycle Cost Analysis)		X	X	Project Manager	
Existing Pavement Section	X	X	X	Project Manager	
Alley Pavement	X	X	X	IPMA	
Pavement Special Materials and Treatments	X	X	X	IPMA	

Section - 6 Trees Planting and Landscaping	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
Tree Species and Planting Requirements		X	X	Urban Forestry Administration (UFA)	
Landscaping Standards		X	X	UFA	
Seeding/Sod		X	X	UFA	
Streetscape Requirements	X	X	X	DDOT Streetscape Committee	
Irrigation Systems		X	X	UFA, DC Water	

Section 7: ROW and Dry Utilities	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
ROW Involvement	X	X	X	District Surveyor's Office, ROW Administration	
Access Control	X	X	X	ROW Administration	
Relocation	X	X	X	ROW Administration	
Permit Requirement		X	X	ROW Administration	
Existing Easement		X	X	ROW Administration	
New Easement	X	X	X	ROW Administration	
Clearance			X	ROW Administration	
Attachment to Structure		X	X	ROW Administration, Infrastructure Project Management Administration	
Utility Cuts			X	ROW Administration	
Utility Cut Repairs			X	ROW administration, Infrastructure Project Management Administration	

Section 8: Water, Sewer and Storm Sewer	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
New Storm Sewer Extension	X	X	X	DC Water	
Special Structure/ Water Quality Improvement	X	X	X	Dc Health, DC Water	
Upgrade Storm Sewer Main/ Combined Sewer	X	X	X	DC Water	
Upgrade Water Main	X	X	X	DC Water	
Standard Catch Basin & Standard 15-inch Connect Pipe		X	X	Project Manager	
Upgrade Fire Hydrant		X	X	DC Water	

Section 9: Agreements, Justifications and Approvals	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
Detour Design		X	X	Infrastructure Project Management Administration (IPMA)	
Railroad/ WMATA Coordination RR/WMATA Company RR Flagging and Insurance Requirements		X	X	Railroad Company, WMATA	
Vertical & Horizontal Clearances at RR & WMATA Crossings		X	X	Railroad Company, WMATA	
Agreement Review		X	X	DDOT Legal Review	
Airport/Heliport Clearances	X	X	X	Police Dept., Capital Police, Fire Dept.	
Safety Review (Including Clear Zone Decisions)			X	IPMA	
Guiderail/Barrier Design (Special/ Unique Designs)		X	X	IPMA	
Erosion Control Scour Storm Water Quality Management		X	@ 65%	DC Health	
Special Bidding Procedures			X	IPMA	
Consolidation of Projects		X		IPMA	
Special Material Specifications			X	IPMA	
Consultant Selection and Contracting Process		X		IPMA	

Section 9: Agreements, Justifications and Approvals	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
Agreements (Intergovernmental, Public, & Private) 1. State Agreements 2. Inter-District- Agency Agreements Memorandum of Understanding (MOU) 3. Agreements with Non-District-Agency Parties Memorandum of Agreement (MOA)			X	DDOT Director	
Disadvantaged Business Enterprise Goals			X	District's Contracting Officer	

Section 10: Construction Documents	Step 1 Project Develop-ment 5-Year Plan	Step 2 Pre-design Design Scoping	Step 3 Design Phase Design Reviews 30%, 65%, 100%	Clearance From Department/ Administration	✓
Surveying Requirement		X	X	Project Manager	
Materials or Source of Materials Furnished by Others		X	X	Infrastructure Project Management Administration (IPMA)	
Work by Utility Companies/DC Water with DDOT Project		X	X	Project Manager	
Work of Others for Inclusion in DDOT Project, Such as Utilities, DC Water		X	X	IPMA	
Work by DC Forces			X	IPMA	
Utilities Certification Prior to Plans, Specifications and Estimates (PS&E)			@ 100%	ROW Administration	
Value Engineering			X	Project Manager	
PS&E Approval			@ 100	IPMA	
PS&E Package to FHWA			@ 100 %	Contract Administration Office	
Advertisement			@ 100 %	Contract Administration Office	
Bid Analysis			@ 100 %	Project Manager	
Recommendation of Approval			@ 100 %	Project Manager	
Re-advertisement			@ 100 %	IPMA	

Appendix E: Bridge Deck Evaluation

E.1 Investigation Prior to Deck Survey

The area of deck that is to be rehabilitated must be determined based on findings from the Field Condition Survey and a Bridge Deck Evaluation Survey, and any material testing conducted. The evaluation should include the following:

- Review the bridge inspection reports or any prior Bridge Deck Evaluation Survey (if available).
- Perform a site visit to determine if a Bridge Deck Evaluation Survey is warranted.
- If authorized by the District, conduct a new Bridge Deck Evaluation Survey.
- Perform a field survey to determine existing/as-built geometrics and deck profile elevations at 10-foot intervals (if warranted).
- When the superstructure is substandard in load capacity or vertical underclearance, determine whether a retrofit study is warranted.

E.2 Guidelines for Determining Deck Condition

Experience, judgment and research have shown that deterioration often continues in partially rehabilitated decks when only the obviously deteriorated portion of the deck is removed and replaced. To minimize this effect, procedures are required that will determine the extent and type of rehabilitation or reconstruction that should be performed.

These guidelines should be followed to determine existing bridge deck conditions and the extent of work required for adequate rehabilitation. They also represent the current state-of-the-art on this subject, and therefore will be updated as necessary when technology improves.

Although these are guidelines and are intended to be flexible, a great deal of care should be exercised in any significant deviation. In all cases, the rationale for any significant deviation should be explained in the project records or correspondence.

E.2.1 Visual Survey

A visual survey should be made to identify bridge decks that may be structurally inadequate or possibly contaminated with deicing chemicals such that normal maintenance is not expected to provide reasonable service. Some examples of deck slab conditions that may warrant rehabilitation or protective measures are:

- Visible concrete spalls and cracking in the deck riding surface and/or evidence of unsound concrete and cracking in the bottom exposed surface of the deck slab (which may indicate structural failure).
- Extensive deterioration of the asphaltic overlay due to underlying concrete deterioration.
- Evidence of delamination (horizontal fracture planes) of the concrete deck.
- Evidence of reinforcing steel corrosion.
- Evidence of inadequate concrete cover over the reinforcing steel.

E.2.2 Structural Adequacy

Actual behavior of the deck is different from the structural model used to analyze it. Decks can usually carry much higher loads than determined by conventional analysis. The structural adequacy of a deck is typically not an issue. The more important issue is the serviceability of the deck. Spalling of the bottom may represent a safety issue; deterioration of the top may affect the quality of the ride, and if the top surface is severely deteriorated, it may become a safety issue.

When the deterioration of the deck requires significant repairs, the structural adequacy of the deck to carry current traffic loads should be checked. An in-depth Bridge Deck Evaluation Survey and Analysis must be performed. This review should determine the extent of deficiencies and the feasibility of rehabilitation. Economics, traffic maintenance, etc., need to be evaluated when balancing the feasibility of structural restoration against complete replacement.

E.2.3 Bridge Deck Evaluation Survey and Testing

If the visual survey indicates that rehabilitation or reconstruction of the bridge deck may be warranted, a detailed Bridge Deck Evaluation Survey should be performed to further define the deficiencies in the existing deck. This appraisal should, to the extent appropriate, consider the following as recommended components of an evaluation system:

- Using appropriate equipment to detect delamination and determine the extent of internal fractures of the concrete.
- Determining the extent of reinforcing steel corrosion by the use of a half-cell corrosion detection device.
- Determining areas with inadequate concrete cover over the reinforcing steel using appropriate equipment.
- Sampling concrete and chemical analysis to determine extent of chloride contamination.

All of the bridge deck evaluation techniques are used to detect extent of deterioration in the deck, as well as potential for future deterioration. Accordingly, the following bridge deck evaluation techniques should be used in sequence and, if warranted, in combination. By using the combined results, the Designer can better evaluate the condition of the bridge deck.

- Delamination Detection:

  The use of a chain drag will readily define the areas of internal cracking in the concrete in the form of delamination at the level of the rebar. On overlaid decks, the test indicates debonding of the overlay. A visible spall is the end result of delamination or debonding. **ASTM D4580** provides the test method for measuring delaminations by sounding. On heavily traveled roadways, truck-mounted ground penetrating radar (GPR) or thermography equipment may be used to avoid road closure for testing.

- Electrical Potential:

  The electrical potential test (or half-cell test) is generally conducted on a grid on the concrete surface. The magnitude of the voltage measured determines the state of the rebar with respect to corrosion. **ASTM C876** provides the test method for measuring electrical potentials.

- Concrete Cover:

  Chloride concentrations are significant near the surface of a concrete bridge deck. When rebar has less than specified concrete cover, it becomes appreciably more susceptible to corrosion. Concrete cover is measured by a cover meter (pachometer) which is a non-destructive magnetic flux test. Generally, a grid is used.

- Chloride Content:

  The test method employs a laboratory chemical analysis of powdered concrete samples (**AASHTO T260**) that are obtained at random, or from certain locations on the bridge deck. At each location, the sample is typically obtained at the depth of the top of adjacent reinforcing steel. In addition, at a few locations, samples are obtained at several depths to determine the chloride profile within the concrete. Test results have established that the corrosion threshold is approximately 2.0 pounds of chloride per cubic yard of concrete at the level of the rebar for typical bridge deck concrete.

E.3 Procedures for Conducting Deck Evaluation Tests

E.3.1 Visual Survey

Introduction:

The first step in a Bridge Deck Evaluation Survey is visual observation to determine the extent of spalling, cracking and scaling. Visual observation, however, does not reveal hidden structural deterioration such as delamination or corrosion of rebar. The information from visual surveys is used to determine further deck condition survey needs. Visual surveys are generally documented in terms of the amount of spalling and patching as a percentage of the total deck area.

Procedure:

1. Document any deficiencies of either the deck or the overlay, such as spalling, cracking, scaling and patching. Include the location and size of deficiencies, if any.

2. Observe the underside of the deck and record the approximate size and location of all areas exhibiting cracks with or without efflorescence. Also, record all areas having concrete spalled from the bottom reinforcing. Determine the percentage of spalls and patches in the exposed concrete deck-wearing surface. Record this percentage for use in the final recommendations.

3. Decks covered with overlays should be similarly inspected, with a general condition statement made about the overlay surface.

E.3.2 Concrete Delamination Detection

Introduction:

A delamination survey gathers information on the subsurface condition of concrete bridge decks. A chain drag can be used to survey concrete bridge decks for areas of delamination. In this investigation, a chain is dragged along the surface of the concrete in a swinging motion, resulting in a ringing sound. When delaminated concrete is encountered, a noticeable "dull" sound is produced. The delaminated concrete area is outlined on the deck with chalk, crayon, or paint and can be plotted to give an overall picture of delaminated areas.

The results of the chain drag are not reliable when the bridge deck has been overlaid with bituminous concrete; therefore, its use is not recommended for bridge decks with bituminous concrete overlays.

When a concrete overlay is used, the survey cannot distinguish delamination from debonding of the overlay.

Recently, GPR or thermography has been practiced on bridge decks to map delamination (or debonding) where high traffic volumes do not justify lane closure for chain dragging. The GPR or thermography equipment is typically mounted on a vehicle that crosses the bridge at low speeds. The data gathered by the equipment is processed by software that maps the deteriorated areas.

Procedure:

1. Drag the chain in a swinging motion while walking along the concrete surface of the deck. Outline the areas of the deck over which the chain produces a distinctive "dull" sound.
2. Plot the delineated deck areas on a scaled map of the bridge deck. Record this percentage for use in the final recommendations.

E.3.3 Chloride Analysis

Introduction:

The purpose of chloride analysis is to determine the areas in the deck in which either active corrosion is present or the potential exists for active corrosion in the future. Chloride analysis provides a quantitative measure of the chloride ion contamination of concrete at selected levels in the deck. Concrete samples for chloride analysis are usually taken by a rotary hammer drill. The concrete is pulverized in the hole from the combined hammering and rotating actions of the drill, thus facilitating removal and analysis. The sampling is done at or above the level of the top reinforcing bars, and the powdered concrete is collected and sent to DDOT's laboratory for analysis. The chloride ion content is then calculated from the lab results. The "threshold" chloride content, or amount of chloride needed to initiate corrosion, is approximately 2.0 pounds of chloride per cubic yard of concrete. See the chart in **Section E.5** for guidance on repair.

Procedure:

1. **Select sample locations for chloride testing using statistical methods and plot the locations on a plan view of the deck. As a minimum requirement, 10 locations should be tested in every 6000-square-yard area.**

a) Do not take samples in areas where, according to the results of the half-cell potential survey, reinforcing steel corrosion activity is high (readings more negative than -0.35 volts)
b) Samples should not be taken in spalled or delaminated areas
c) A minimum of 10 samples per bridge should be taken or, for bridges with three spans or more, four samples should be taken in each span

2. **Locate the depth of the top reinforcing steel with a pachometer to determine the chloride sampling depth.**
3. **Obtain each of the random samples with a rotary hammer drill. Pulverize the concrete down to within 1/2 inch of the rebar location, vacuum the hole, pulverize approximately 1 inch of concrete, then collect the powdered concrete sample in an uncontaminated container. All of the samples should be properly labeled and sent to a laboratory for chloride analysis.**
4. **After all holes have been drilled and all samples collected, refill the holes with materials similar to the material that was there prior to drilling, (e.g., concrete slabs with a fast-curing "concrete compound" and asphalt overlays with asphaltic materials).**
5. **After the lab has analyzed the samples taken, calculate the percentage of the samples with a chloride content higher than 2.0 pounds per cubic yard as follows:**

$$\frac{\text{No. of Samples with Cl Greater Than 2.0 Pounds per Cubic Yard}}{\text{Total No. of Samples}} \times 100 = \_\_\%$$

E.3.4 Half-Cell Test

Introduction:

The purpose of half-cell testing is to determine the areas in the deck where active corrosion is present. Corrosion of the reinforcing bars in concrete decks is detected by an electric current flowing from the rebar at one point (the anode) to another point (the cathode). During active corrosion, an electrical potential difference exists between the anode and cathode that can be measured by copper/copper sulfate half-cells (CSE). The CSE is a pure copper rod suspended in a saturated solution of its own ions. Corrosion of the reinforcing steel can be detected by grounding the CSE to the deck slab reinforcing steel, placing the CSE in contact with the bridge deck electrolyte (i.e., touching it to a small section of deck wetted with water) and measuring the electrical potential from a volt meter attached to the CSE.

Research has demonstrated that electric potential differences more negative than -0.35 volts correspond to a high probability of active corrosion of the reinforcing steel. Potential readings of -0.20 volts or under indicate the probability of inactive or no corrosion, while potential readings between -0.20 volts and -0.35 volts indicate the possibility of active corrosion. The potential readings collected are then used to plot an equipotential map of the deck and estimate the percent area of the deck with actively corroding reinforcing steel. Surveys are temperature sensitive and should only be performed if the ambient air temperature has been above 40 degrees Fahrenheit for a minimum of 72 hours immediately prior to the date of the survey.

Procedure:

1. **Measure and mark a 5-foot grid pattern on the surface of the deck. Start the grid with a 1-foot offset from the curb to keep the equipment out of the dirt and debris, and an offset from the first deck joint that will allow convenient placing of the grid pattern on the deck.**
2. **Uncoil an ample length of wire to reach all grid points to be tested, and connect the CSE to the positive jack of the voltmeter.**
3. **Pre-wet the deck at the grid points with water, saturate a sponge with water, and attach it to the bottom of the half-cell.**
4. **Begin to take readings of the electrical potentials at every other grid point with the half-cell, and continue the testing until the whole grid pattern has been completed. The time it takes to get a stable reading will indicate the proper "soak" time for the deck. The voltmeter needle should have an immediate response and settle down when good connections have been made. Note: If the deck is too wet or frozen, reliable readings cannot be taken.**
5. **After the fieldwork is completed, the data can be recorded on graph paper and the equipotential lines plotted to produce an equipotential contour map.**
6. **The percentage of possible corrosion-affected deck area is then calculated from the results by counting the number of test points equal to or more negative than -0.35 volts:**

No. of Samples Equal to or More Negative than -0.35 volts x 100= __%

E.3.5 Pachometer Test

Introduction:

To properly establish the deck condition, the depth of cover over the top reinforcement needs to be determined. A pachometer is a magnetic device that can determine the concrete cover, and rebar sizes, spacing and length. This will provide the evaluator with the information to judge the existing condition relative to the required minimum depth of cover.

Procedure:

1. **Conduct a pachometer survey, preferably on a grid, to determine the depth of the concrete cover over the reinforcement steel. The equipment must be calibrated according to the equipment manufacturer's specifications.**

E.3.6 Petrographic Analysis and Examination

Petrographic examination of the concrete will determine if there is presence of, or potential for, other types of deterioration. The test involves coring concrete in the field, preparing the samples in the lab and microscopic examination by an experienced technician. This test will detect deterioration from freeze-thaw, reactive aggregate, sulfate attack or other non-corrosion factors.

E.4 Test Result Analysis to Determine Deck Condition

An example of the summary calculations for a composite result of the previously described tests is as follows:

- Visual: The percentage of visual spalls over the top of the deck is 10 percent.
- Concrete Delamination Detection: The analysis of the data revealed that 65 percent of the tested area is delaminated.
- Chloride Analysis: The results of the chloride analysis (shown below) revealed that 60 percent of the samples tested were above the 2.0 pounds per cubic yard threshold.

$$\frac{\text{Unacceptable Samples} = (6)}{\text{Total Samples} = (10)} = 60\%$$

- Half-Cell Test: The results of the half-cell testing (shown below) revealed that 13.5 percent of the tests taken were equal to or more negative than -0.35 volts.

$$\frac{\text{Unacceptable Samples} = (13)}{\text{Total Samples} = (96)} = 13.5\%$$

E.4.1 Composite Result, to Determine Compromised Deck Area

Starting with 100 percent of the deck and deducting non-duplicative contaminated areas from the tests above:

Visual	100.0 - (100.0 x 0.10) = 90.0% Remaining uncontaminated
Delamination	90.0 - (90.0 x 0.65) = 31.5% Remaining uncontaminated
Chloride	31.5 - (31.5 x 0.60) = 12.6% Remaining uncontaminated
Half-Cell	12.6 - (12.6 x 0.135) = 10.9% Remaining uncontaminated

Composite Result, Giving Compromised Deck Area = 100.0 - 10.9 = **89.1%.**

E.4.2 Conclusions and Recommendations

The final category classification, using the percentage of bridge deck area compromised shown in the example above, should be made in accordance with the Category Classification section below. The classification and evaluation of the deck should also incorporate engineering judgment in addition to the test results to provide a meaningful and complete recommendation for deck treatment.

E.4.3 Category Classification

The three categories of condition described below are based on the best judgment available nationally.

Note that Category 2 will in many cases overlap Category 1. In such cases, DDOT will exercise its best judgment based on engineering, economics and other factors to properly categorize a given bridge deck.

E.4.3.1 Category 1 - Extensive Active Corrosion

Corrosion is ranked as Category 1 if the deck meets any of the following:

- 5 percent or more of the deck is spalled.
- The compromised deck area (see **Section E.4.1**), i.e., combination of spalls, delamination and corrosion potentials equal to or more negative than -0.35 volts (CSE), is 40 percent or more of the deck area.
- Random chloride sampling indicates that 40 percent of the area of the bridge deck contains greater than 2.0 pounds of chloride per cubic yard of concrete at the level of the top rebar.

E.4.3.2 Category 2 - Moderate Active Corrosion

Corrosion is ranked as Category 2 if the deck meets any of the following:

- 0 to 5 percent of the deck is spalled.
- The compromised deck area, i.e., combination of spalls, delamination and corrosion potentials equal to or more negative than -0.35 volts (CSE), is 5 to 40 percent of the deck area.

- Random chloride sampling indicates that 5 to 40 percent of the area of the bridge deck contains greater than 2.0 pounds of chloride per cubic yard of concrete at the level of the top rebar.

E.4.3.3 Category 3 - Light to No Active Corrosion

Corrosion is ranked as Category 3 if the deck meets any of the following:

- 0 percent of the deck is spalled.
- The compromised deck area, i.e., combination of delamination and corrosion potentials equal to or more negative than -0.35 volts (CSE), is 0 to 5 percent of the deck area.
- Random chloride sampling indicates that 0 to 5 percent of the area of the bridge deck contains greater than 2.0 pounds of chloride per cubic yard of concrete at the level of the top rebar.

E.5 Recommended Deck Treatment Procedures

Based on the above bridge deck categorization, Table E-1 may be used as a guide to determine the procedures for extending the bridge deck life: 1) 75 years, 2) 30 years, or 3) 10 to 15 years.

Table E-1 | Treatment Procedure Chart

Category	Deck Treatment Procedure	
	(Est. extended life 75 or 30 yrs.)	**(Est. extended life 10 to 15 yrs.)**
1 Extensive Corrosion	**Restoration (75 years):** Complete deck replacement **Protection:** No additional protection is needed beyond the standard bar cover depth and epoxy-coated bars	**Restoration:** Removal and replacement of all areas of deterioration and chloride-contaminated concrete as determined by corrosion potentials and/or chloride sampling. **Protection:** Concrete overlay protective system.* **However, if deck is deemed structurally inadequate,** deck replacement is recommended, to extend life 75 years. ☜

Category	Deck Treatment Procedure	
	(Est. extended life 75 or 30 yrs.)	(Est. extended life 10 to 15 yrs.)
2 **Moderate** **Corrosion**	Same as Category 1 above * OR Same as Category 3 below*	Same as Category 1 above
3 **Light** **Corrosion**	**Restoration (30 years):** Removal and replacement of all areas of deterioration and chloride-contaminated concrete as determined by corrosion potentials and/or chloride sampling. (**Note that only less than 5 percent of the deck area is compromised.)** **Protection:** Waterproofing membrane with bituminous concrete overlay* OR Concrete overlay protective system*	Note: For this category of condition, more durable treatment is recommended, extending life 30 years minimum. ☜

* When approved by DDOT.

E.6 Deck Evaluation Reporting Requirements

This section explains how to document findings of the deck evaluation. It is important that all parts of this section be completely satisfied to document deck condition properly and support the recommendation to repair or replace the deck. Content of the section may vary because of the severity of deck deterioration or extensiveness of the proposed rehabilitation.

A. TITLE: BRIDGE DECK EVALUATION REPORT

Identify Structure

- BIN Number
- Ward
- Feature Carried
- Feature Crossed

B. INTRODUCTION

Bridge History

- Year built
- Bridge type
- Structure length and out-to-out width
- Previous work done, particularly on the deck
- Planned future work

Highway Classification

- Traffic volumes
- Plan for maintenance and protection of traffic

C. DECK INSPECTION FINDINGS

This includes data collected and developed during deck evaluation field work. All survey work must be recorded by span for both the top and bottom of the deck. The following should be provided for review:

1. SKETCH OF DECK UNDERSIDE:

   a) Framing system
   b) Cracks
   c) Damp areas
   d) Areas of efflorescence
   e) Rusted stay-in-place forms
   f) Spalls and exposed rebars
   g) Other indications of deterioration

   All deterioration should be quantified based on percentage of the deck exhibiting the respective type of deterioration.

2. COLOR PHOTO OF UNDERDECK:

   a) Typical good areas
   b) Areas of deterioration in each span, showing any of the seven types of deterioration just listed.

3. SKETCH OF DECK SURFACE:

   a) Spalls
   b) Cracks
   c) Joint problems
   d) Patches
   e) Other indications of deterioration

f) Core locations
g) Areas of high potential (-0.35 volts), as appropriate
h) Areas of delamination, as appropriate

All deterioration should be quantified based on percentage of deck exhibiting the particular type of deterioration.

4. COLOR PHOTOS OF DECK SURFACE:

a) Typical good areas
b) Areas of deterioration in each span, showing any of the seven types of deterioration.

5. Color photos of the bridge in elevation, approaches, substructures and any problem areas.

6. Photo layout sheets indicating location of photographer and camera orientation.

7. Forms: Copies of the most recent biennial inspection should be reviewed for comments prior to the start of the deck inspection. These forms should be attached to the deck report with additional comments added, as appropriate:

8. FINDINGS AND RECOMMENDATION

a) Classify the deck category using the percentage of bridge deck area compromised, following the procedure provided in **Section E.4**.
b) Recommend a deck treatment procedure per Table E-1.

D. SUPPLEMENTAL DECK CORING, EVALUATION AND TEST RESULTS

Deck coring may be required, as determined by the Engineer, for bridge decks with extensive or moderate corrosion, to verify the results obtained from the conventional, non-destructive deck evaluation tests, i.e., pachometer and half-cell. In addition, the deck cores are inspected visually or under petrographic analysis to detect deterioration from factors other than corrosion, i.e., freeze-thaw, reactive aggregate, and sulfate attack. Cores may also be tested for compressive strength or freeze-thaw resistance.

1. DETAILED VISUAL EXAMINATION:

General description of core(s) and any defects. Surveyor records field data and notes to help differentiate between any coring damage and concrete deterioration. The surveyor should also note the depth and location of materials encountered in the core.

For each core or series of cores, report the following:

a) Explain why this core location was selected.

b) Depth of Coring: Note whether core is full-depth or partial-depth, and if appropriate, the reason for partial-depth coring. Also note deck surface and underside condition in the core vicinity.

c) Note the thickness of layers making up the core. If all concrete layers are intact, this will only entail measurements. If rubble or broken layers are encountered, their thickness and original position in the deck should be determined during coring by measuring inside the core hole. Thicknesses, type and condition of bituminous overlays or patches should be noted.

d) Presence of a membrane, and its thickness, type and condition.

e) Reinforcing steel location, size and condition, e.g., 1-1/2 in. cover, No. 5 bar, no rust. A rebar will often have to be broken out of the core after examination to check for corrosion.

f) Concrete: Condition of the concrete may range from sound to rubble.

  1) Concrete Mortar Quality: type, depth and amounts of deterioration should be noted. Look for the following conditions:

    a) Concrete mortar scaled away due to moisture freezing and thawing.

    b) Concrete spalling caused by internal pressures such as expansive corrosion.

    c) A smooth, dense mortar on the core circumference indicates sound concrete.

    d) A rough, porous core circumference indicates possible deterioration. Coring may wash away poor quality mortar, leaving a rough irregular surface.

  2) Any voids and honeycombing due to lack of consolidation, or excess entrapped air voids should be noted.

  3) Cracking (whether horizontal, layered, or vertical) should be described.

This information can be summarized in the Bridge Deck Core Record.

Close-up photos of each core with proper identification (including BIN Number) on a card in the photos. They should be taken straight-on, with a scale used as a reference in each shot. In addition to the photos, each core should be documented as follows:

SAMPLE BRIDGE DECK CORE RECORD

Core No.:	1
Depth:	18-inch full-depth depression in asphalt overlay, underside normal
Overlay:	5 inches total, two 1-inch layers of top course over a 3-inch binder
Wearing Course:	4-inch total deterioration, steel mesh 1/2 inch from bottom
Membrane:	None
Structural Slab:	9-inch total slab thickness, slight 1/8-inch scaling at top, layered cracking through mortar around crushed stone, coarse aggregate in top 3 inches. No. 5 bar top rebar 1-1/2 inches down shows heavy corrosion; remaining 6 inches of concrete appears sound, no excess voids, good consolidation, no corrosion on bottom steel, no staining on bottom of core.
Tests:	As determined by Engineer: Petrographic, compressive strength, or freeze-thaw resistance.

Appendix F: Consultant Roadway Plan Checklist

Item	Preliminary Plans	Interim Plans	Final Plans
Title Sheet			
Identification Block			
Street Name			
Project Number			
Stationing Limits			
Signature Block			
Designer Block			
Bar Scales			
Vicinity Map			
Design Information			
Plan Sheets			
Centerlines and Stations			
Limits of Project			
Edges of Pavement			
Curb and Gutter			
Sidewalk			
ROW and Property Lines			
Ownership			
Structures			
North Arrow			
Street Names			
Railroads			
Federal Government Lands			
Political Boundaries			
Historic Designation			
Boundaries			
Sheet Identification			
Legend			

Item	Preliminary Plans	Interim Plans	Final Plans
Scale			
Curve Data			
Easement Notes			
Top and Drainage within ROW or Affecting ROW			
Excavation and Embankment Lines			
All Utilities Affecting Project Limits			
Profile Sheets			
Limits of Work			
Structures and Clearances			
Grades			
Horizontal Line of Sight Distnace or Stopping Sight Distance			
Datum			
Grades			
PVC, PVI, PVT			
All Curve Data			
Pipes and Drainage			
Utilities Affecting Project			
Summary and Quantity Sheets			
Pay Items			
Item Numbers			
Quantities			
Alternates			

Appendix G: **Standard Plan Abbreviations**

Item	Abbreviation
Addition	ADD
Avenue	AVE
Back of Curb	BOC
Back of Sidewalk	BOW
Bearing	BRG
Benchmark	BM
Bottom of Cut	BC
Bottom of Fill	BF
Bottom of Wall	BW
Building	BLDG
Centerline	CL
Cast Iron Pipe	CIP
Cubic Foot	CF
Cubic Yard	CY
Drawing	DWG
East	E
Eastbound	EB
Estimate	EST
Face of Curb	FC
Feet	FT
Flow line	FL
Gallons	GAL
Highway	HWY
Hours	HR
Inch	IN
Invert	INV
Junction	JCT
Left	LT
Linear Foot	LF
Lump Sum	LS
Manhole	MH

Item	Abbreviation
Monument	MON
National	NTL
North	N
Northbound	NB
Northeast	NE
Northeast	NE
Northwest	NW
Number	No.
Offset	OFF
Point of Intersection	PI
Point of Vertical Intersection	PVI
Point of Vertical Curve	PVC
Point of Vertical Tangent	PVT
Pounds	LBS
Property Line	PL
Radius	R
Railroad	RR
Revision	REV
ROW	R/W
South	S
Southbound	SB
Southeast	SE
Southwest	SW
Tangent	T
Temporary	TEMP
Top of Curb	TOC
Typical	TYP
West	W
Westbound	WB

Appendix H: Contents of Traffic Impact Study

1. Summary

- Project Name
- Project Location (include section, township, and range)
- Applicant Name/Address/Phone
- Traffic Engineer Name/Address/Phone

The Summary is a condensed, stand-alone document summarizing the key elements (including introduction, methodology, analysis results, etc.) in the text of the report.

2. Introduction

- Purpose of the study
- Description of site including site location and study area boundaries

3. Site Plan

- Existing and Proposed Uses in Vicinity of the Site
- Existing and Committed Surface Transportation Network
- Short-term and long-term planning horizon
- Please attach the following maps:
- Vicinity map, with site and study area
- Site plan with transportation network
- Study area land uses
- Committed surface transportation network

4. Existing Traffic Conditions

- Attach the daily, a.m., and p.m. peak hour traffic map(s)
- Description of analysis methodology
- Attach levels of service tables or maps

5. Future Traffic Conditions without Proposed Development

- Background traffic volume forecast for short-term and long-term study year
- Attach the projected daily, a.m., and p.m. peak hour traffic map(s) for the study years

- Attach levels of service tables and maps
- Tables showing average and 95th percentile queue lengths of each approach or movement at intersections
- Volume-to-Capacity (v/c) ratio

6. Proposed Project Traffic

- Development plans in the study area for the short-term and long-term planning horizon years
- Describe trip generation methodology and include trip generation table
- Provide documentation for making adjustments to the trip generation rates (include a brief explanation/justification)
- Attach the trip assignment and traffic volume map(s)

7. Future Traffic Forecasts with the Proposed Development

- Attach the projected daily, a.m., and p.m. peak hour traffic map(s) with the proposed development
- Attach levels of service tables or maps
- Attach tables showing average and 95th percentile queue lengths of each approach or movement at intersections
- Volume-to-Capacity (v/c) ratio
- Traffic signal and access improvements

8. Special Analysis/Issues

Summarize any special analysis or issues that have influenced the results of this traffic impact study.

9. Required Mitigation Measures/Recommendations

- Attach a “Recommended Improvements Summary Sheet”
- Attach a scaled map or aerial photograph showing proposed improvements
- Attach a map showing level of service resulting from recommended improvements

Appendix I: List of References

- American Association of State Highway and Transportation Officials
    - A Policy on Geometric Design of Highways and Streets
    - AASHTOWare DARWin 3.1 Pavement Design and Analysis System User's Guide
    - Guide for Design of Pavement Structures
    - Guide for the Development of Bicycle Facilities
    - Guide for the Planning, Design, and Operation of Pedestrian Facilities
    - Guidelines for Skid Resistant Pavement Design
    - Highway Drainage Guidelines (2014)
    - Information Guide for Roadway Lighting
    - LRFD Bridge Design Specifications Customary U.S. Units, 6th Edition with 2012 and 2013 Interim Revisions; and 2012 Errata.
    - Manual for Bridge Evaluation
    - Roadside Design Guide
    - Roadway Lighting Design Guide
    - Standard Specification for Highway Bridges
    - Supplement to the 1993 AASHTO Guide for Design of Pavement Structures, 1998
- American Concrete Institute 318 Committee. Building Code Requirements for Structural Concrete (2014)
- American National Standard for Polyethylene Encasement for Ductile-Iron Pipe Systems C105/A21.5 Standard 2005
- American Society of Civil Engineers, Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data (2003)
- American Society for Testing and Materials
    - Annual Book of ASTM Standards 2003. Vol. 5. West Conshohocken, PA: ASTM International, 2003. Print. Ser. 4.
- American Traffic Safety Services Association

- Code of Federal Regulations
- DC Water Standard Design Guidelines, Drawings, and Specifications
- District of Columbia, Department of Energy & Environment
    - Soil Erosion and Sediment Control Handbook
    - Stormwater Management Rule and Guidebook
    - Sustainable DC Plan
    - Watershed Protection (July 2013) Stormwater Management Guidebook
- District of Columbia, Department of Transportation
    - Anacostia Waterfront Transportation Architecture Design Standards, 2005
    - Bicycle Facility Design Guide
    - Context-Sensitive Design Guidelines
    - DC Bicycle Master Plan
    - Design Guidelines for Traffic Calming Measures for Residential Streets in the District of Columbia, 2005
    - Downtown Streetscape Regulations
    - Environmental Policy and Planning Manual
    - Green Infrastructure Standards
    - Life-Cycle Cost Analysis and Load Carrying Capacity for the District of Columbia
    - moveDC
    - Pedestrian Design Guide
    - Pedestrian Master Plan
    - Public Realm Design Manual
    - Right-of-Way Policies and Procedures Manual
    - Speed Hump Request Procedures and Engineering Guidelines (2010)
    - Standard Specifications for Highways and Structures (2013)
    - Streetlight Policy and Design Guidelines

  - Temporary Traffic Control Manual & Work Zone Pocket Guide
  - Traffic Calming Assessment – Application Petition
  - Work Zone Safety and Mobility Policy
- District of Columbia Municipal Regulations (DCMR)
  - DCMR Title 18: DC Traffic Laws and other applicable District regulations and statutes
  - DCMR Title 21, Chapter 5: Stormwater and Soil Erosion and Sediment Control Regulations
- Illuminating Engineering Society Lighting Handbook
- Institute of Transportation Engineers, Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities
- National Association of City Transportation Officials
  - Urban Bikeway Design Guide
  - Urban Street Design Guide
- Smart Growth America
  - Bicycle & Pedestrian Guidelines
  - Complete Streets Policy
- Society for Protective Coatings, PA 16, Method for Evaluating Scribe Undercutting of Exposed Steel Test Panels
- Transportation Research Board, Highway Capacity Manual
- Uniform Federal Accessibility Standards
- United States Access Board
  - Americans with Disabilities Act (ADA) Accessibility Guidelines for Buildings and Facilities
  - ADA Standards for Accessible Design
  - Outdoor Developed Areas, May 2014
  - Public Rights-of-Way Accessibility Guidelines

- United State Department of Defense, Department of the Army, Army Corps of Engineers
  - Design of Sheet Pile Cellular Structures Cofferdams and Retaining Structures, EM 1110-2-2503
  - Design of Sheet Pile Walls, EM 1110-2-2504
  - Geotechnical Investigations, EM 1110-1-1804
- United States Department of Transportation, Federal Highway Administration
  - Accessible Sidewalks and Street Crossings
  - Design and Construction of Driven Pile Foundations. Reference Manual – Volume 1
  - Geotechnical Engineering Circular No. 5 (Publication No. FHWA NHI-01-031)
  - HEC No. 11 – Use of Riprap for Bank Protection
  - HEC No. 18 – Evaluating Scour at Bridges
  - HEC No. 20 – Stream Stability at Highway Structures
  - HEC No. 21 – Bridge Deck Drainage
  - HEC No. 22 – Urban Drainage Design Manual (2013)
  - HEC-23, Bridge Scour and Stream Instability Countermeasures
  - Highway Functional Classification Concepts, Criteria and Procedures
  - Manual on Uniform Traffic Control Devices
  - Publication No. FHWA NHI-05-042: Design and Construction of Driven Pile Foundations (April 2006)
  - Publication No. FHWA-NHI-10-016: Drilled Shafts: Construction Procedures and LRFD Design Methods (May 2010)
  - Roadway Lighting Handbook
  - Subsurface Investigations – Geotechnical Site Characterization (Publication No. FHWA-IF-02-034)
  - Underwater Bridge Repair, Rehabilitation, and Countermeasures (Publication No. FHWA-NHI-10-029), April 2010

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