CHAPTER 1
TRAFFIC SIGNAL DESIGN STANDARDS AND GUIDELINES

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SECTION 1: INTRODUCTION

Currently, the format and information presented on design plans for traffic signals owned and operated by VDOT throughout the State can appear significantly different depending on:

- The year the plan was developed.
- The VDOT Region where the traffic signal will be constructed and operated.
- The entity designing the plan (e.g. consultants, locality engineering departments, VDOT Region staff, VDOT Central Office staff, etc.)
- The type of design project (e.g. a VDOT regional traffic signal plan, a design-bid-build or design-build design contracted to a consultant, a traffic signal-only construction project or a roadway construction project with traffic signal design plans included, developer project, etc.)

Therefore, the purpose of this chapter in the 2014 VDOT Traffic Engineering Design Standards and Guidelines is to establish a consistent and uniform set of guides and standards for the design and plan development of VDOT traffic signals. Statewide uniformity of traffic signal plans is intended to improve the overall quality of design plans, create consistency in the information presented and required on plans throughout the State, and create significant efficiencies in the development and review of VDOT traffic signal design plans. Consistency of plan development will also aid maintenance staff as they address preventative maintenance activities and trouble calls.

This document is intended to be a resource for State and local agencies, as well as consulting engineers for design work in the Commonwealth of Virginia to identify the recommended steps to follow for the development of VDOT traffic signal design plans, as well as provide a set of plan standards for traffic signal designs. It should be noted that each VDOT Regional Operations staff have region-specific design or equipment preferences that will need to be identified by the designer prior to the start of design work. However, the format, appearance and information presented on each traffic signal design plan are hereby required to be uniform.

ACKNOWLEDGMENTS

The following references are used throughout the Section:
- The latest version of the Virginia Supplement to the MUTCD.
- VDOT Guidelines for the Installation of Marked Crosswalks policy issued by VDOT Traffic Engineering Division.
- VDOT Road Design Manual
- VDOT CADD Manual
- Traffic Detector Handbook (FHWA-IP-90-002)
SECTION 2: TRAFFIC SIGNAL PLAN REQUIREMENTS

VDOT traffic signal plans shall follow the standards described below and shall utilize the symbology, formatting and spacing for plan items as presented in the example plans provided in the Appendix to this chapter and as defined in the VDOT CADD Manual utilizing the standard symbology contained in the VDOT Traffic Engineering Design MicroStation Cell Library. In addition, the VDOT CADD Manual provides additional information relative to the file management of CADD files used for traffic signal design. Please contact CADDsupport@vdot.virginia.gov or (804) 786-1280 to obtain the appropriate Microstation files and cell libraries to be used for design.

• VDOT traffic signal plans use a combination of “Engineering” (MicroStation Font 3) and “Italics” (MicroStation Font 23) fonts. Text sizes are based on the drawing scale. Generally, for legibility purposes, the minimum text size is 1/8”. The MicroStation text size for scales may be computed by dividing the drawing scale by 8 [For example, a 25 Scale drawing should have a minimum text size of 3.125. (25 / 8 = 3.125)]. Title text should be approximately 3/16”. The MicroStation title text size for scales may be computed by multiplying the drawing scale by 3 and dividing by 16.

• A majority of text notes, legends, and call-outs are included in the VDOT Traffic Design cell libraries, as described in the VDOT CADD Manual. The text size in the cell libraries is based on 25 scale plans.

TRAFFIC SIGNAL PLAN SET GUIDELINES:

There are several different traffic signal design plan packages that may be required by VDOT, depending on the context of design being performed. Below are the most common types of design contexts relative to VDOT traffic signal design:

• Regional Traffic Signal Modification
• Regional Traffic Signal Replacement or New Installation
• Design for a New Construction Project:
  o As a stand-alone traffic signal design plan package
  o As part of a larger design project

The following descriptions of the typical plan package content and considerations are provided for each design context. It should be noted that this is guidance for typical projects, and that the VDOT project manager may require alterations to the plan package. The designer should verify the requirements of the plan package with the VDOT project manager at the start of each design project.
Regional Traffic Signal Modifications
These projects are typically considered “No Plan” maintenance, safety, or operations projects, and therefore may not require detailed (or any) survey information and will typically consist of a single signal plan sheet that is either modified using CADD, or marked up by hand. The designer shall coordinate with the applicable VDOT Regional / District representative to determine the plan sheet standards and plan package requirements. Depending on the level of development of the existing plan sheet or information being used as a base for the modification plan, the plan sheet standards as set forth in this document may not be practical.

Regional Traffic Signal Replacements and/or New Installations:
For this design context, the plan package requirements will likely vary depending on the VDOT Region / District. The appropriate VDOT Regional representative shall give specific guidance to the designer on the requirements for each plan package.

- Typically, this type of design has a minimum requirement of a single traffic signal plan sheet.
- These designs will require survey information in order to produce a base plan that will aid in the avoidance of conflicts with existing traffic signal equipment and utilities, and to ensure equipment is placed within right-of-way.
- Cost estimate using approved VDOT bid item costs from the Regional contract.
- These designs may require Title Sheet with General Notes, Traffic Management Plan Sheet or Quantities Summary Sheet.

New Construction Projects:
Type C projects are the focus of this manual. The following plan sheets are presented in the proper sequence to produce a traffic signal plan set for new construction projects. Of the plan sheets listed below, those sheets noted as, “For stand-alone projects” are typically not included if the signal design(s) are part of a roadway construction project.

Of the plan sheets listed below, those sheets noted as a “Standard sheet” requires the designer to reference the VDOT CADD Manual for detailed discussion on the format, data and sheet numbering.

a) Title Sheet (Standard sheet for stand-alone projects)
   - This is a Standard Sheet.

b) Location Map Sheet (For stand-alone projects)
   - A location map is inserted on a sheet giving enough detail to clearly identify the area and location of the project. This sheet can be combined with the Title Sheet, General Notes Sheet, Plan Index Sheet, or other if information can be consolidated legibly on a single page.
c) Plan Sheet Index (Standard sheet)
   - Generally, this sheet is not used for traffic signal design projects, but this information could be included on the Title Sheet or General Notes Sheet. If there are projects where a number of traffic signal designs are included within the project limits, then a Plan Sheet Index may be appropriate.

d) Right of Way Data Sheet (Standard sheet for stand-alone projects)
   - For projects that require right-of-way.

e) Revision Data Sheet (Standard sheet for stand-alone projects)
   - For projects that require right-of-way.

f) General Notes & Legend Sheet
   - This sheet typically contains the legend and symbology that are required to be used as well as all general notes.
   - If space permits, this sheet should include “Maintenance of Traffic” notes, otherwise a Traffic Management Plan sheet may be required.
   - An example of the General Notes and Legend Sheet is provided in the Appendix.

g) Traffic Management Plan Sheet (For stand-alone projects)
   - This sheet may be required if requested by the VDOT Region / District representative or project manager.

h) Summary Sheet (Standard Sheet)
   - An example of the Summary Sheet is provided in the Appendix.

i) Interim Standard Sheets/ Insertable Sheets
   - Provide any VDOT interim standard sheets or Insertable sheets that may be applicable to the design project.

j) Detail Sheet(s)
   - Occasionally, additional details may be necessary on the intersection plan sheets to thoroughly illustrate the design intent. These details may include:
     - Signal pole location detail (at a larger scale)
     - Pavement markings
     - Intersection signing
     - Demolition plan (when appropriate)
     - Special foundation or other structural features
     - Design features specifically related to the intersection
Plan Sheet – An example of the required format of a VDOT Traffic Signal Plan Sheet is provided in the Appendix to this chapter. Traffic signal plan sheets shall be developed in MicroStation and shall utilize the symbology presented in this chapter and included in the example plan for General Notes in the Appendix. Plan sheets shall include the following (at a minimum):

- North arrow
- Scale, typically 1"=25'
- Speed limits
- Street names and Route Number
- Regulatory and guide signs (Mast Arm mounted and ground mounted, as appropriate)
- Intersection geometry (to scale)
- Curb ramps (as required)
- Right of Way (including easements if needed)
- Show only underground and overhead utilities that are in proximity to the traffic signal infrastructure or those utilities that provide the contractor sufficient information to properly bid the traffic signal work.

In addition, plan sheets shall show all graphics and illustrations depicting signal system components including:

- Pole Locations
- Controller Cabinet Location
- Vehicle Signal Heads
- Pedestrian Signal Heads
- Vehicle Detectors/Detection Zones
- Pedestrian Push Buttons
- Luminaires (as required)
- Conduits
- Pipe (Conduit) Sleeves
- Junction Boxes
- Span Wire Routes, connections, and guy wires (as required)
- Signal Face Identification
- Controller Phasing Diagram
- Initial Timing Chart (as required)
- Color Sequence Chart
- Wiring Information
- Electrical Service Identification and Location
- Special Equipment, such as Preemption Hardware
- Plan notes
SECTION 3: VDOT PROJECT DEVELOPMENT PROCESS

The following describes how the signal design process within a new construction project aligns with the VDOT Project Development Process. Information pertaining to the Project Development Process can be found on VDOT’s website or through the VDOT Project Management Office. The specific plan requirements for each project milestone can be found in checklist format in VDOT’s Form LD-436.

• Scoping Phase:
  o Determine if survey needs to be completed for the subject project and, if so, schedule/or obtain the appropriate survey information ASAP.
  o Obtain the design input data and prepare the base plan as highlighted in Steps 1 and 2.
  o Specifically, be sure to verify that signal warrant analysis and operational analysis has been completed, and that the lane arrangements to be accommodated by the traffic signal plan have been confirmed and approved by the Regional Traffic Engineer.

• Preliminary Design Phase:
  o Collect all applicable information that will influence the design of the signal, as detailed in Steps 3, 4 and 5.
  o If required, complete an airport clearance review for the traffic signal.
  o Prepare the preliminary plan sheets required for the specific project.
  o Establish stop line and crosswalk placements, pole and controller cabinet locations, and locate traffic signal heads as required in Steps 6 through 11.
  o Determine if any traffic signal equipment will require any additional right-of-way or easements, and if so, coordinate with project manager to identify the specific limits of the required right-of-way or easements.

• Detailed Design Phase:
  o Complete detailed design including locating and designing vehicle detectors, junction boxes and conduit runs, signing and pavement marking requirements and signal wiring design as required in Steps 12 through 16.

• Final Design Phase:
  o Complete Steps 17 and 18. This includes detailing the equipment and size/length of mast arm and other poles, and develop intersection specific details, legends, diagrams, charts and notes. Also develop general notes, quantity summaries and plan notes.
SECTION 4: TRAFFIC SIGNAL DESIGN PROCESS

The VDOT signal design process is a sequence of steps that build on each other to produce a plan set. The following recommended design steps produce a plan set specifically as part a new construction project. It should be noted that ideally, these steps should apply to all designs performed for VDOT traffic signals, however, the requirements for regional traffic signal replacements, modifications and installations may vary depending on the design project and Region. The designer should obtain clear guidance on the expected design elements required for these plans from the appropriate Region / District representatives.

Step 1 – Obtain Design Input Data

❖ Obtain preliminary design information. This includes the following:

♦ Obtain the required base survey information that is a required element of the traffic signal plan. This will include the location of edge of pavement or curb lines, pavement markings, surface evidence of underground and overhead public and private utilities, any existing VDOT traffic signal equipment if present, and property lines that may impact the design. Elevation contours may be required at locations with steep slopes that may impact 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 should additional right-of-way or easement be required as part of the traffic signal design. During the survey phase, approach grades should also be collected for use in calculating clearance intervals. **NOTE: Survey information may not be required for a regional traffic signal replacement, installation or modification.**

♦ Obtain any approved traffic volume data and/or relevant traffic studies that may provide guidance on the development of signal timings or phasing that will have an impact on the design of the traffic signal equipment.

♦ To ensure that unwarranted or unauthorized traffic signals are not installed at an unsignalized location, the designer should verify that a PE-stamped and VDOT-approved traffic signal warrant study has been completed. This study should be formally approved by the applicable Regional Traffic Engineer or their assigned designee.

❖ Meet with the applicable VDOT representative (likely the Regional Traffic Engineer or their designated representative) that will provide final approval of the traffic signal
design plan sets to determine any new or area-specific design preferences for the subject intersection. VDOT has prepared a Traffic Signal Design Questionnaire that can be used to facilitate the initial discussion between the designer and the VDOT approving entity, which is attached in the Appendix to this guide.

**Step 2 – Prepare Survey/Base Plan**

The preferred level of detail for a typical traffic signal base plan is shown in Figure 1: Traffic Signal Base Plan Sheet. This sheet for a new construction project shall meet the following standards and elements:

- The base plan (and all other signal design plans) shall be prepared using Microstation and shall not be post-converted files from any other CADD software such as AutoCAD, unless otherwise approved by the Regional Traffic Engineer or their designated representative.
- The base map plan sheet should preferably be prepared utilizing the appropriate set of Microstation Survey files prepared in accordance with the VDOT CADD Manual Standards. This includes the appropriate uses of file names, official VDOT Microstation cells for traffic signal design elements, and Microstation level structures as applicable.
- The base plan should retain the appropriate VDOT survey coordinates within CADD file (if possible).
- For new construction projects, or for projects that require property acquisitions or easements, roadway alignment baselines shall be provided with sufficient data to determine stationing along the main line and intersecting cross street. For stand-alone or regional traffic signal projects, the triangulation method as described later in this document can also be used to locate signal equipment.
- The base plan should preferably illustrate “Finished” roadway elements only. “Finished” roadway elements are defined as the combined existing and proposed curb lines, roadway edge of pavement, sidewalks, drainage, curb ramps, utilities etc., as well as, existing and proposed right of way that will be in place when the project is complete. It is understood however, that depending on details of the CADD files that referenced into the base plan, additional information such as existing curb lines and roadway features that are to be removed, and other pertinent labels and annotations may be shown on the base plan, as appropriate.

The base plan sheet shall include the following (at a minimum):

- North arrow.
- Graphic Scale.
- Speed limits.
- Street names and Route Numbers.
- Finished roadway elements (to scale).
- Approach grades as defined in VDOT TE Memo 306 for use in calculating clearance intervals.
- All existing and/or proposed underground and overhead utilities in place when project is completed.
- Right of Way limits.
Figure 1: Traffic Signal Base Plan Sheet
Step 3 – Perform an Initial Site Visit and Field Verification

- The designer should perform a field verification of the intersection survey to verify the intersection geometry and to 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 survey data of all approaches, and all roadside features in and near VDOT right-of-way.
- This initial field visit can be combined with the initial Step 1 meeting with the appropriate VDOT Regional / District representative. Additionally, the designer could confirm information required in Step 4.
- The designer can meet with the local VDOT traffic signal technician to discuss the location of the power source and potential signal controller location, etc.

Step 4 – Identify Traffic Signal Operation/Lighting Requirements

The designer shall coordinate with the appropriate VDOT Regional/District representative to identify any ITS equipment requirements, the desired traffic signal operational requirements such as signal phasing, type of pedestrian accommodations, vehicle preemption, and any other operational requirements that may affect the proposed design.

If intersection lighting is not currently provided, VDOT Regional / District representatives may wish to have an intersection lighting warrant analysis performed to determine if lighting should be provided.

Step 5 – Review Geometric Design

The designer should verify that:

- Sight distance requirements for the visibility of traffic signal heads are met by referring to the latest version of FHWA's Manual on Uniform Traffic Control Devices (MUTCD).
- Existing and proposed pavement markings and/or intersection geometry can accommodate the appropriate passenger car/truck/bus turning radii as specified by VDOT representatives.

If intersection geometry modifications are being made as part of the signal design project, the designer is be required to utilize AUTOTURN Software or Turning Vehicle Templates to check that appropriate turning movements can be made within the intersection, including concurrent left-turn phases as appropriate.

Step 6 – Establish Crosswalks

- This step is performed iteratively with Steps 7 and 8.
- Verify all guidelines and preferences with the appropriate VDOT Regional Operations representative.
• Locate crosswalks, (Both Marked and Unmarked).
  − Location of crosswalks and their associated curb ramps must be evaluated concurrently and should be placed in accordance with the latest version of IIM-LD–55 and the Virginia Supplement to the MUTCD and VDOT’s Marked Crosswalk Policy. Ideally, crosswalks should be designed as an extension of the sidewalk.
• Determine whether crosswalks are to be marked per the appropriate VDOT Regional/District representative and referring to VDOT Guidelines for the Installation of Marked policy issued by VDOT Traffic Engineering Division.
• Identify crosswalk type, (Marked Only)
  − Longitudinal lines (ladder-style crosswalk). Suggested for consideration at urban locations with high traffic volumes and/or speeds where it is paramount to clearly identify marked pedestrian crossing areas, unless otherwise directed by the Regional / District representative. Longitudinal or other high-visibility crosswalks should also be considered at location with higher pedestrian volumes.
  − Transverse lines (two lines placed perpendicular to the vehicular travel path). Suggested for consideration in low-volume rural or residential areas, unless otherwise directed by the Regional/District representative.
  − Diagonal lines or other.
• Identify Crosswalk Width. The crosswalks shall be a minimum of 6 feet in width, but may be wider depending on District/Region or locality preferences and site-specific conditions.

Step 7 – Review Curb Ramp Locations
• This step is performed iteratively with Steps 6 and 8.
• Coordinate curb ramp locations. Detailed instructions concerning curb ramps are provided in the latest version of VDOT’s Instructional and Informational Memorandum IIM-LD-55 and the MUTCD.

Step 8 – Establish Stop Lines
• This step is performed iteratively with Steps 6 and 7.
• Locate stop lines. Detailed instructions for establishing stop lines are provided in the MUTCD. Additionally, the designer should seek any additional guidance information that may be utilized by the VDOT Region / District in the placement of stop lines.

Step 9 – Locate Vehicle / Pedestrian Signal Heads and Push Buttons

When determining the location of vehicle and pedestrian signal heads and push buttons, the designer should take into consideration the proposed signal operations. For instance, the following operations have effects on the selection and placement of signal heads:
• Lane usage and signal phasing including shared option lanes exclusive overlap phases, and protected, protected / permissive left-turn phases and through movements.
• Review placement of signals and signs to ensure that existing or planned improvements do not obstruct the visibility to any traffic control device.
• Place vehicle signal heads over receiving lanes, where possible. In the case of horizontal curves, the placement should reinforce proper path choice. Supplemental near-side pedestal or pole mounted signal heads should be considered for curved or skewed approaches, and/or intersections with unusual geometry or sight-distance limitations.
• In addition, verify that the vehicle and pedestrian signal heads meet the most recent requirements of the MUTCD, and conform to the preferences of the VDOT Region or District, if applicable.
• Pedestrian push button locations shall meet the standards set in the most recent ADA Standards and the MUTCD. Additional push-button poles may be need in some locations if pushbuttons mounted on main traffic signal poles conflict with ADA/MUTCD requirements.

Step 10 – Locate Signal Poles

• For Any Pole Type:
  − Ensure that clear zone and lateral offset guidelines as described in VDOT’s Road Design Manual are met or an accommodation is made.
  − Ensure adequate clearance to overhead utilities. Check NESC requirements and contact the local power provider. Typical clearances from overhead primary power lines are a 10-foot minimum in accordance with Virginia’s Overhead High Voltage Line Safety Act, but may be higher and should be verified with the local power provider.
  − Adjacent utility power poles may also carry cable, telephone, or other telecommunication utility lines. The minimum clearances for those cables should be verified with the appropriate utility owner.
  − Due to the potential that traffic signal foundations may require significant depths depending on soil type and structural loads (typically to be determined during the pole design by the contractor), the designer shall avoid placement of poles and foundations over any underground utilities. Specific clearances from the different types of utilities can be determined in coordination with the utility provider.
  − Ensure crosswalks, curb ramps and required landing areas of curb ramps are unobstructed for pedestrian use.
  − Consider pedestrian signal head locations when locating traffic signal poles in order to minimize use of pedestal poles for pedestrian signal use, if possible.
  − Consider planned future widening or improvements when locating poles.
  − For constructability purposes, new traffic signal poles and arms should be located on the downstream side of existing pole locations so that the existing signal can remain operational until the new construction is complete, when possible.
- Consider that the MUTCD requires that signal heads be placed no more than 180 feet away from the stop line without supplemental near-side signal heads. This rule typically guides the pole location and signal arm orientation required at each intersection.
- Review existing or proposed cross-sections to ensure that mast arms, signal heads, and signs will have meet or exceed the minimum vertical clearance above the road, but will not be mounted higher than the maximum allowable height above the road, as per VDOT Road & Bridge Standards and the MUTCD.
- The size of the signal pole and foundations are guided by the most recent VDOT Road and Bridge Standards.
- **Pole Labeling on Plans:** Mast arm/strain poles SHALL be labeled on plans and in the Legend starting with Pole A as the pole closest to the controller cabinet, then each mast arm/strain pole in consecutive order in a clockwise direction. After the primary poles are labeled, the controller cabinet and pedestal location should be labeled in the same methodology.

• For Pedestal Poles:
  - Consider pedestrian use when placing pedestal poles that have pedestrian indications or push buttons, so that they meet the requirements of the MUTCD and most recent ADA Standards, as well as the VDOT Road and Bridge Standards.
  - Pedestal poles may be used to support left / double left protected phase indications in median sections. Consult with the appropriate VDOT Regional/District representative to determine regional preferences relative to the permitted placement of pedestal poles in the median.

• For Combination Poles (signal poles with luminaries) and Other Street Lighting:
  - Check that entire intersection is lit to acceptable standards. The Lighting Chapter in this document provides further discussion on intersection lighting warrants and requirements.
  - Check clearances to overhead utilities and structures.
  - Coordinate with representatives of the local utilities that are in proximity to the poles as well as the local VDOT representative regarding design and maintenance standards.

• Existing poles to be modified - The designer shall prepare documentation comparing existing and proposed loading and submit to the District Structure and Bridge Engineer or his/her designee for approval. If information is not available on the design parameters used when the signal pole mast arm was originally installed, it may not be feasible to add new loads to the existing mast arm.
Step 11 – Determine Sign Requirements

- Consult the MUTCD and the Virginia Supplement to the MUTCD for appropriate sign requirements.

- Determine who will be fabricating the signs.
  - If VDOT or the Maintaining Jurisdiction is fabricating the signs, then the pay item will be for sign installation only. Show all sign dimensions on the plan sheet such that any signs located on the traffic signal structure can be included in the structural analysis by the contractor.
  - If the contractor is supplying the signs, then the pay item will be for sign fabrication and installation. A Sign Schedule plan sheet and a Sign Detail plan sheet may be necessary for fabrication of these signs, if requested by VDOT.

- Locate and illustrate Overhead Street Name Signs (OSNS).
  - Discuss street name blade design criteria with the maintaining agency.
  - Street name signs shall be designed in accordance with the latest version of the Virginia Supplement to the MUTCD. VDOT policy is that Clearview Font 5-W (desirably 12”, with 6 “-8” minimum depending on posted speed) shall be used for overhead street name signs.
  - Ensure that OSNS do not exceed the maximum width or height established by VDOT standards, and that there is enough room on the mast arm to fit the OSNS. The VDOT standards also give guidance on when and how the text height can be shrunk to reduce the overall sign width.
  - Where OSNS signs are not feasible because of constraints such as an unusually long street name, lack of room on the mast arm, or signals with diagonal arms, advance street name signs (D3-2 or D3-V2) should be considered as an alternative.

- Coordinate with sign and pavement marking designs:
  - If the traffic signal design is part of road construction plans, the traffic signal, sign and pavement marking designs will be in separate plan sets:
    - Coordinate with the sign and marking plan sets for continuity of designs.
    - Signs mounted on signal mast arms and pole shall be shown on signal plan set. Reference these signs in the sign schedule sheet of sign plan set.
    - Show all ground mounted signs related to signal design in the sign plan set.
  - If the traffic signal design is a stand-alone project, perform a field investigation of existing signs to ensure continuity with the traffic signal plan set.
    - Include in traffic signal plan set, all signs necessary for the operation of the traffic signal.
Step 12 – Identify Electrical Service Connection and Locate Controller Cabinet

• Coordinate with local power provider and the appropriate VDOT Regional Operations representative regarding electrical service point and type of service connection to be provided.
  – Document discussions and identify individuals that participate in establishing the service connection location. Include pole number where service is being provided, when possible.
  – Identify conduit, cable, riser, and junction boxes, etc. that are required to provide electrical service to the controller cabinet from the electrical service point.
  – Refer to the most recent VDOT Road and Bridge Standards for electrical service types, Standards SE-1 thru SE-11.
  – Ensure that electrical service and traffic signal system wiring are kept in separate conduit runs.
• Locate controller cabinet as convenient to the electrical service point as possible, within the parameters of the VDOT electrical service standards (typically 3’ – 20’). In addition:
  – Ensure that the controller cabinet location will not be a visibility obstruction for right turn on red movements.
  – Ensure grade at proposed cabinet location is adequate and that the controller cabinet is unobstructed for maintenance activities.
  – Locate controller cabinet where there is a less likely potential for vehicle collision.
  – Locate the cabinet so that technicians have the ability to access the lower wiring panels and be sure the cabinet is either not in a possible high water location or is elevated to reduce the possibility of water entering the cabinet. Another possible entrance for water is conduit that is slightly higher than the cabinet foundation. Ensure water has an easy means of draining out of cabinet.
  – If possible locate controller cabinet to allow technician to see as many signal heads as possible. Discuss the location with the appropriate VDOT Regional /District personnel for specific preferences.
  – Evaluate existing and/or proposed Landscaping. For stand-alone signal projects evaluate existing landscaping. For signal projects as part of a roadway construction project evaluate proposed landscaping.

Step 13 – Locate Vehicle Detectors

• Select detector technology. Coordinate with the appropriate VDOT Regional Operations representatives to identify the desired type of detector technology to be used.
• Locate detectors based on signal operation requirements and anticipated approach speeds. In general, guidance on advance loop detector or detection zone placement can be obtained from VDOT Regional / District representatives, as they are dependent on the signal timing settings used in each Region.
Step 14 – Locate Junction Boxes and Conduit Runs

- Locate junction boxes to serve detectors.

- Locate a junction box for the Electrical Service Connection, if appropriate and requested by VDOT Regional Operations staff. Refer to VDOT Standards SE-1 thru SE-11.

- Locate intermediate junction boxes.
  - Conduit runs should generally not be greater than 200-feet without intermediate junction boxes.
  - Locate junction boxes to serve signal and pedestal poles. Combine junction boxes to serve multiple services, if possible.

- Locate primary junction box.
  - It is standard practice to locate a primary junction box (usually a 24x36 inch box or larger) closest to the signal controller for convenient access to all cable runs that terminate at the controller.

- Determine junction box sizes and note in plan.
  - Coordinate with the appropriate VDOT Regional/District representative to determine junction box preferences.
  - Refer to the VDOT Road and Bridge Standards for VDOT standard junction box sizes and types.
  - Refer to the National Electric Code for properly sizing junction box.

- Evaluate where junction boxes and conduits can be placed in order to minimize costs and maximize efficiency.
  - Minimize total length of conduit used.
  - Maximize the utilization of common trenching.

- Three typical methods of conduit installation are:
  - Open Trenching Installation.
  - Jacked Pipe Installation.
  - Directional Boring Installation.

Step 15 – Final Field Visit / Design Verification Meeting

A final field visit should be held after all design work up to Step 14 is completed. The purpose of the final field visit is to field verify the final placement of the poles and cabinet, and any other key equipment to be installed at the intersection. It is highly recommended to field stake the pole and cabinet locations and determine if there are any remaining conflicts with the proposed design. Therefore, it is recommended that underground utilities and VDOT equipment (and property lines, if possible) are marked prior to the final field visit. Other factors that can be considered during the final field visit are:
• The impact of existing or future grading on the design.
• The visibility of all appropriate signal equipment as well as adjacent property features such as private signs, etc.
• The impact of the signal equipment on nearby property owners.
• Adequacy of right-of-way for maintenance and construction.
• Verify the electrical service for the proposed signal.
• Verify the communications equipment placement, if any.
• Any other issues that may affect the design.

Step 16 – Develop Signal Wiring and Conduit and Cable Legend

• If necessary, prepare a sketch of the proposed wiring / conductor layout of the intersection. The wiring schematic will ensure that all signal components are properly wired.
• All non-metal conduits are required to have equipment ground conducting (EGC) cables. The most recent VDOT Road and Bridge Standards provide discussions and applications of equipment grounding conductors.
• The wiring and conduit details shall be in a Conduit and Cable Legend to be located on the plan sheet that specifically matches the format shown in Figure 2 and in the VDOT Sample Plan provided in the Appendix. The information presented shall include the number, type and size of conduit(s) within each conduit run. The wiring details per conduit run should itemize the number and size / type of cables to be installed within each conduit. If necessary, prepare a sketch of the proposed wiring / conductor layout of the intersection.
Step 17 – Sizing Conduits

- Determine conduits size based on wiring requirements. The conduit fill chart shown below provides cable and conduit sizing requirements.
  - Maximum desirable conductor fill on new conduit installation should be 25%.
  - According to NEC requirements, maximum conductor fill for existing and new conduit shall be 40%.
  - Conduit that is not metal and is subjected to vehicle loading may require encasement in a metal pipe sleeve that is 2-inches larger in diameter than the diameter of the conduit being carried.
- If pulling new conductors through existing conduit is being considered, verify with the maintaining jurisdiction that pull ropes exist. Also, inquire whether the existing conduit has a history of conductor failures, which would indicate that the conduit is damaged.
- Include spare conduits if requested by Region/District staff.
Step 18 – Detail Mast Arm and Other Poles

- Determine mast arm length.
  - Ensure a minimum 1-foot extension of mast arm beyond the last signal head.
  - Standard mast arm lengths are limited to lengths presented in the latest version of VDOT IIM-LD-250 and TE Memo 375. If arm lengths longer than those limits are required for a design, a design waiver will be required to be submitted.

- Determine luminaire arm length, if combination poles are used.
• Determine mast arm and luminaire arm orientation.
  - Figure 4 provides guidance in determining arm and luminaire arm orientation procedures.
• Detail pole locations
  - When signal design is part of road construction project: Use station and offset method.
  - When signal design is a stand-alone project: Use triangulation method, where the pole location is fixed by establishing three distances from known objects at the intersection (e.g. fire hydrants, utility poles, etc.) Also include distance from edge of pavement or face of curb.
• Detail signal heads, signs and all devices proposed on the mast arm such as emergency preemption devices and video detection cameras, such that the loading of these devices are included in the signal pole structural calculations.

![Figure 4: GUIDE TO DETERMINE MAST ARM AND LUMINAIRE ARM](image)

**Step 19 – Develop Intersection Specific Details, Legends, Diagrams, Charts and Notes**

The following figures are provided as a guide. Specific illustrations, legends, diagrams, charts and notes must be prepared for the intersection and may not always be in the formats shown below. The design requirements of the intersection will dictate the information and formats to be shown on the plans. The following details, legends, diagrams, charts and notes are depicted in the General Notes Example Plan provided in the Appendix.
Develop a Signal Pole/Structures Detail as shown in Figure 5.
- Label signal and pedestal poles on plan sheets. In order to match the assigned structural numbers – Mast arm / strain poles SHALL be labeled starting with Pole A as the Pole closest to the controller cabinet, then each mast arm/strain pole in consecutive order in a clockwise direction.
- Identify the pole type, using VDOT Road and Bridge Standards or refer to the pole types as described in VDOT regional contracts, as applicable.
- Identify pole locations using station and offset method, (if triangulation method is used, show diagrams).
- Identify mast arm length and orientation.
- Identify signal head placement along mast arm, (dimensioned from center of pole).
- Identify sign placement along mast arm, (dimensioned from center of pole).
- Identify specialty equipment, (cameras, preemption equipment, etc. and dimension from center of pole).
- Identify luminaire arm orientation, if required.
- Identify luminaire arm mounting height, if required.

**Figure 5: SIGNAL POLE/STRUCTURE DETAILS**
Develop a Signal Head Detail as shown in Figure 6.

- Use phase numbering convention identified or otherwise directed by the appropriate VDOT Regional/District representative.
- Ensure that the signal operation and signal head details are compatible.

![Proposed Signals Diagram](image)

**Figure 6: SIGNAL HEAD DETAIL**

Develop a Sign Detail as shown in Figure 7.

- Designate signs S-1, S-2, etc.
- Show dimensions when standard signs dictate
- Identify applicable signs using MUTCD designations in the Sign Detail

![Sign Details Diagram](image)

**Figure 7: SIGN DETAIL**
Develop a Phasing Diagram as shown in Figure 8.
- Consult the signal operation analysis to ensure approved phasing.
- Show protected turning and through movements as solid lines.
- Show permissive movements and pedestrian movements as dashed lines.
- Figure 4-7 represents an 8-phase signal operation with protected only left turns and right turn overlaps.
- Provide a separate preemption phasing chart, if requested by VDOT staff.
- Overlap phases should be called out specifically as OLA, OLB, OLC, etc. and match the red and yellow clearance interval worksheet.

![Figure 8: PHASING DIAGRAM](image)

Develop a Color Sequence Chart as shown in Figure 9.
- Identify signal head designations along the left-most column, including pedestrian signal heads.
- Identify all possible phases and phase combinations that are permitted during the operation of the signal.
- Show the signal green face that would be indicated during their respective green phases on the chart.
- Show protected left and right turn movements with left and right arrows.
- Show a G to represent a circular green signal face indication.
- In cases where a protected / permissive left turn or right turn movement (five section head) is used, illustrate in the same cell when two signal faces are illuminated at the same time for the five section head, such as a left turn arrow and green circle.
- Show the appropriate vehicular/pedestrian signal face indication during Flash operations.
- Show the pedestrian signal face that would be indicated during their respective phases on the chart.

![Figure 9: COLOR SEQUENCE CHART](image)
Develop Clearance Interval Timings

- Determine clearance intervals based on the latest version of VDOT TE Memo 306.
- At final submission, the design engineer shall provide a completed and P.E.-stamped copy of the VDOT Yellow Change & Red Clearance Interval Calculator worksheet.

Develop General, Summary and Plan Notes

Notes provide clarity and simplification of plans. There are three types of notes typically used on VDOT plans and are defined as follows:

- **General Notes**
  
  Notes that apply to the entire plan set. General notes are to be numbered sequentially on the “General Notes” sheet. General notes must be tailored to the specific needs of the project. Typical topics that are addressed on the “General Notes” sheet are:
  
  - Traffic Signal Legend and Symbology. The standard required legend is presented in the figure below.
  - VDOT contact information
  - Maintaining Jurisdiction contact information Power Company contact information
  - Maintenance of Traffic notes
  - Special information specific to the overall project

Several examples of General Notes are shown in the Example Plan provided in the Appendix.

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**STANDARD TRAFFIC SIGNAL LEGEND**

<table>
<thead>
<tr>
<th>PLAN ITEM</th>
<th>PLAN SYMBOL</th>
<th>PROPOSED</th>
<th>EXISTING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Sign Pole &amp; Foundation and Mast Arm 10 ft. North of Signal Pole Legend</td>
<td><img src="symbol1.png" alt="Symbol" /></td>
<td><img src="symbol2.png" alt="Symbol" /></td>
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<tr>
<td>Pneumatic Relay and Ground Switch</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pedestrian Sign and Pedestrian Push Button</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Traffic Signal Head w/ Backplate</td>
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<td><img src="symbol4.png" alt="Symbol" /></td>
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<tr>
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<td><img src="symbol6.png" alt="Symbol" /></td>
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<tr>
<td>Pedestrian Push Button &amp; Sign</td>
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<tr>
<td>Traffic Signal Pole Mounted</td>
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<td><img src="symbol10.png" alt="Symbol" /></td>
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<tr>
<td>Emergency Vehicle Pre-emption (EVPI) Sensor w/ Conf Light</td>
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<td><img src="symbol12.png" alt="Symbol" /></td>
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<td>Video Detection Camera</td>
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<td>Video Detection Zone (Size as noted on plan)</td>
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<td><img src="symbol24.png" alt="Symbol" /></td>
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**LABELS**

<table>
<thead>
<tr>
<th>PLAN ITEM</th>
<th>PLAN SYMBOL</th>
<th>PROPOSED</th>
<th>EXISTING</th>
</tr>
</thead>
<tbody>
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<td><img src="symbol43.png" alt="Symbol" /></td>
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<td>Proposed Pedestrian Signal Head</td>
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<tr>
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<td><img src="symbol51.png" alt="Symbol" /></td>
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</tbody>
</table>

Electric Service Meter
Electric Service Safety Switch (Disconnected)
Controller Cabinet
Master Controller Cabinet
Master Controller Cabinet & Foundation
Controller Cabinet & Foundation
Controller Cabinet & Pole, with Uninterruptible Power Supply (UPS)
Video Detection Camera
Emergency Pre-emption Detector

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- **Summary Notes**
  Place notes related to a specific “Pay Item” that has application to the entire plan set on the Quantities Summary Sheet. Summary notes typically provide minor detail regarding a “Pay Item” as it applies to the specific project. If a “Pay Item” requires considerable detailing to be included in the pay item, then a special provision may need to be developed. Summary notes are numbered sequentially and circled.

  The circled number is associated with the “Pay Item” by placing it in the appropriate pay item block above the pay item description on the Summary Sheet.

- **Plan Notes**
  Notes related to the design that is unique to an individual plan sheet. Plan notes are numbered sequentially and shown on the Plan Sheet.

- **Examples of General, Summary and Plan Notes:**
  Additional examples of notes that may be included in the plans are provided in the Appendix. The example notes listed above and noted in the Appendix shall be modified in accordance with the specific needs of the traffic signal design.

**Develop Other Details, as needed.**

- **NOTE:** Some VDOT Regions require the development of an initial timing chart. Coordinate with the appropriate VDOT Regional Operations staff to determine their requirements.
- Develop special details, signal operation notes, electrical service notes, or special provisions, as required.