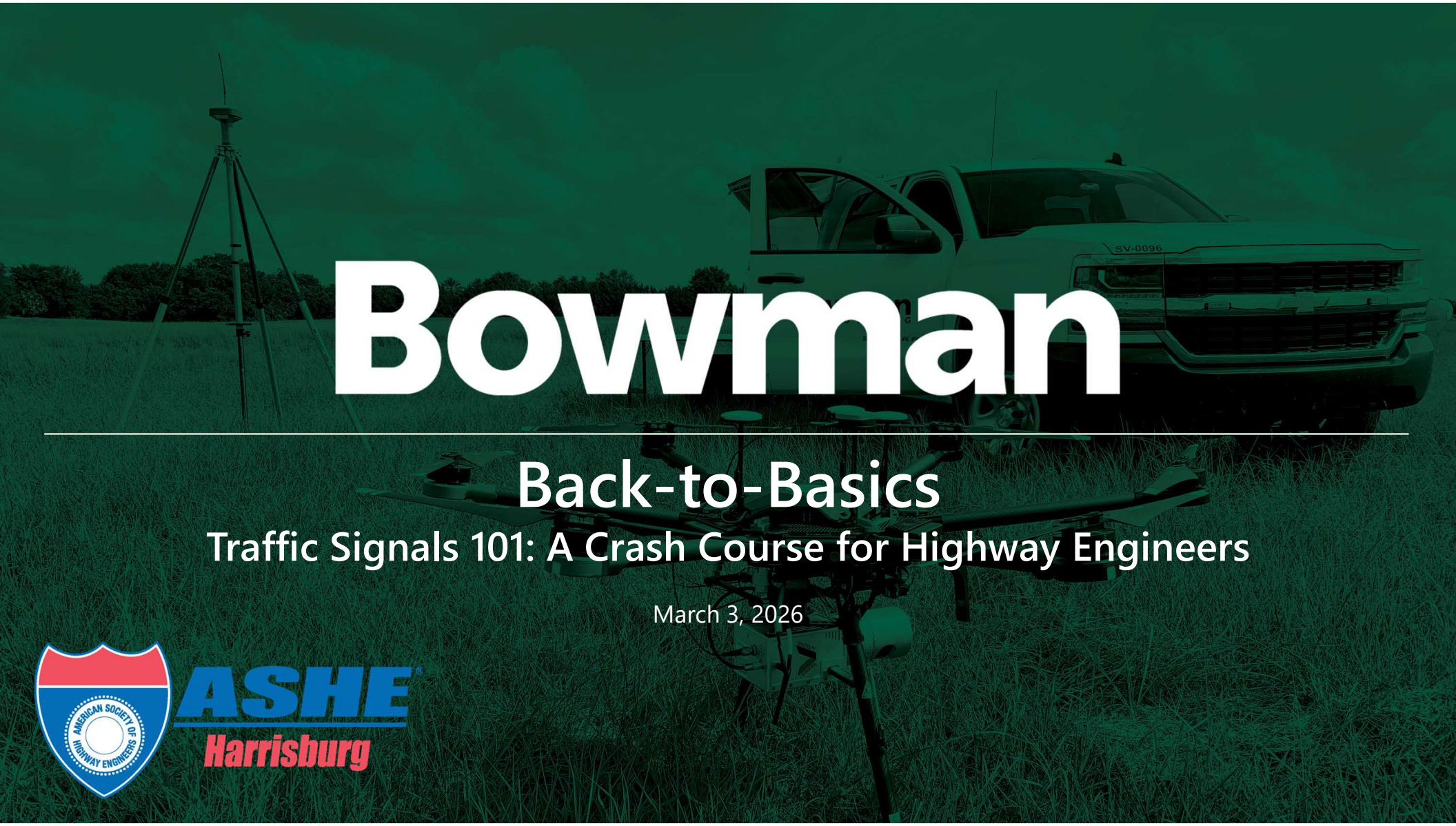


Bowman

Back-to-Basics

Traffic Signals 101: A Crash Course for Highway Engineers

March 3, 2026

ASHE Harrisburg

Introduction

Eric Roth, PE
Assistant Project Manager, Transportation

Temple University – Class of 2016
- *Bachelor of Science in Civil Engineering*

McMahon Associates, Inc
- *December 2016 to May 2022*

Bowman Consulting Group, Inc. (through acquisition)
- *May 2022 to Present*

bio

Bowman

Experience

Areas of expertise include...

- *Traffic Signal Design*
  - *Traffic Control Signals*
  - *Rectangular Rapid Flashing Beacons*
  - *Traffic Signal System*
- *Highway Occupancy Permitting*
- *Municipal Engineering Representation*
  - *Land Development Review*
  - *Grant Writing and Administration*
  - *Traffic Signal Design/Review*

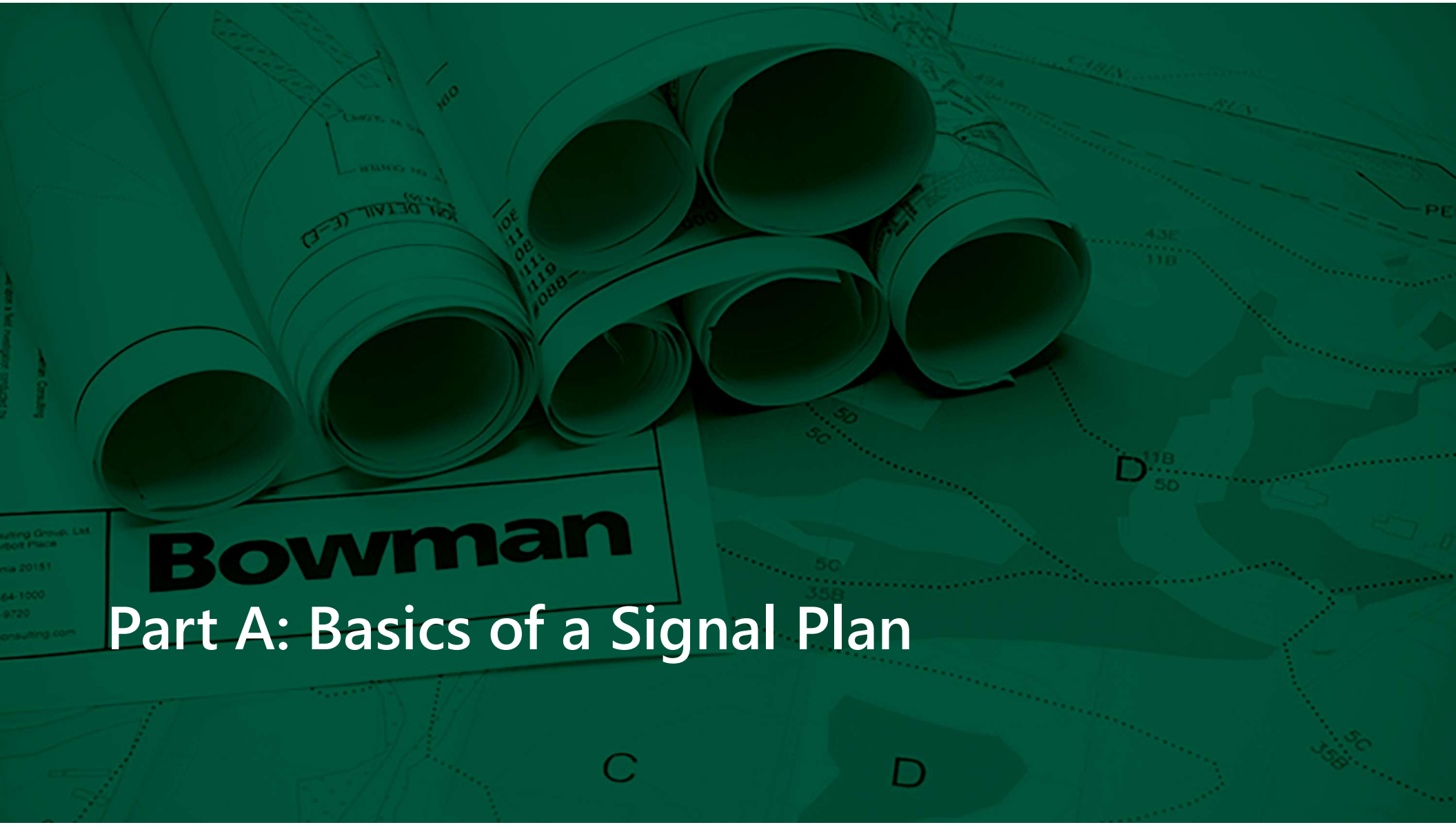
Fun Fact:
I spent several years (part time) working at PennDOT District 6-0 through an open-end signals and safety contract.

bio

Bowman

Agenda

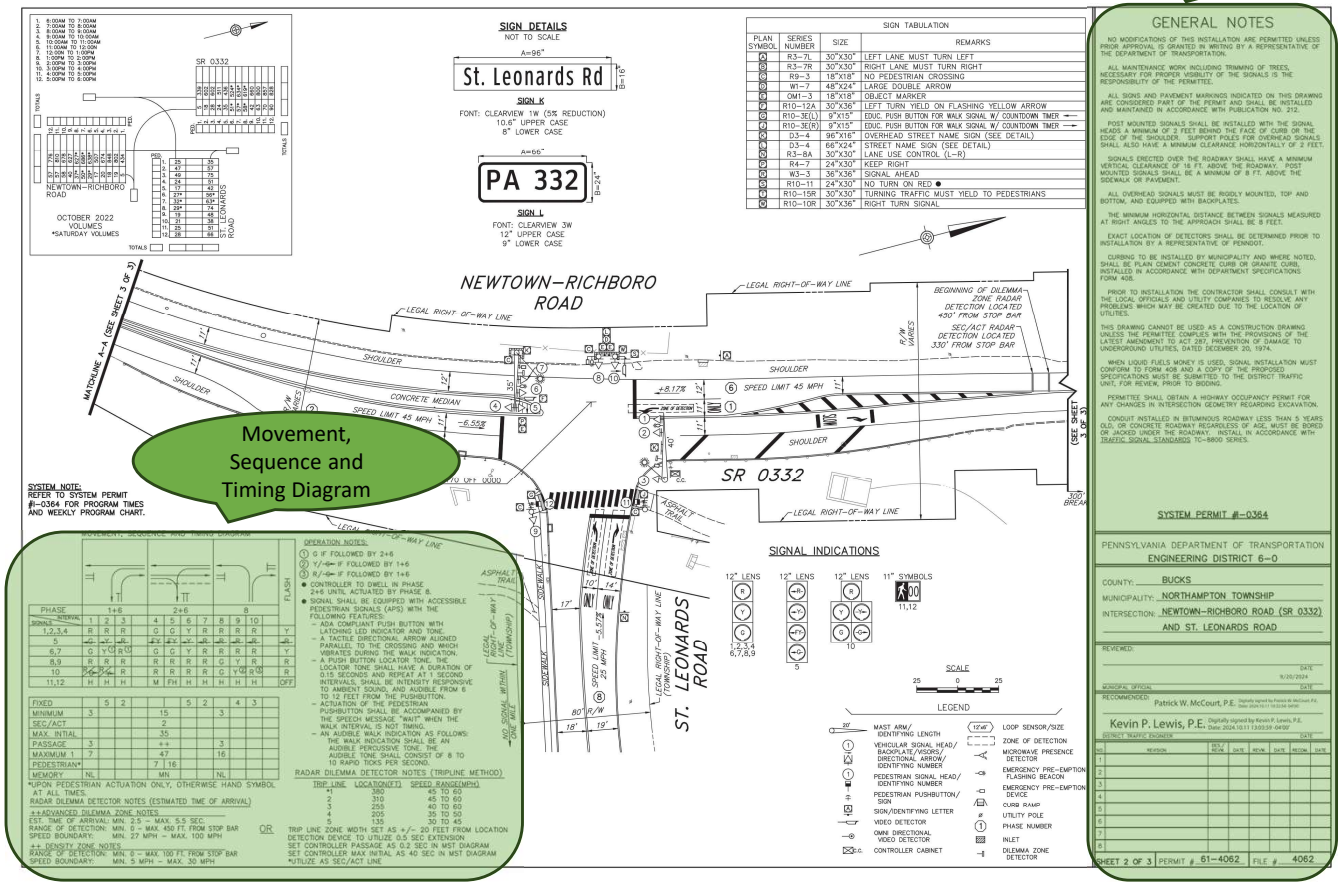
- Part A: Basics of a Signal Plan
- Part B: Traffic Signal Design
  - Governing Publications/Guidelines
  - Support/Signal Head Locations
  - Detection
  - Support Types
  - Junction Boxes
  - Coordination
  - Temporary Traffic Signals
- Part C: Traffic Signal Permitting
  - Traffic Signal Warrant Analysis
  - Traffic Signal Design Submission
  - As-Built/Permit Close-Out Process



Part A: Basics of a Signal Plan

Basics of Traffic Signal Plan

Borders and General Notes may vary

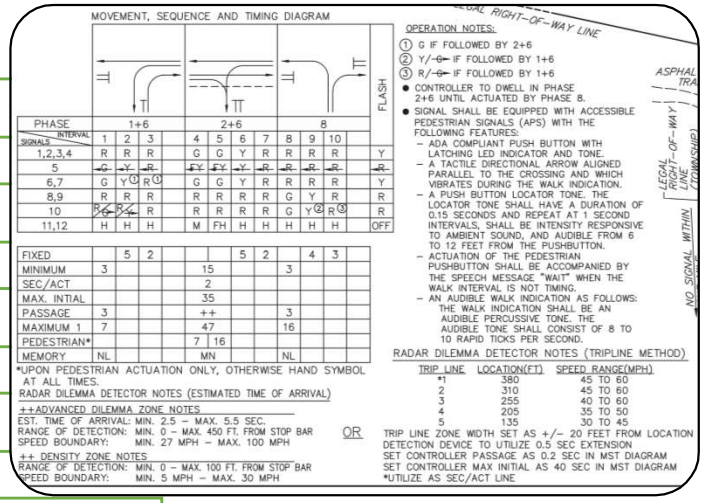


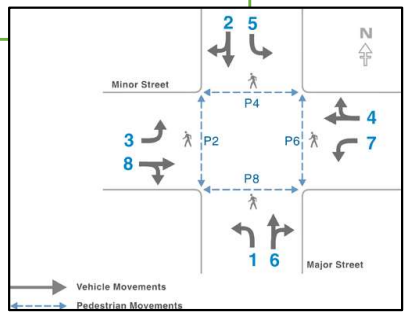
Movement, Sequence and Timing Diagram

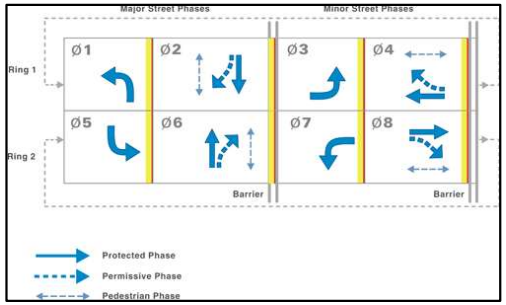
Bowman

Basics – Movement, Sequence and Timing Diagram

- Vehicular and Pedestrian Movements and Phases
- All possible phase combinations
- Order of phase combinations
- Signal indications
- Timings and phase settings







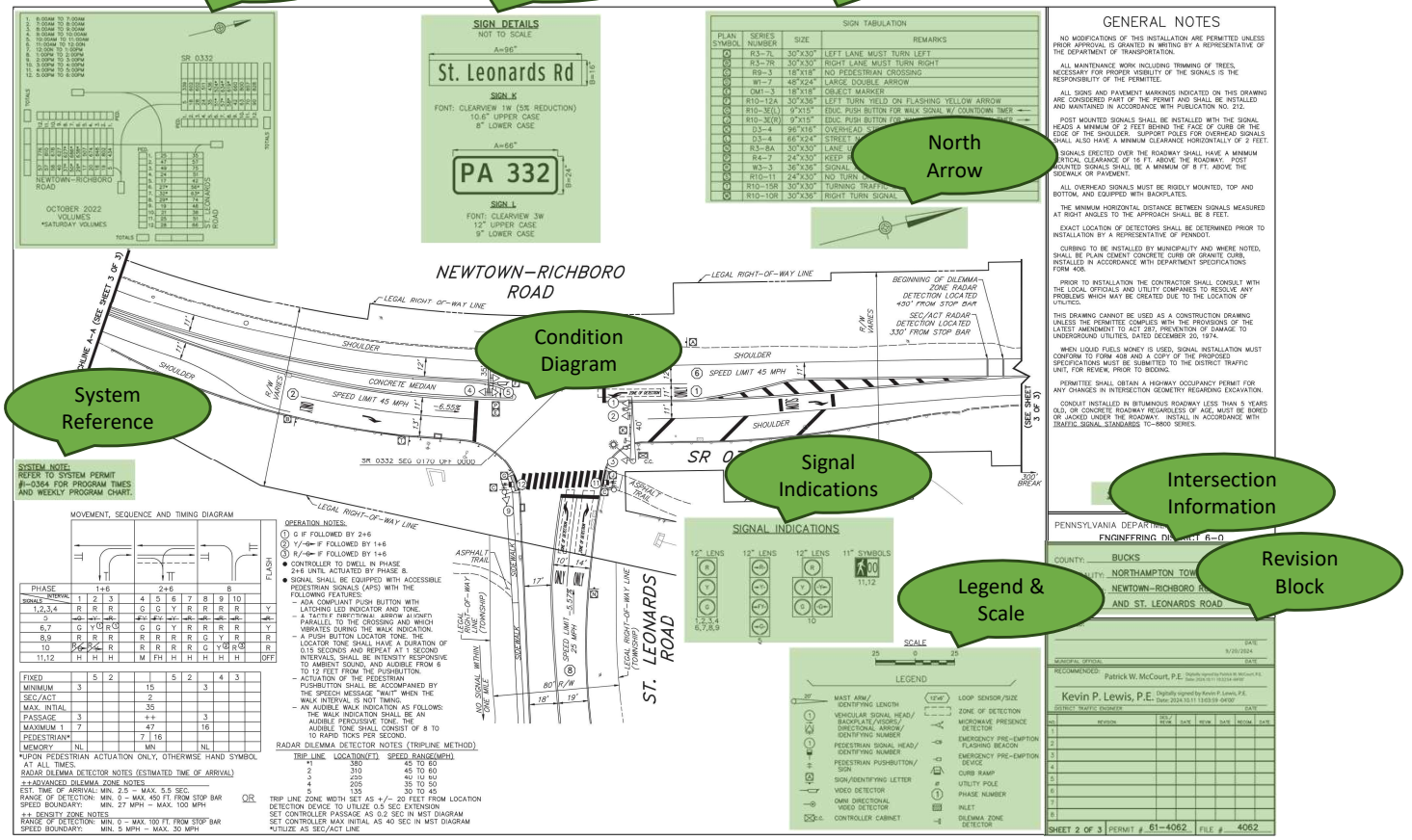
5.1.2 Ring-and-Barrier Concept

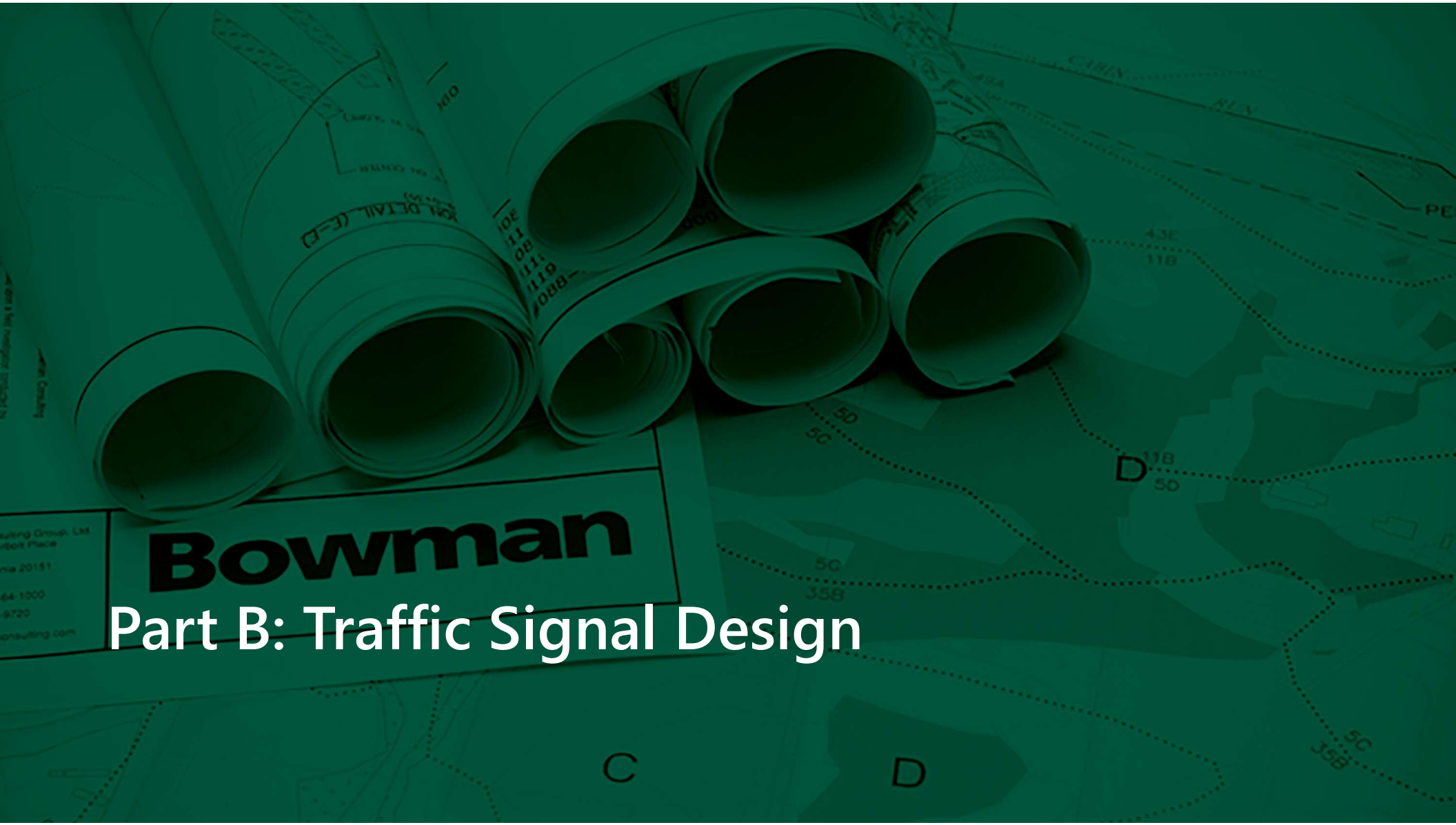
Rings and barriers fundamentally define how a controller organizes phases, so that compatible phases can time together and conflicts do not occur.

- ***Ring:*** A ring shows a sequence of conflicting phases. Dual (or two) ring operations allow compatible phases to operate concurrently with (i.e., at the same time as) phases in another ring.
- ***Barrier:*** A barrier is the point at which the phases in both rings must end simultaneously. Barriers typically separate major and minor street phases.

Bowman

Basics of Traffic Signal Plans

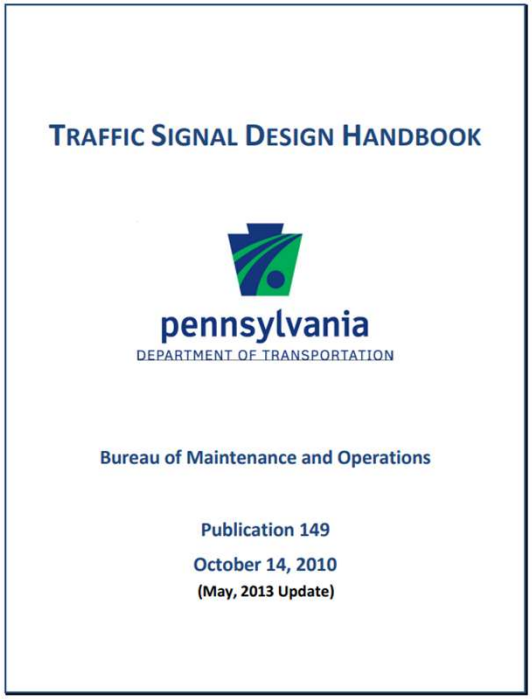




Part B: Traffic Signal Design

Basics – Governing Publications

- Manual on Uniform Traffic Control Devices, 11th Edition
  - *Overarching standards & guidance*
- PennDOT Publication 46, Traffic Engineering Manual
  - *Pennsylvania specific standards & guidance for traffic control devices*
- PennDOT Publication 111, Traffic Control – Pavement Markings and Signing Standards
  - *Pennsylvania specific standards for pavement markings and signing*
- PennDOT Publication 148, Traffic Standards (TC-8800) Signals
  - *Pennsylvania specific traffic signal standards*
- PennDOT Publication 149, Traffic Signal Design Handbook
  - *Pennsylvania specific traffic signal manual for design of signals*
  - ***New update is currently being developed and will be released in coming months***
- PennDOT Publication 236, Handbook of Approved Signs



[PennDOT - Traffic Signal Portal]

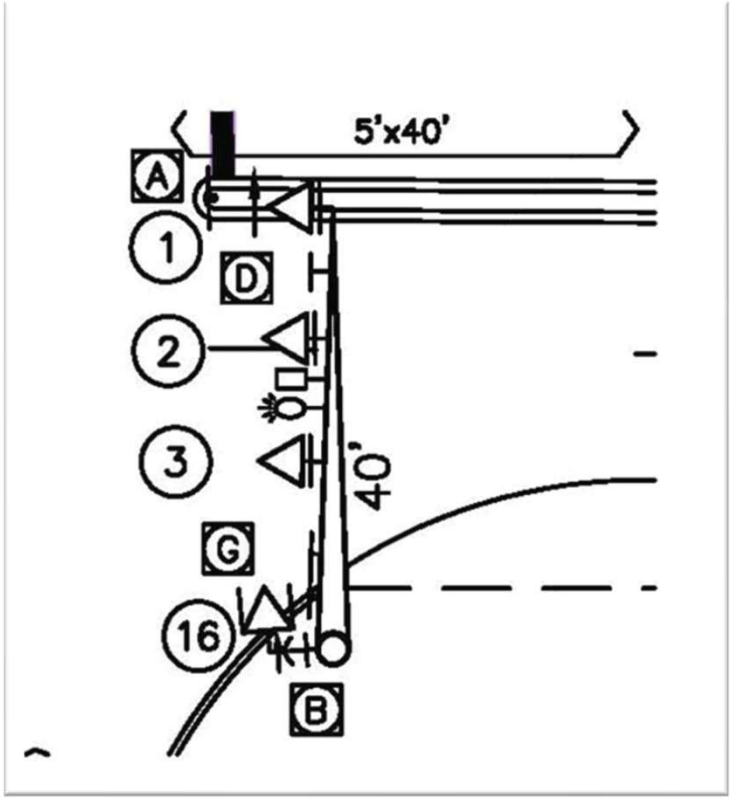
Bowman

Elements of a Traffic Control Signal

- Traffic Signal Controller
- Signal Supports
- Signal Heads
  - *Vehicular*
  - *Pedestrian*
- Detection System
- Emergency Preemption System

Traffic Signal Support Location Considerations

- Minimum setbacks from roadway
  - *Scenarios in Publication 149*
- Utility conflicts
  - *Underground*
  - *Overhead*
- Right-of-Way
- Pedestrian visibility/access
- Signal head visibility



Bowman

Signal Head Placement/Alignment

- Vehicular Signal heads:
  - *Two vehicular signal faces per approach, minimum (additional through lanes require additional signal faces)*
  - *20° cone of vision*
  - *Minimum distance from stop bar: 40'*
  - *Maximum distance from stop bar: 180'*
  - *Mounted over receiving lane to discourage drifting from roadway*

- Pedestrian Signal heads:
  - *One pedestrian signal head per direction*
  - *Two pedestrian signal heads per crossing*
  - *Utilize engineering judgement on placement*

Exhibit 16-4 Lateral and Longitudinal Location of Primary Signal Faces

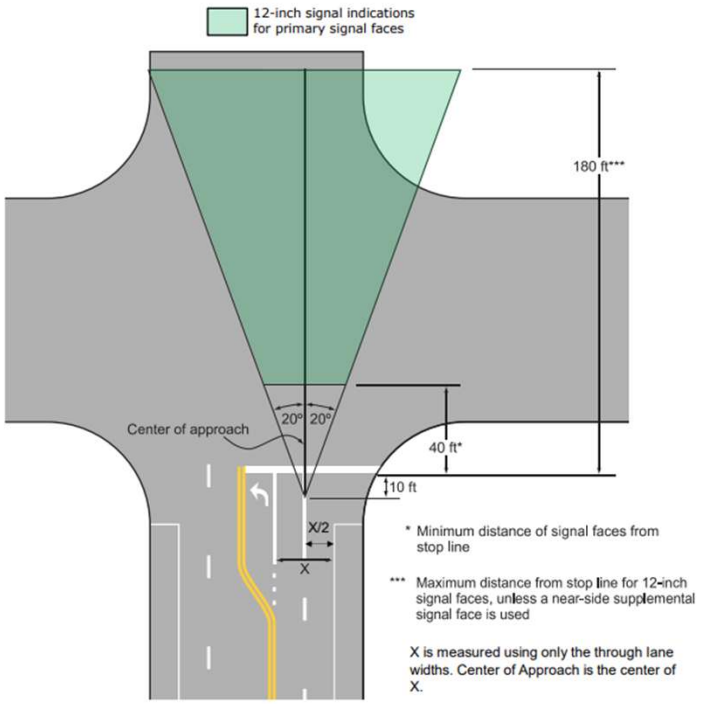


Exhibit 16-3 Minimum Number of Primary Signal Faces for Through Traffic

Number of Through Lanes on Approach	Total Number of Primary Through Signal Faces for Approach[1]	Minimum Number of Overhead-Mounted Primary Through Signal Faces Per Approach
0	2	1[5]
1	2	1[4]
2	2	1
3	3[3]	2[2]
4 or more	4 or more	3[2]

Bowman

Signal Head Placement/Alignment

- Supplemental/nearside signal heads are required…
  - *When distance from stop bar to signal head exceeds 180'*
  - *Horizontal or vertical curve does not allow for minimum sight distance*

Left turn phasing requirements may also be governed by horizontal/vertical curves in the roadway!

Table 4D-2. Minimum Sight Distance for Signal Visibility

85th-Percentile Speed	Minimum Sight Distance
20 mph	175 feet
25 mph	215 feet
30 mph	270 feet
35 mph	325 feet
40 mph	390 feet
45 mph	460 feet
50 mph	540 feet
55 mph	625 feet
60 mph	715 feet

Note: Distances in this table are derived from stopping sight distance plus an assumed queue length for shorter cycle lengths (60 to 75 seconds).

Exhibit 16-5 Addressing Signal Visibility at Vertical Curves

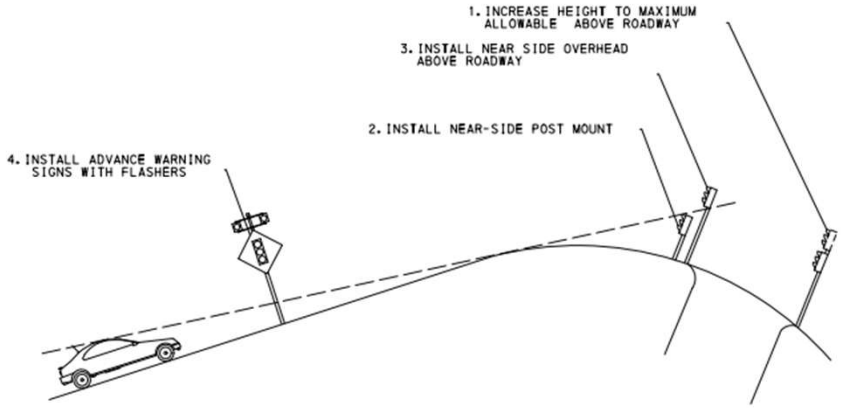
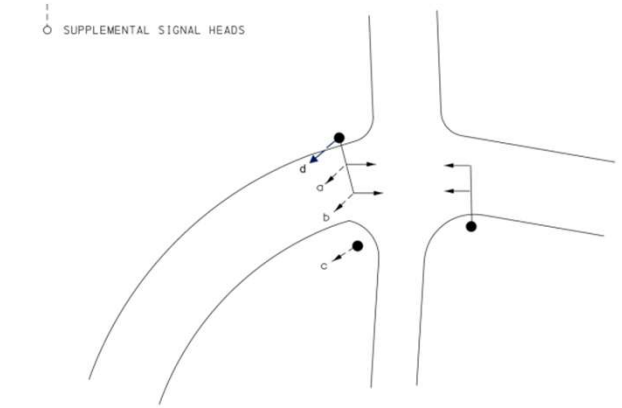


Exhibit 16-6 Supplemental Signal Placements for Horizontal Curves



Bowman

Detection

- When is detection needed?
  - *To be responsive to vehicle/pedestrian demand*
  - *Implemented based on type of operation desired*

PennDOT does NOT govern type of detection to be utilized!

Bowman

Types of Detection

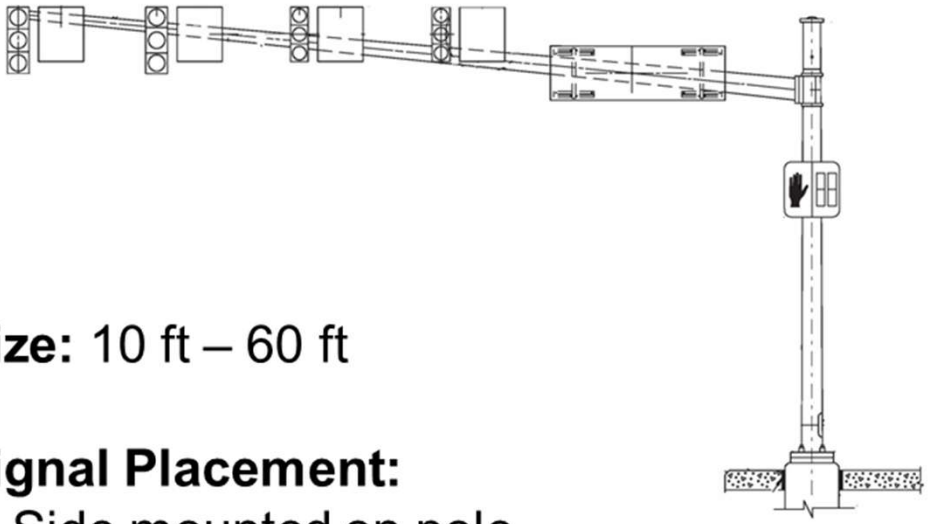
- Stop Bar Detection
  - *Inductive loops*
  - *Traditional Video*
  - *Radar*
  - *Omni-Directional*
- Advance Detection
  - *Radar Dilemma Zone*
  - *Volume Density Inductive Loops*
- Pedestrian Detection
  - *Active (Push Buttons)*
  - *Passive (Video/Radar)*

Emergency Preemption Systems

- Types of Preemption
  - *Optical (preferred)*
  - *Acoustic*
  - *GPS*
- Optical requires clear line of sight
- Provide 1300’ minimum sight distance for new installation
  - *Utilize advance detector if necessary*

Emergency operation is also shown on permit plan and varies by District.

Mast Arms



Size: 10 ft – 60 ft

Signal Placement:

Side mounted on pole

Overhead on the arm

Standard layout: four mast arms

Bowman

TC-7800 Standards

TC-8800 Standards

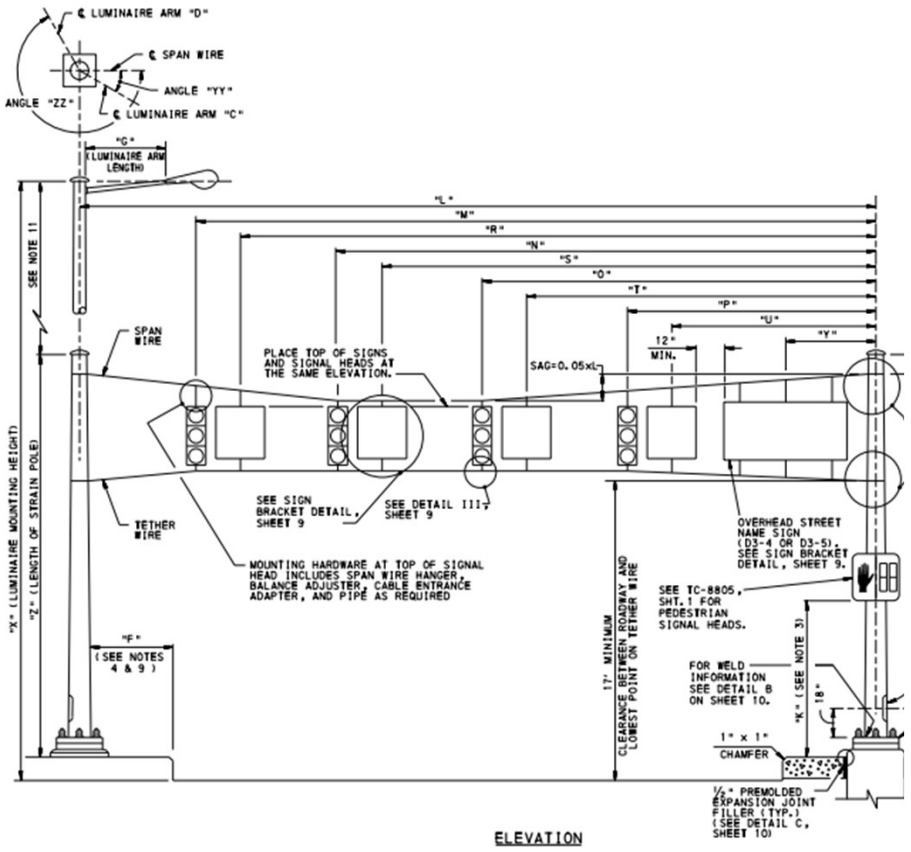
In 2011 Publication 148 revised from 7800 to 8800

- Increase in signal support pole sizes and signal support foundations.
- 4-bolt pattern revised to a 6-bolt pattern
- Foundation size for mast arms > 35’ increased from 3’x3’ to 3.5’X3.5’

Bowman

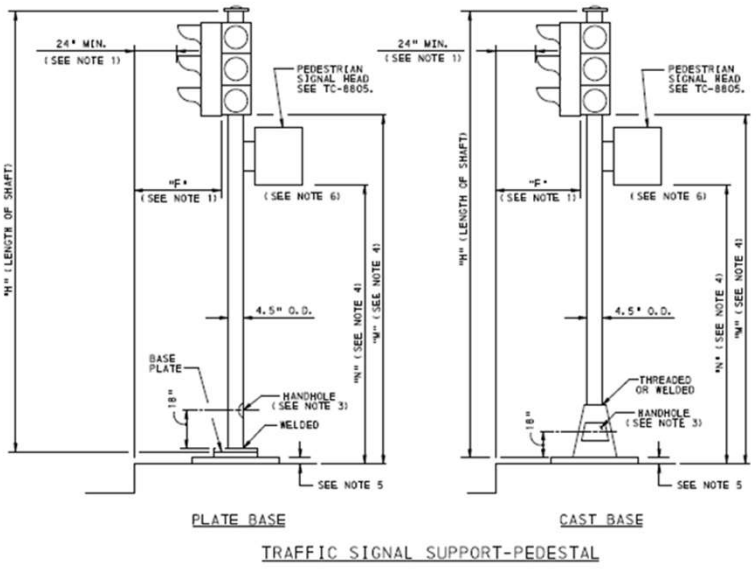
Strain Poles

- Signal Placement
  - *Side mounted on pole*
  - *Overhead on a tether and span wire*
  - *Primarily for temporary signals*
- Standard Layout
  - *Box formation*
  - *Angled Layout*



Bowman

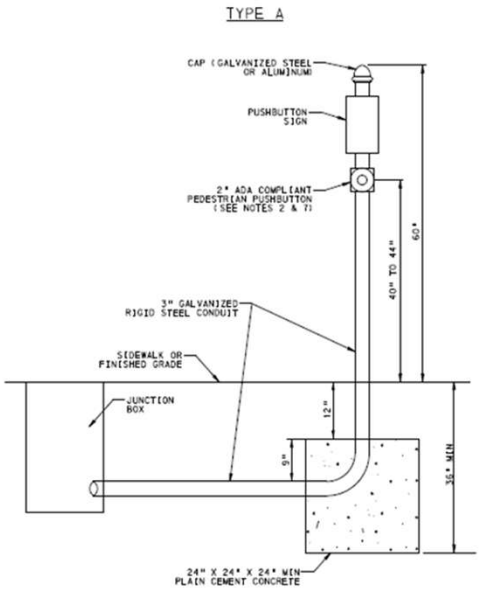
Pedestal Pole



- Utilized when pedestrian signal head and push button are required on same pole
- Signal heads cannot be placed on stub poles due to minimum vertical clearance
- Standard height is 14′
- Designed foundation (3′x3′)

Bowman

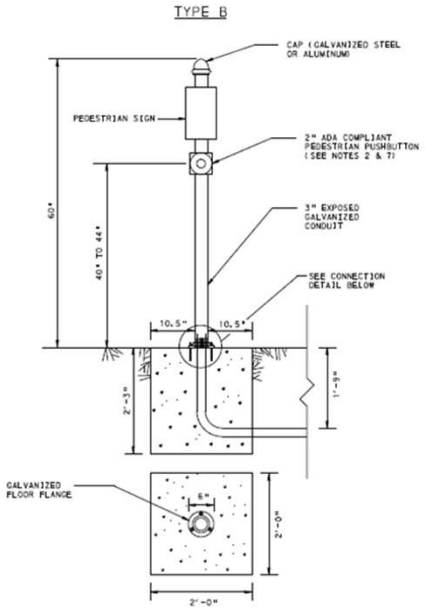
Pedestrian Stub Poles – Type A



- 3″ rigid conduit runs above ground to nearest junction box in one unbroken section
- Not typically utilized due to challenges with maintenance

Bowman

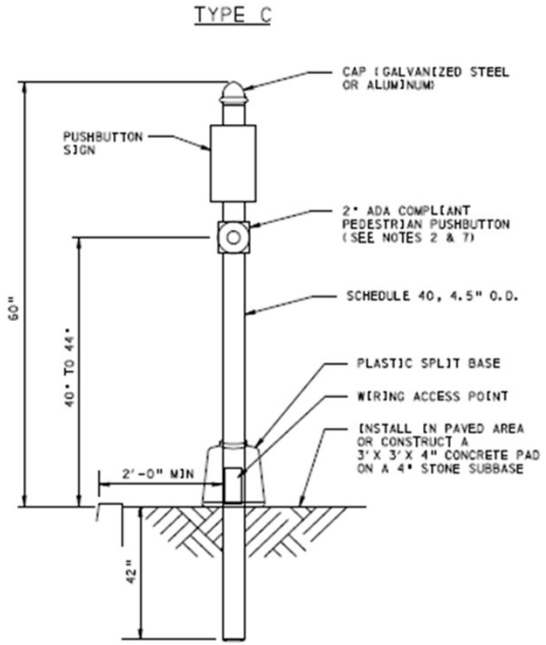
Pedestrian Stub Poles – Type B

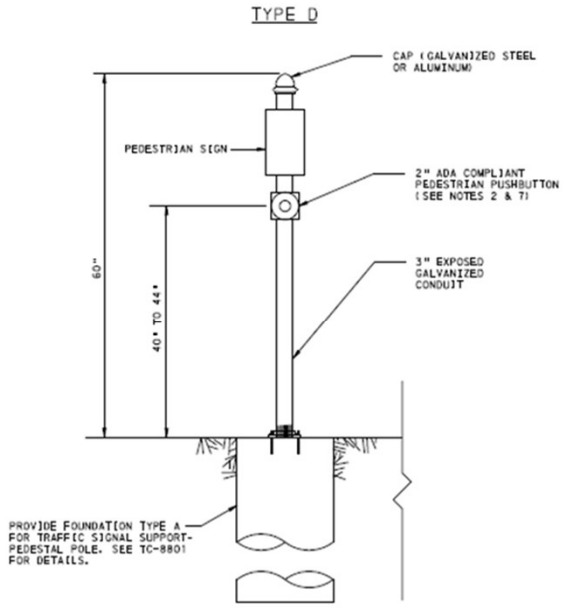


- 3″ conduit above ground and 2" conduit below ground
- Two conduits meet at a breakaway connection
- Anchor bolts are drilled into concrete after the pour

Bowman

Pedestrian Stub Poles - Type C & D





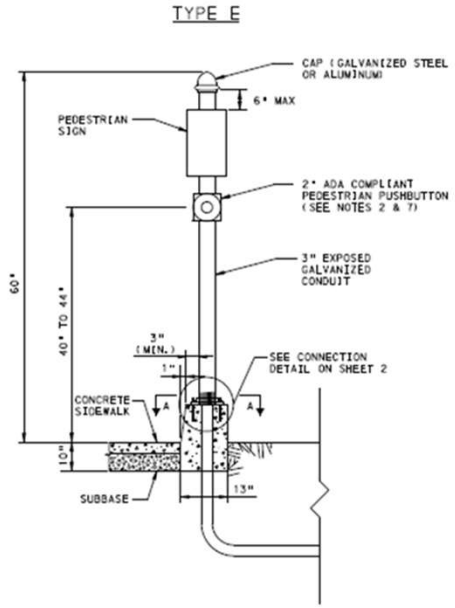
- 4.5″ conduit direct buried to a depth of 3.5'

  Neither are used often

- Above ground this type is similar to the Type B
- Below ground this has a pedestal type foundation

Bowman

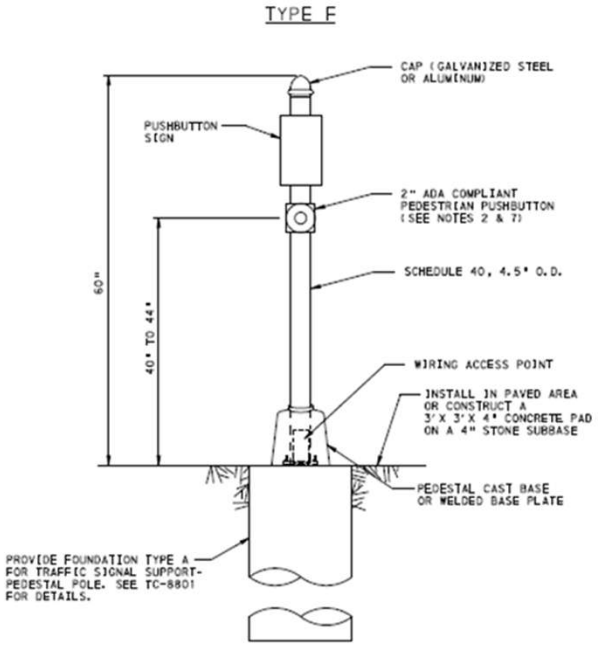
Pedestrian Stub Pole - Type E



- 3″ conduit above ground and 2" conduit below ground
- Two conduits meet at a breakaway connection
- Utilized to meet required PAR and push button reach when a cheekwall is proposed adjacent to ramp

Bowman

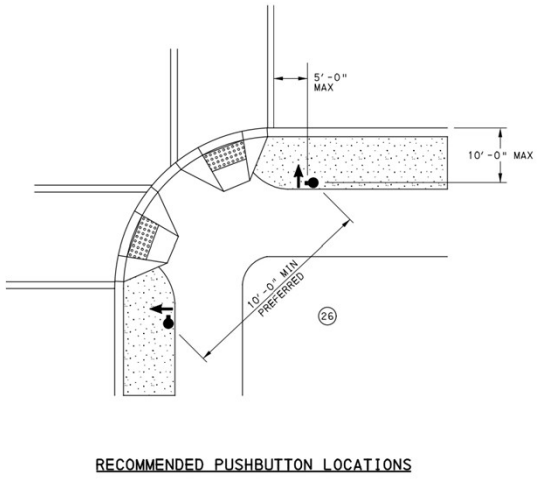
Pedestrian Stub Pole – Type F

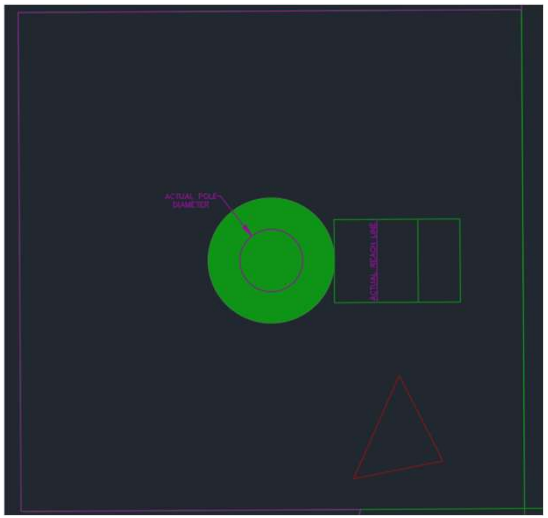


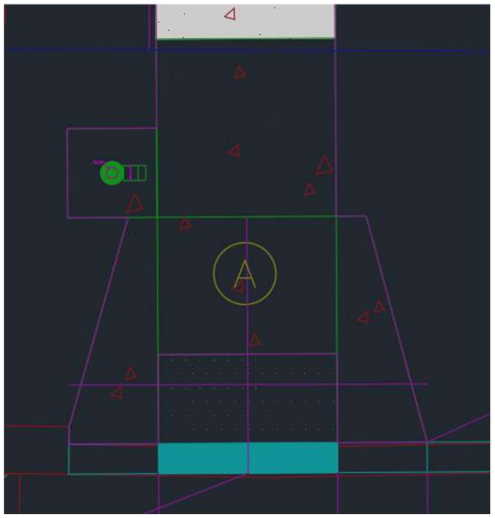
- Above ground this type is similar to the Type C
- Below ground this has a pedestal type foundation

Bowman

Push Button Placement



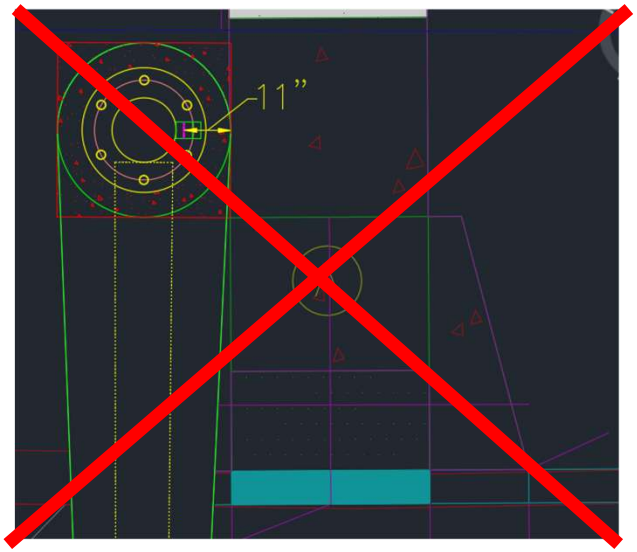


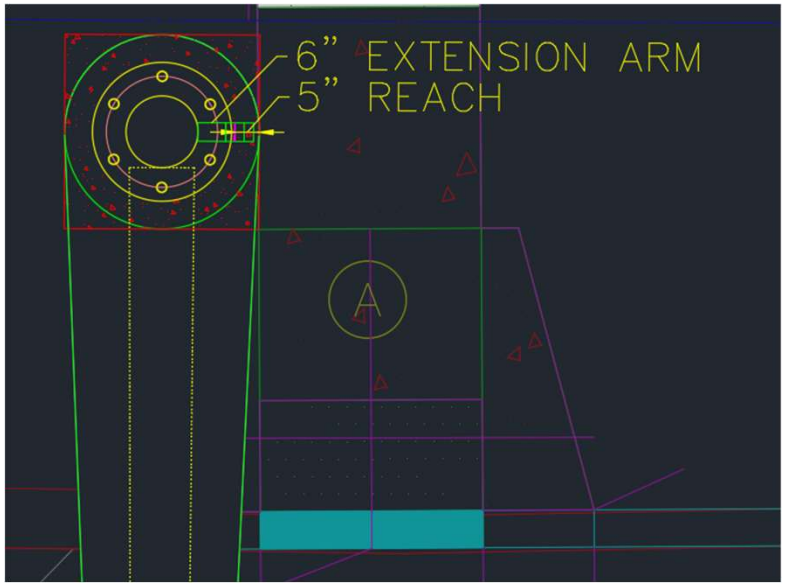


- 10" max reach to turning area requirement
- 10’ max distance from face of curb

Bowman

Push Button Placement (Continued)



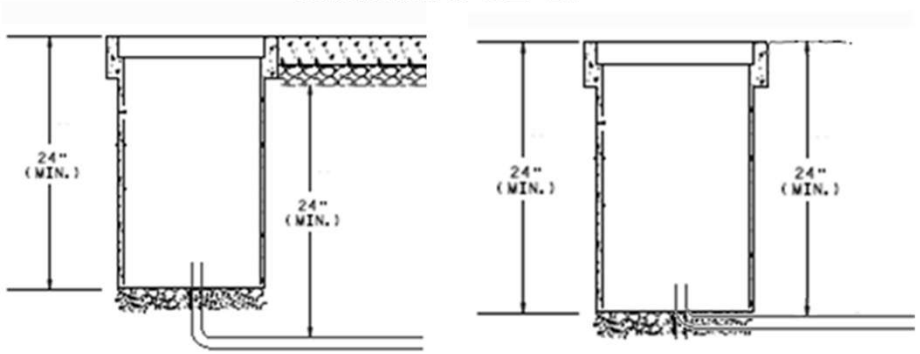


- In limited circumstances push button extension arms can be used to meet push button reach requirements, but are highly discouraged

Bowman

Junction Box/Mast Arm Design

Standard JB-27

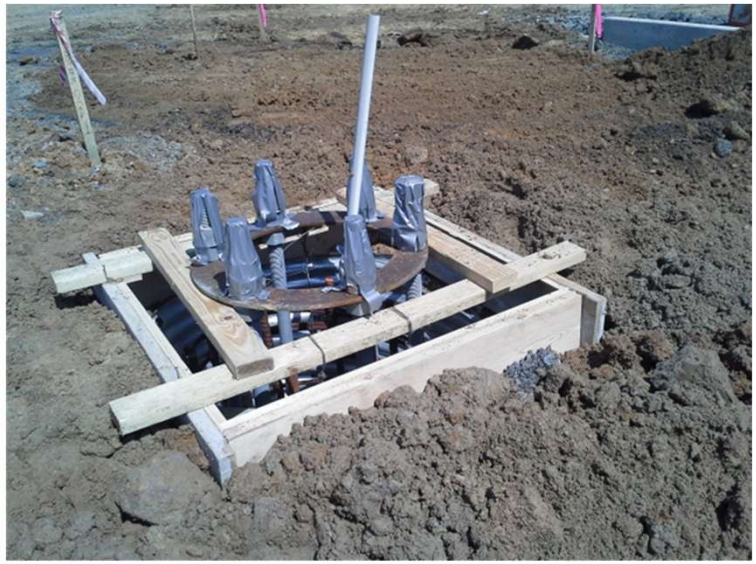


- **Signal Conduit depth:**
  - 24” minimum from ground level or bottom of stonebase.
- **JB-27 depth:** 24” minimum

Example of conduit & junction box layout for pedestal installation.

Bowman

Junction Box/Mast Arm Design



- Pictures above show framed signal foundations prepared for concrete
- Foundations dug utilizing auger
- Rebar cage is hung from form within the hole
- Top 6" of foundation is framed with boards

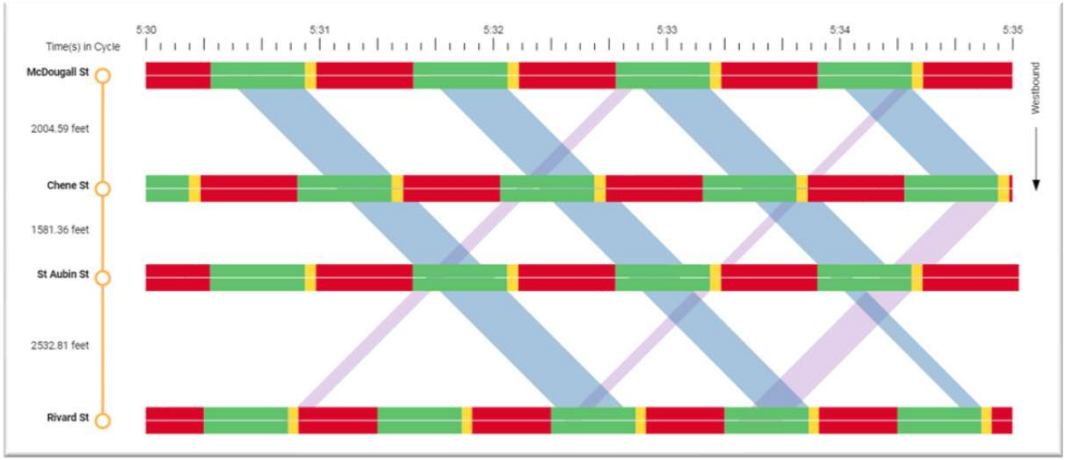
Junction Box/Mast Arm Design

Junction Box/Mast Arm Design

Bowman

Coordination

- Time-Based Coordination (TBC)
  - *Coordination based on time of day*
  - *GPS time clocks can be installed to eliminate "drift"*
- Interconnect/Centralized System
  - *Can be accomplished via:*
    - *Fiber Optic Connection*
    - *Spread Spectrum Radio*
  - *Provide opportunity to relay information back to central location*
- Adaptive
  - *Utilizes data from detectors at the intersection to select program times within the selected parameters*

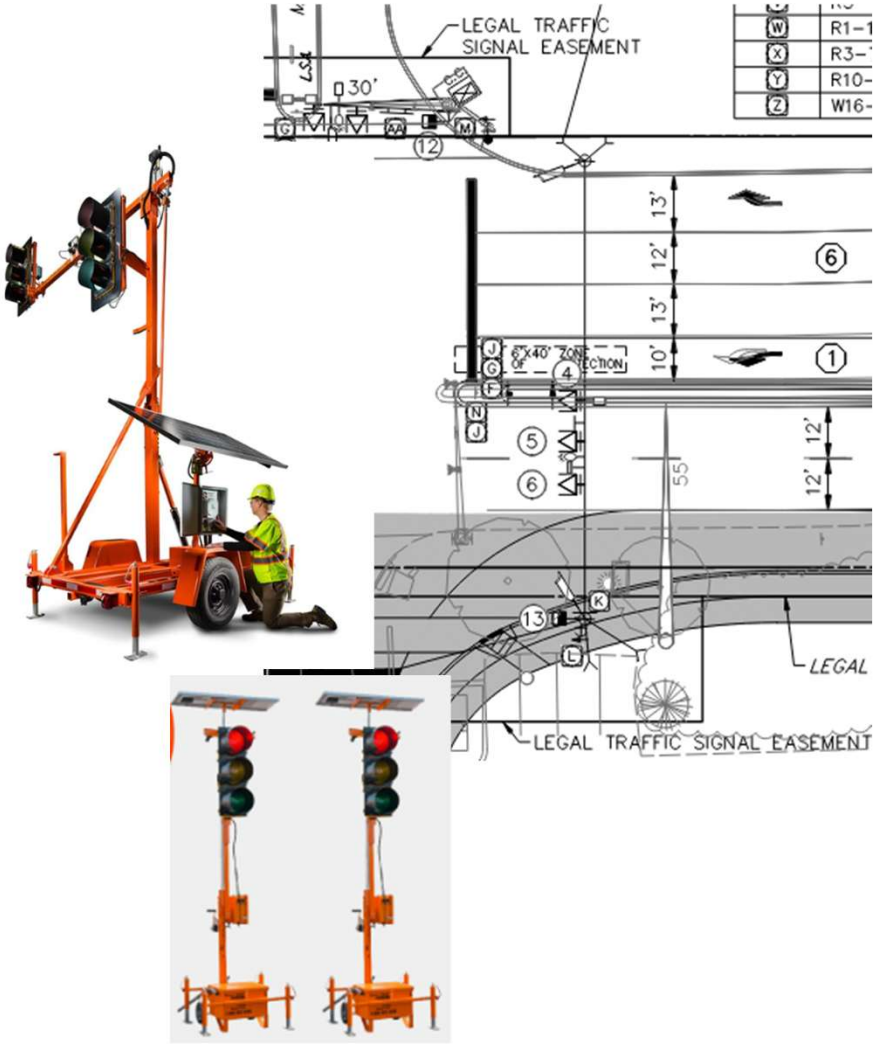


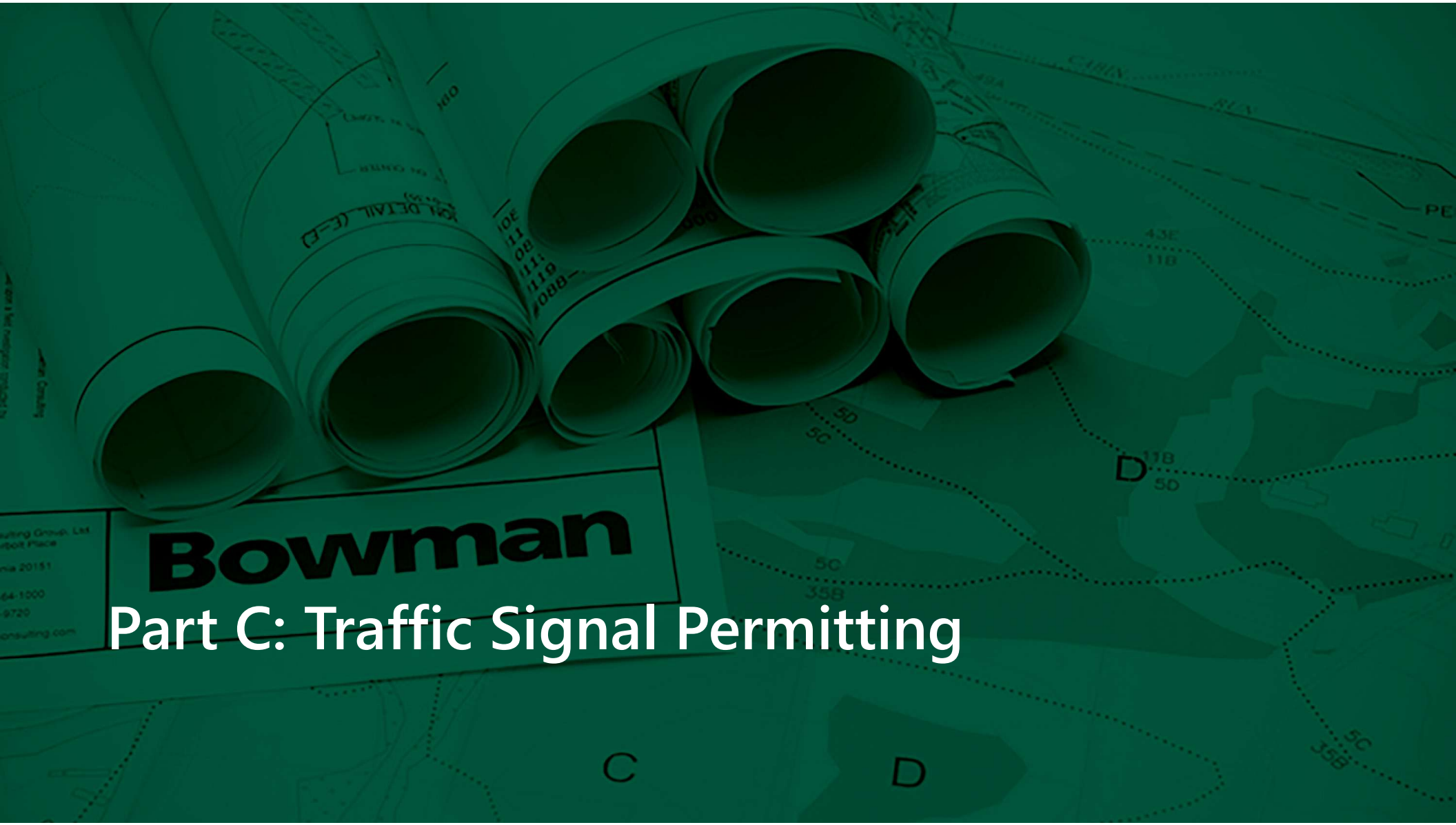
"A traffic signal control system exists whenever two or more signals operate in a synchronous manner. The objective of a traffic signal control system is to improve the flow of traffic along a major street or throughout a network of streets. A traffic signal control major system consists of an appropriate signal-timing plan and the hardware components to implement that signal-timing plan. The signal-timing plan must satisfy traffic demand, traffic flow patterns and the geometrics that exist at each intersection and in the network as a whole.

Bowman

Temporary Traffic Signal Designs

- Signal operation must be maintained during construction
  - *If possible maintain with existing equipment*
- Wood/strain pole with span wire configuration
- Portable and Trailer Mounted

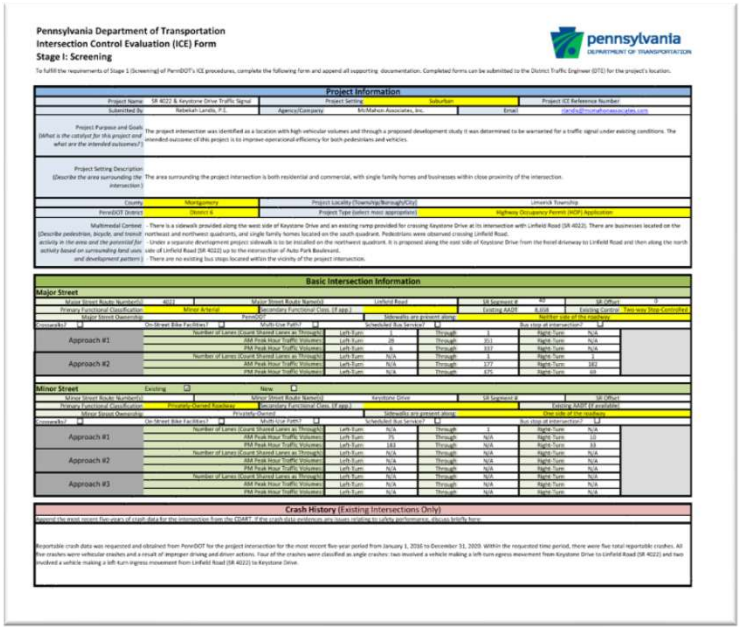




Part C: Traffic Signal Permitting

Traffic Signal Warrant Analysis

- **Required when evaluating need for a new traffic control device**
- Often submitted as part of the first EPS submission with the Traffic Impact Study (TIS)
- Typical considerations include:
  - Warrant Analysis
    - *Completed using requirements from PennDOT design publication 46 and 212 and Warrants 1 through 9 listed in the MUTCD, 11th Edition*
  - PennDOT Intersection Control Evaluation (ICE)
  - Pedestrian Study
  - Speed Study
  - Crash Analysis
  - Sight-Distance Evaluation
- Intersection must meet under existing or opening year conditions



Pennsylvania Department of Transportation
Intersection Control Evaluation (ICE) Form
Stage I: Screening

pennsylvania
DEPARTMENT OF TRANSPORTATION

Project Information

Basic Intersection Information

Major Street

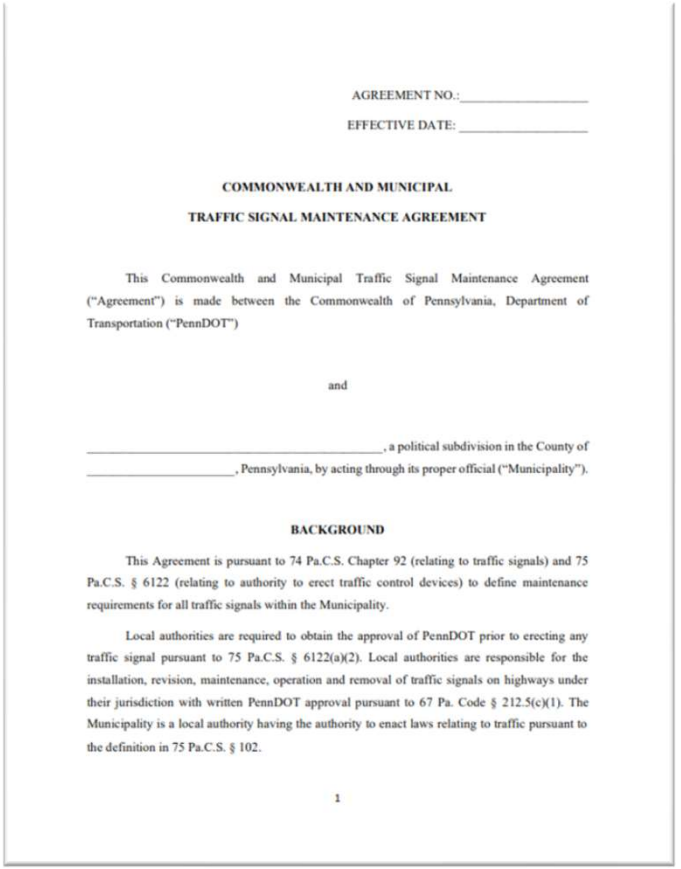
Minor Street

Crash History (Existing Intersections Only)

Bowman

Traffic Signal Design Submission

- Process begins after concurrence is received from the Department in response to Warrant Analysis submission **OR** if there is an existing traffic control signal
- Typical submission documents include:
  - *TE-160 (Application for Traffic Signal Approval)*
    - *Form has been modified recently due to introduction of the Traffic Signal Maintenance Agreement*
    - *Existing TSMA information on TSAMS*
    - *Instructions/resources for new TSMA located on traffic signal portal*
  - *Traffic Signal Permit Plan*
  - *Traffic Signal System Permit Plan*
  - *Traffic Signal Design Report*
  - *Fiber Relocation Plan*
  - *Synchro Analysis*



AGREEMENT NO.:_____

EFFECTIVE DATE: _____

COMMONWEALTH AND MUNICIPAL

TRAFFIC SIGNAL MAINTENANCE AGREEMENT

This Commonwealth and Municipal Traffic Signal Maintenance Agreement ("Agreement") is made between the Commonwealth of Pennsylvania, Department of Transportation ("PennDOT")

and

_____, a political subdivision in the County of _____, Pennsylvania, by acting through its proper official ("Municipality").

BACKGROUND

This Agreement is pursuant to 74 Pa.C.S. Chapter 92 (relating to traffic signals) and 75 Pa.C.S. § 6122 (relating to authority to erect traffic control devices) to define maintenance requirements for all traffic signals within the Municipality.

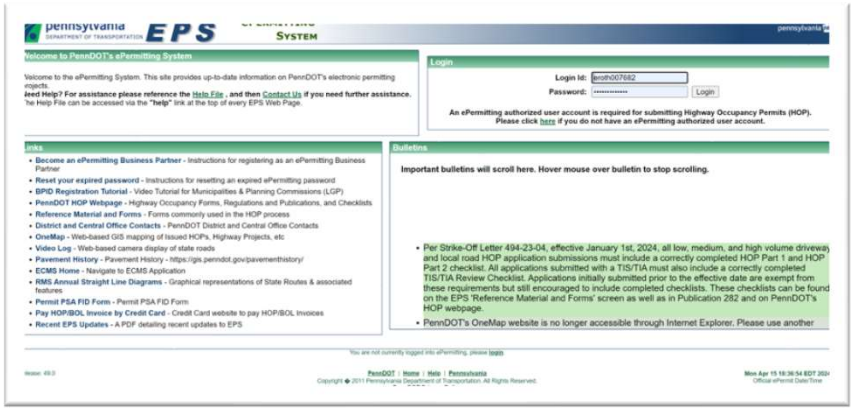
Local authorities are required to obtain the approval of PennDOT prior to erecting any traffic signal pursuant to 75 Pa.C.S. § 6122(a)(2). Local authorities are responsible for the installation, revision, maintenance, operation and removal of traffic signals on highways under their jurisdiction with written PennDOT approval pursuant to 67 Pa. Code § 212.5(c)(1). The Municipality is a local authority having the authority to enact laws relating to traffic pursuant to the definition in 75 Pa.C.S. § 102.

1

Bowman

Traffic Signal Design Submission

- First Traffic Signal design submission is included with the first HOP design plan submission
  - *Preliminary submissions limited to proposed equipment locations are typical on large projects including significant geometric changes*



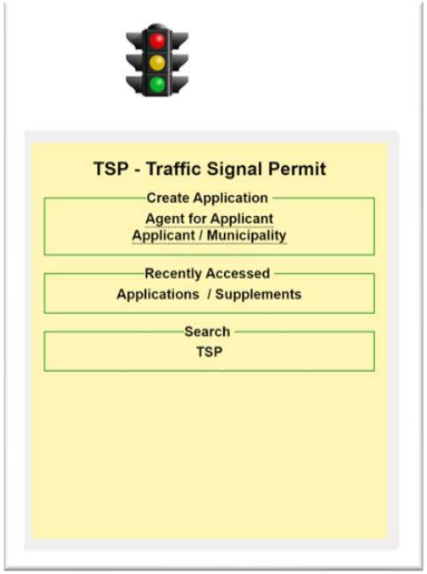
Traffic Signal Design Submission

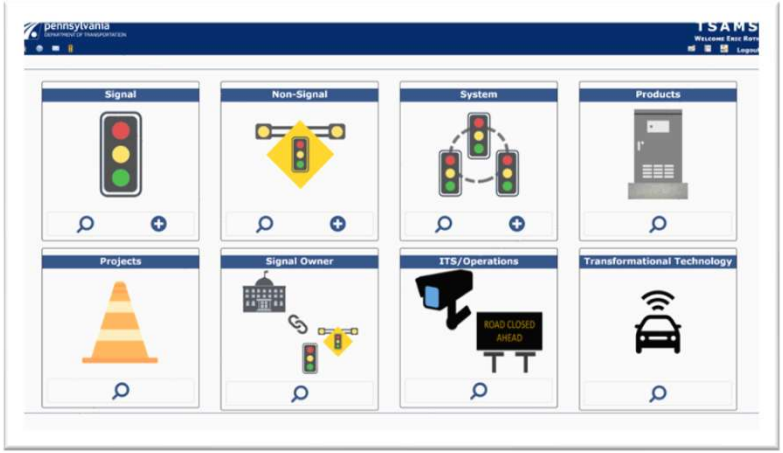
- Important coordination items to keep in mind during the design process:
  - *Clear communication of submission date to signal task lead*
  - *Coordination of necessary signal easements, proposed sign locations and pavement markings*
  - *Notification of any design changes that will impact signal support location (proposed drainage facilities, radius changes, curb ramp locations, stop bar locations, etc.)*
  - *Notification of any updated site plans for locations of proposed utilities, signs, etc.*
  - *Notification of receipt of comment letter*
  - *Coordination on pole spot meeting (required preparation, design engineer attendance, etc.)*

Traffic Signal Permit Close-out

- Typical close out process occurs as follows:
  1. *Final inspection meeting scheduled to review traffic signal improvements*
  2. *Punch list generated – responsibilities assigned*
  3. *Coordination of completion of tasks*
     a) *TSAMs component entry, As-Built completion, etc.*
  4. *Close-out letter form*
     a) *Required to close-out HOP permit*

Traffic Signal close out process can often take months if an As-Built is required. Process needs to be started as soon as possible, and reasonable expectations should be communicated to client*





Bowman

Questions?

E-mail me! eroth@bowman.com