# Chapter 5
# SIGNAL PLAN

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# 5 SIGNAL PLAN

This chapter will discuss all the design elements that are shown on a sign plan sheet, in order of the recommended process for designing a new traffic signal.

There are many ways to build a traffic signal. In this chapter, there is flexibility for some design elements based on the Region Electrical Crew preferences. It is critical to coordinate with the Electrical Crew during the design phase to ensure maintenance concerns are addressed and documented. To accomplish this, download the Electrical Crew Preferences Form from Chapter 24 and follow the directions.

## 5.1 Roadway Design

The signal design work starts with the roadway base map and geometric design. It is important to review the roadway geometric design and work with the roadway designer early on in the process, as fundamental roadway features such as the number of lanes, the lane use, horizontal/vertical alignment, and the crosswalk ramp locations all have a direct impact on how the signal will be built.

If the scope of the project is minor, such as changing from protected only left turn phasing to protected/permitted phasing, there likely won't be a roadway base map or survey data to work from. In these cases, you will need to work from the most current as-built plan sheet. Of course, field verification is essential when working only from an as-built drawing.

### 5.1.1 Number of Lanes and Lane use

The Operational Approval for the traffic signal will show the required number of lanes, lane use, and signal phasing. The roadway design must match what is shown in the Operational Approval. Any discrepancy between the roadway design and the Operational Approval must be resolved, either by amending the Operational Approval (typically requires an additional engineering study) or by correcting the roadway design.

### 5.1.2 Pedestrian Crosswalks Closures

The Operation Approval for the traffic signal will indicate where the signalized pedestrian crossings are located and will identify any crosswalk closures. Crosswalk closures will normally be approved in a separate approval letter where the requirements for closure treatments will be specified. Closure treatments will normally be required in both visual and detectable formats. Sign OR 22-7 is the standard visual treatment for a crosswalk closure; this sign will nearly always be required at crosswalk closure at a signalized intersection. The crosswalk closure support shown in Standard Drawing TM240 is a typical treatment to meet the requirements for a detectable barrier, but other treatments may be used such as a buffer strip, a railing, or bollards with chains. A detectable barrier will nearly always be required when there is a sidewalk

at a closed crosswalk. See the Traffic Manual for additional information on crosswalk closures.

Crosswalk closure supports (TM240) and "CROSSWALK CLOSED" signs (OR22-7) used at signalized intersections are typical shown on the signal plan sheet, NOT on the signing plan sheet. Crosswalk closure supports are no longer included in the traffic signal lump sum bid item; use bid item in specification 00902 (see Chapter 19).

It is likely that a project will also include crosswalk closure supports for unsignalized intersections. These are typically shown on the signing plan sheet and will use the same 00902 specification and bid item. Coordinate with the sign designer to determine the EOR for the 00902 specifications and ensure the bid item quantity is correct.

**Verify that all crosswalk closures (even existing closed crosswalks) have been approved by the State Traffic-Roadway Engineer. If there is no documented Operations Approval for the closure, either the crosswalk must be opened OR a request for closure will need to be submitted by Region Traffic.**

**Follow the requirements stated in the crosswalk closure Operational Approval! If these requirements are not met, the crosswalk closure will not pass ADA inspection.**

### 5.1.3 Selecting & Locating Pedestrian Ramps for Proper Crosswalk Alignment

Each signalized crosswalk shall:

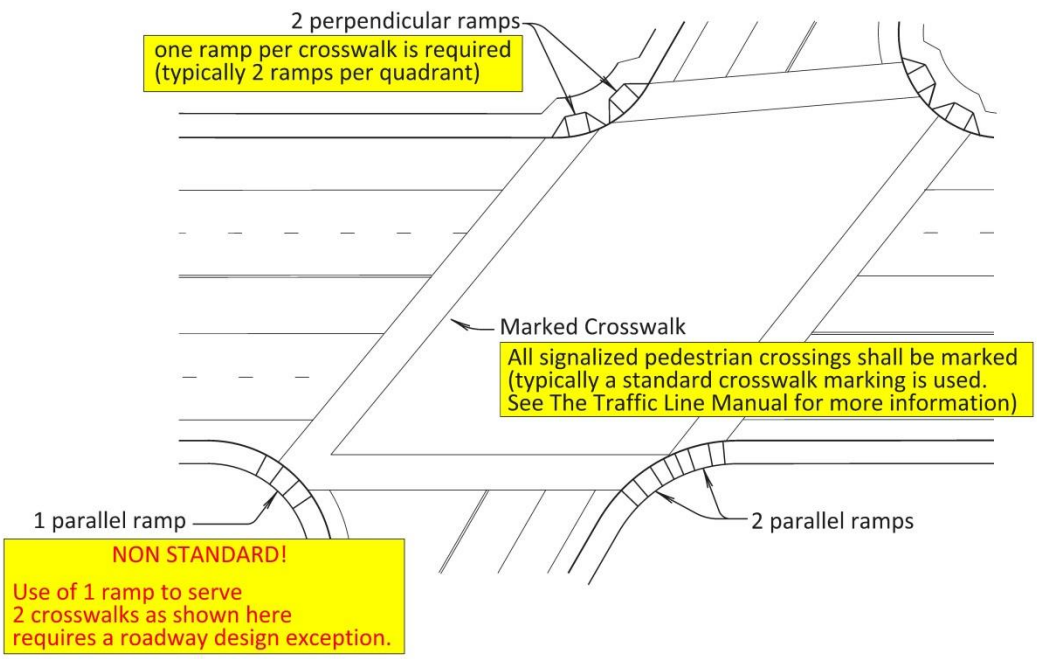
- Be marked with appropriate crosswalk pavement markings as per the ODOT Traffic Line Manual.
- Have a separate curb ramp at each end of the crosswalk if sidewalk is present. If no sidewalk is present, (i.e. rural locations and interchange ramps), a level landing area in lieu of curb ramps should be used. **Note that a Roadway Design Exception is required if a single curb ramp is used for more than 1 crosswalk.**

When locating ramps and crosswalks, consult the latest Roadway Section Standard Drawings for current sidewalk ramp configurations and discuss with the roadway designer. The roadway designer is responsible for the ramp design, but the signal designer should be involved in the selection and placement of the ramps as the following signal design features are dependent on ramp type and placement:

- Crosswalk alignment and stopping location for vehicles (affects line of sight, signal timing parameters, and detection system)
- Location of signal poles
- Location of signal pedestals
- Location of pushbuttons

Figure 5-1 shows the standard requirements of ramp installation.

**Figure 5-1 | Standard Ramp Requirements for Signalized intersection**



There are two main objectives for proper crosswalk alignment:

1. To maximize the visibility of the pedestrian and maintain a good line of sight between the pedestrian and the motorist. The way to accomplish this is to move the crosswalk as close to intersection as possible (as opposed to crosswalk located beyond the intersection radii). Figure 5-2 illustrates this crosswalk placement. This configuration should be used if the signal timing plan can accommodate the longer crossing time without resulting in unacceptable delay.

2. To reduce the amount of exposure the pedestrian has in the intersection. The way to accomplish this is to place the crosswalk perpendicular to the travel lanes, resulting in the shortest path for the pedestrian and the most efficient signal timing. Figure 5-3 illustrates crosswalks this crosswalk placement. Having the shortest path is a very important consideration when the traffic signal is interconnected to a rail crossing, as it may not be feasible or cost prohibitive to obtain extra seconds from the rail equipment to accommodate the Pedestrian Clear Out Interval (PCOI). However, this configuration does not really meet the first objective (especially for the side street right turning vehicles which will be able to pick up quite a bit of speed before the crosswalk).

As Figure 5-2 and Figure 5-3 illustrate, these two objectives will often times be in conflict with each other and the benefits of having crosswalks pulled into the intersection will need to be balanced with the path of the crosswalk. Figure 5-4 is a good compromise if the pedestrian crosswalk timing has a large impact on the effectiveness of the signal timing plan (typically in a highly congested corridor with system timing and a high frequency of pedestrian phase activations) and line of sight to the pedestrian can be maintained. Coordinate with Region Traffic concerning the needs of the pedestrian signal timing.

**Selection and placement of ramps shall be done with the assistance of the roadway designer to determine the ramp type that best addresses all ADA and geometric design issues, while still addressing the signal design needs.**

**Figure 5-2 | Crosswalk Example 1**

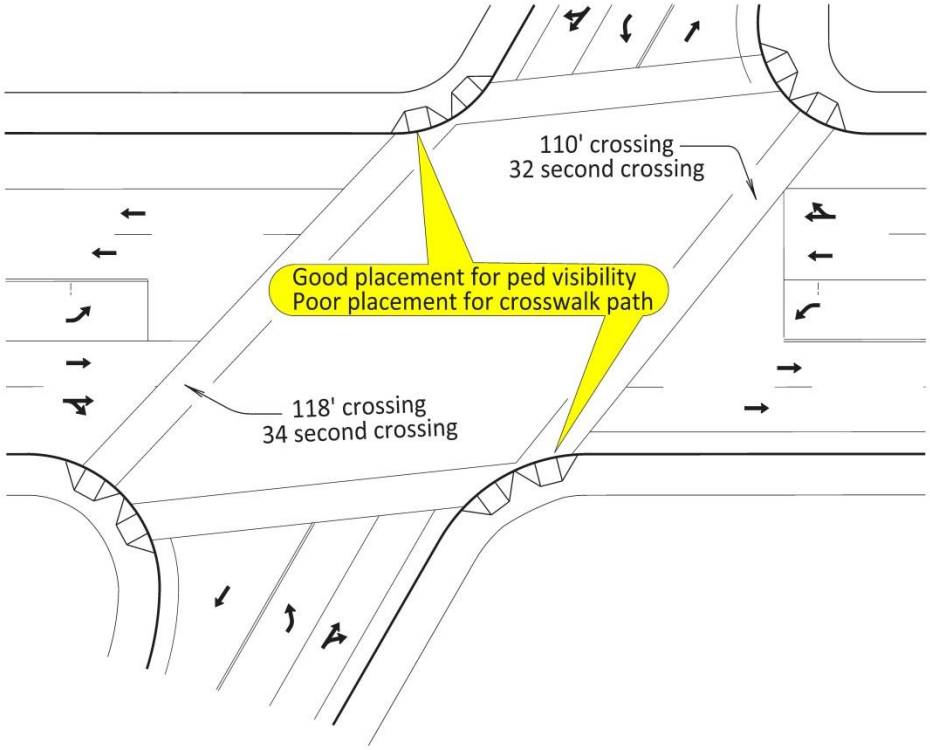



**Figure 5-3 | Crosswalk Example 2**

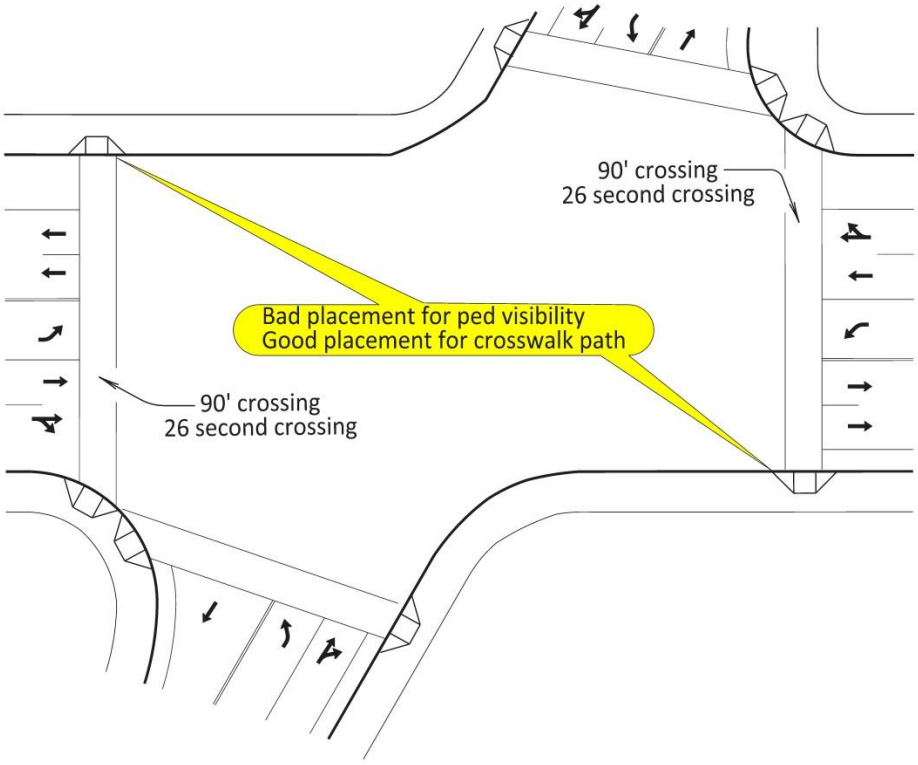
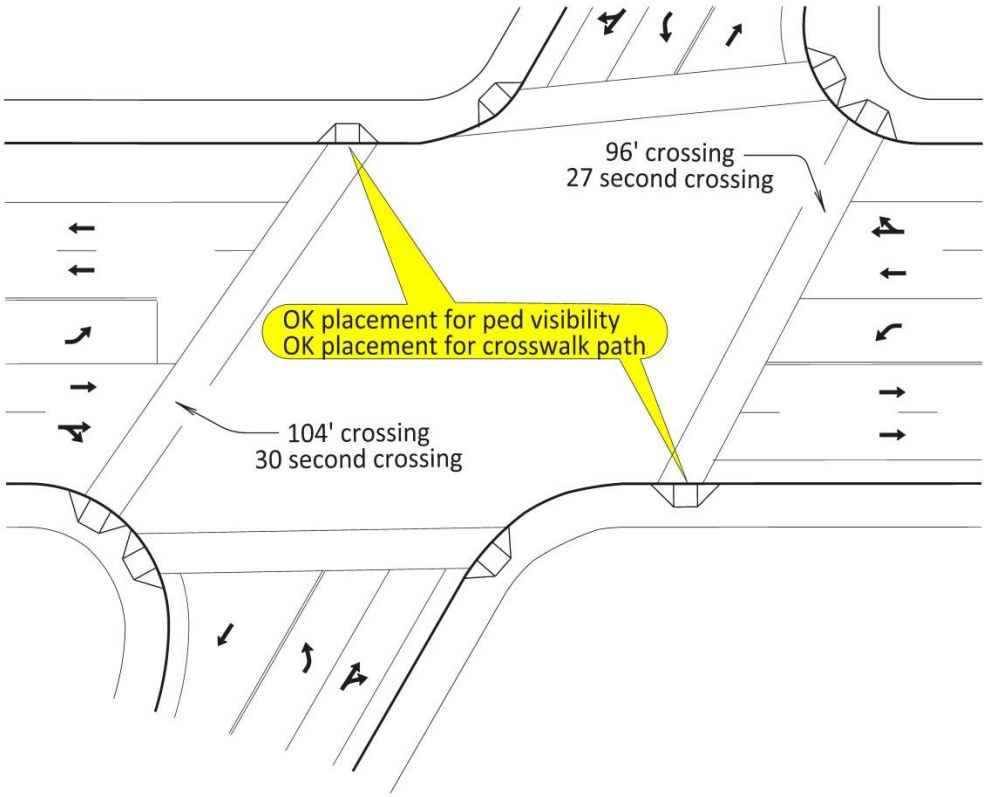


**Figure 5-4 | Crosswalk Example 3**




### 5.1.4 Signal Pole, Pedestal, and Pushbutton Posts

As per Technical bulletin RD17-01(B), ADA sidewalk curb ramp detail – minimum requirements in construction plans, Roadway Designers are required to show full detail of each ramp in the contract plans. This includes showing the exact location and critical elevations for signal poles, pedestrian pedestals, pushbutton posts and pushbutton locations. See Roadway Standard Details DET1720 and DET1721 for examples of ramp details. The Signal Designer will need to work closely with the Roadway Designer during ramp design, following the guidance in Section 5.4 to provide accurate pole and pedestal locations. The signal plan sheets should reference the ramp detail plan sheets.

### 5.1.5 Raised Median Islands and Crosswalk Alignment

Raised median islands are recommended by the ODOT Highway Design Manual and Oregon Highway Plan based on the highway classification (i.e. Statewide NHS routes) and to address certain safety, operational, and access concerns. The type of end treatment for the median island at signalized intersections should be carefully considered as it directly impacts the design of the pedestrian equipment (pushbuttons and pedestrian indication requirements) and signal phasing (number of pedestrian phases and potential phase restrictions due to truck turning radii).

**Two-Phase Pedestrian Crossing**

If a two-phase pedestrian crossing is required (according to the operational approval) the crosswalk configuration should be staggered with enough distance such that each phase of the pedestrian crossing is clearly defined. The pedestrian indications for the first phase of the crossing should not be visible to pedestrians using the second phase of the crossing (and vise-versa). See Figure 5-5 and Figure 5-6. This eliminates the potential confusion of which signal indication pertains to which crossing and the pedestrian crossing on an incorrect indication. Louvers and programmed heads are not an option for pedestrian indications. Count down heads can eliminate the confusion associated with non-staggered two-phase crossings (if the time for each of the two-phases is the same), but non-staggered two-phase crossings should be avoided when possible. Pushbuttons for each phase should also be separated and clearly indicate which crossing they apply to, preferably located on the same pedestal as the applicable pedestrian indication.

**Figure 5-5 | Two-Phase Pedestrian Crossing (Staggered Crosswalk Alignment) Example 1**

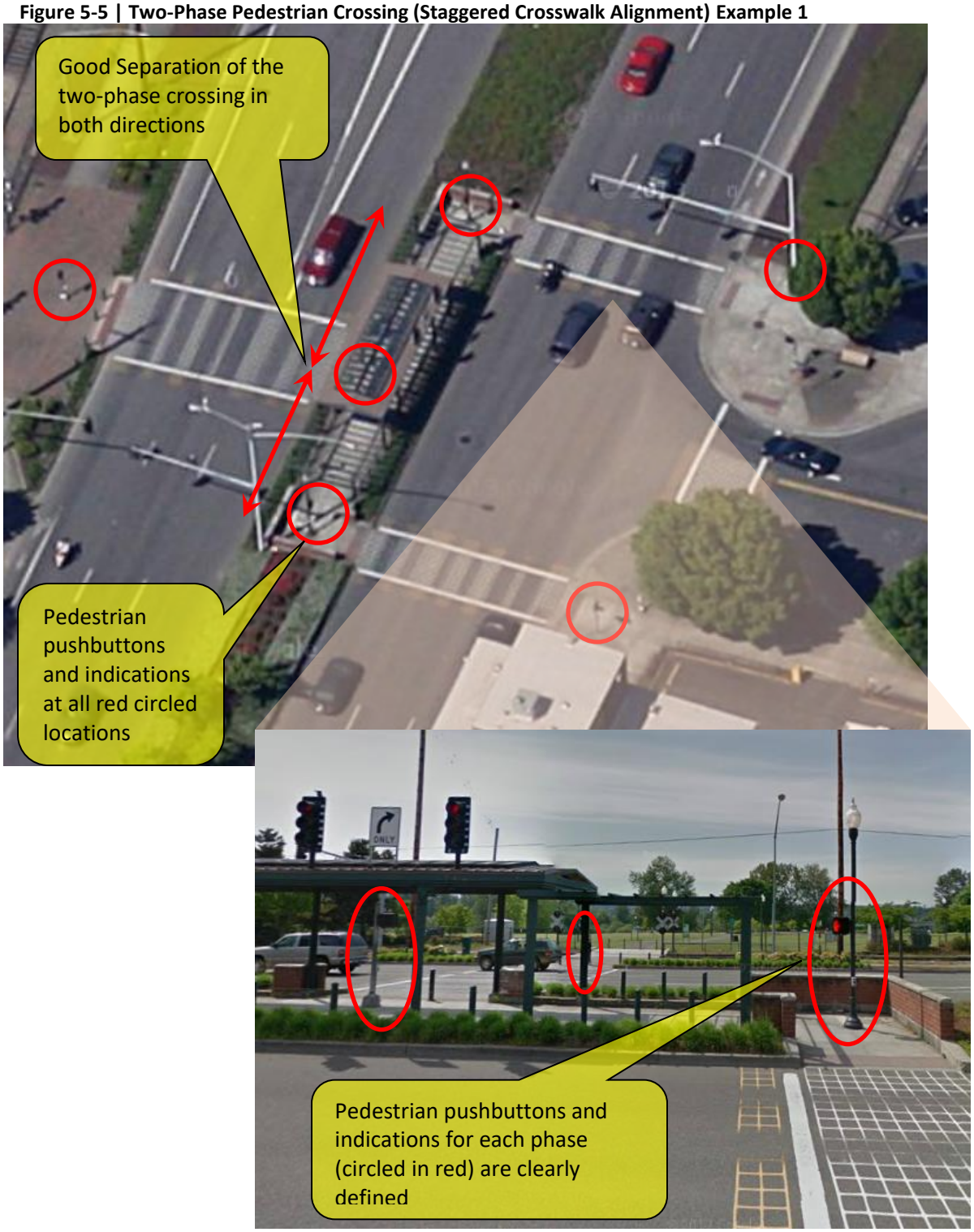
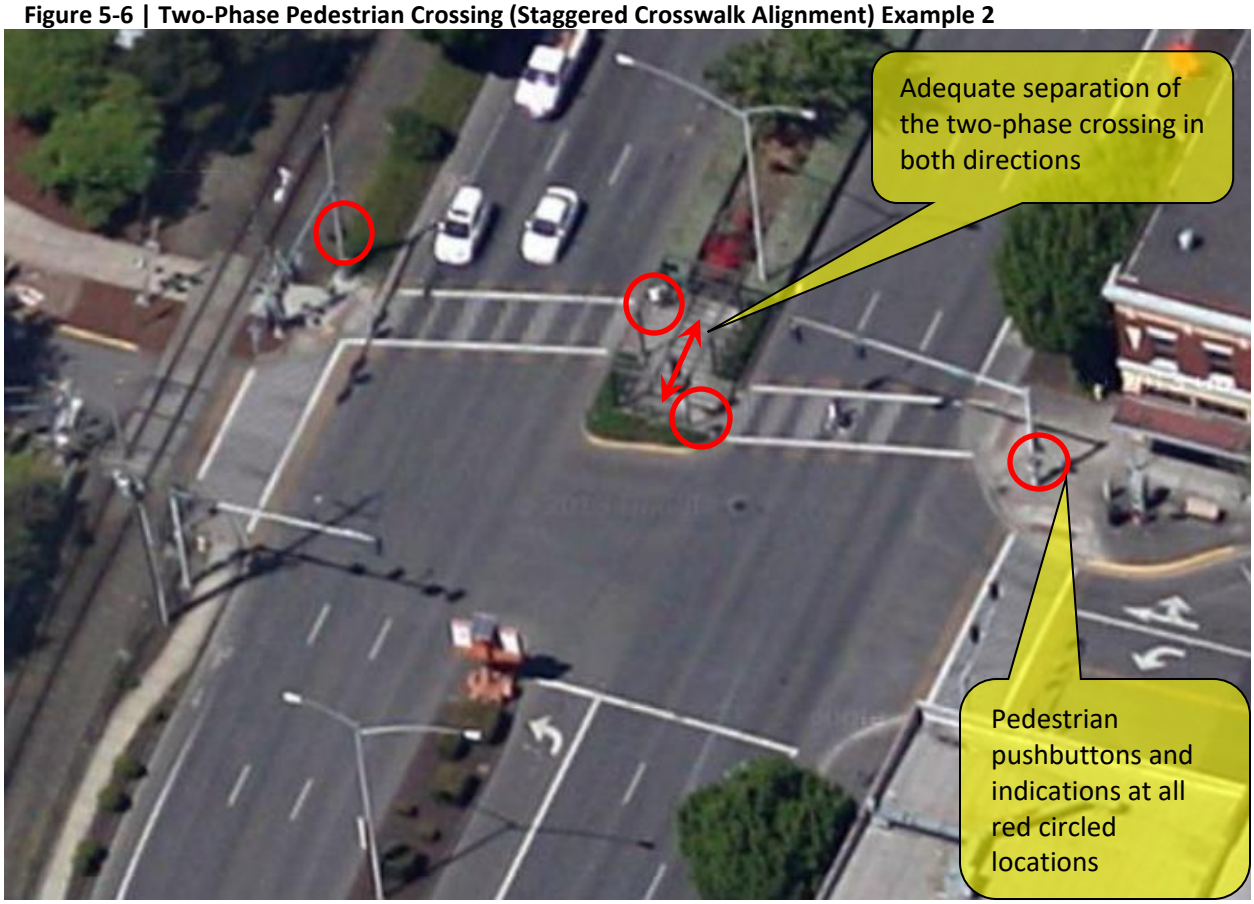


**Figure 5-6 | Two-Phase Pedestrian Crossing (Staggered Crosswalk Alignment) Example 2**



**Single Phase Pedestrian Crossing**

If a two-phase pedestrian crossing is NOT required (according to the Operational Approval) the crosswalk should be aligned as per section 5.1.3 with a median that ends prior to the crosswalk. This eliminates the need for a pushbutton located in the median as the design provides clear direction to the pedestrian that they will be crossing the entire crosswalk in one stage. See Figure 5-7 and Figure 5-8. Pushbuttons in the median, as shown Figure 5-9, in shall NOT be installed for a single phase pedestrian crossing where the raised median ends prior to the crosswalk (pedestrians should not be encouraged to take refuge where there is no pedestrian refuge).

**Figure 5-7 | Single Phase, One Stage Pedestrian Crossing (Recommended Crosswalk & Median Design) Example 1**

**Figure 5-8 | Single Phase, One Stage Pedestrian Crossing (Recommended Crosswalk & Median Design) Example 2**

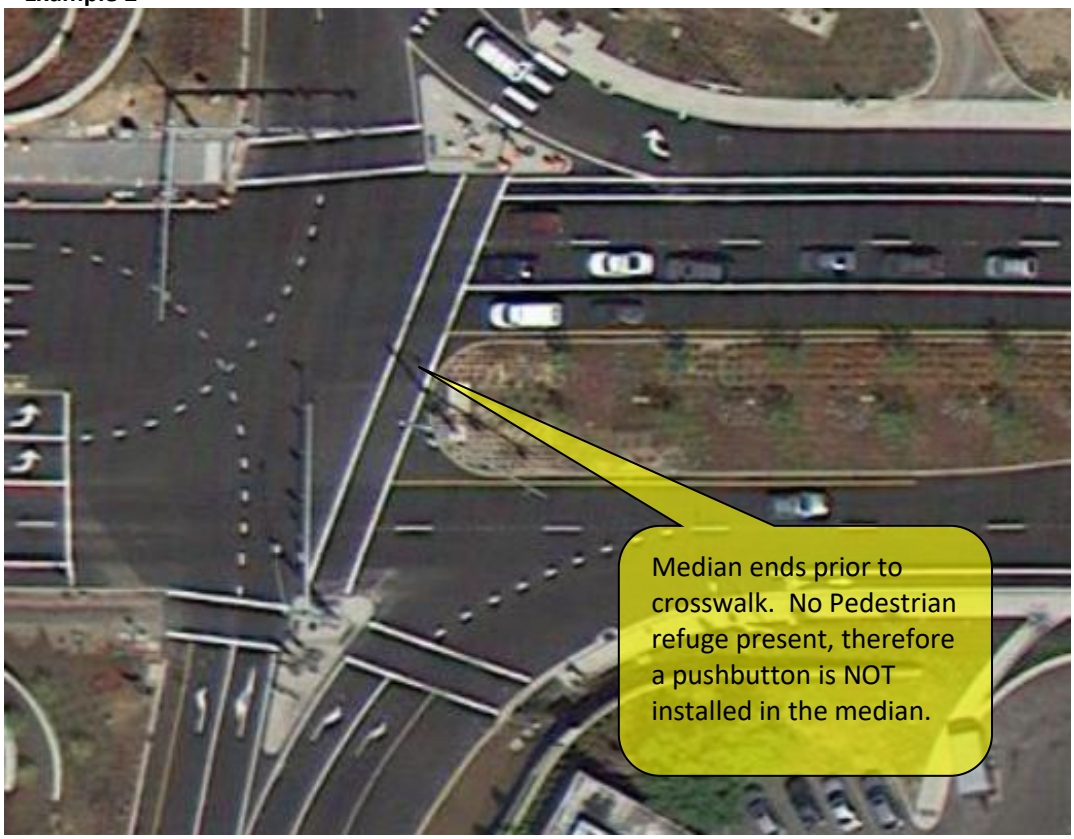
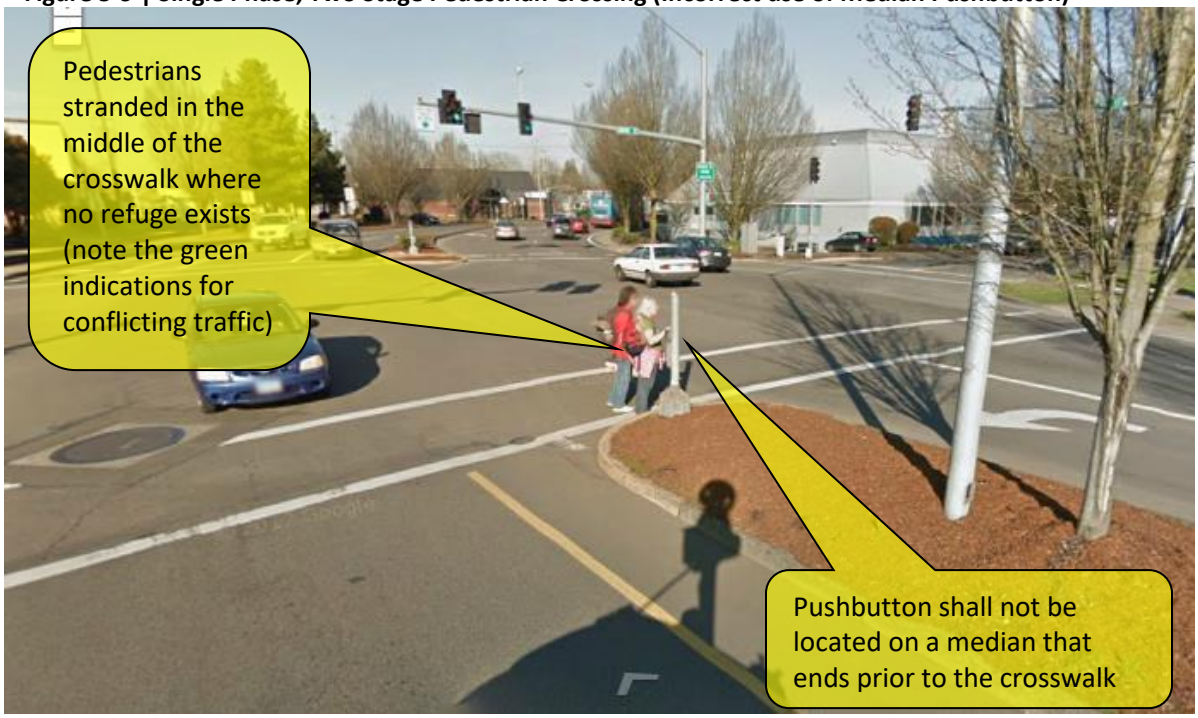



**Figure 5-9 | Single Phase, Two Stage Pedestrian Crossing (Incorrect use of Median Pushbutton)**

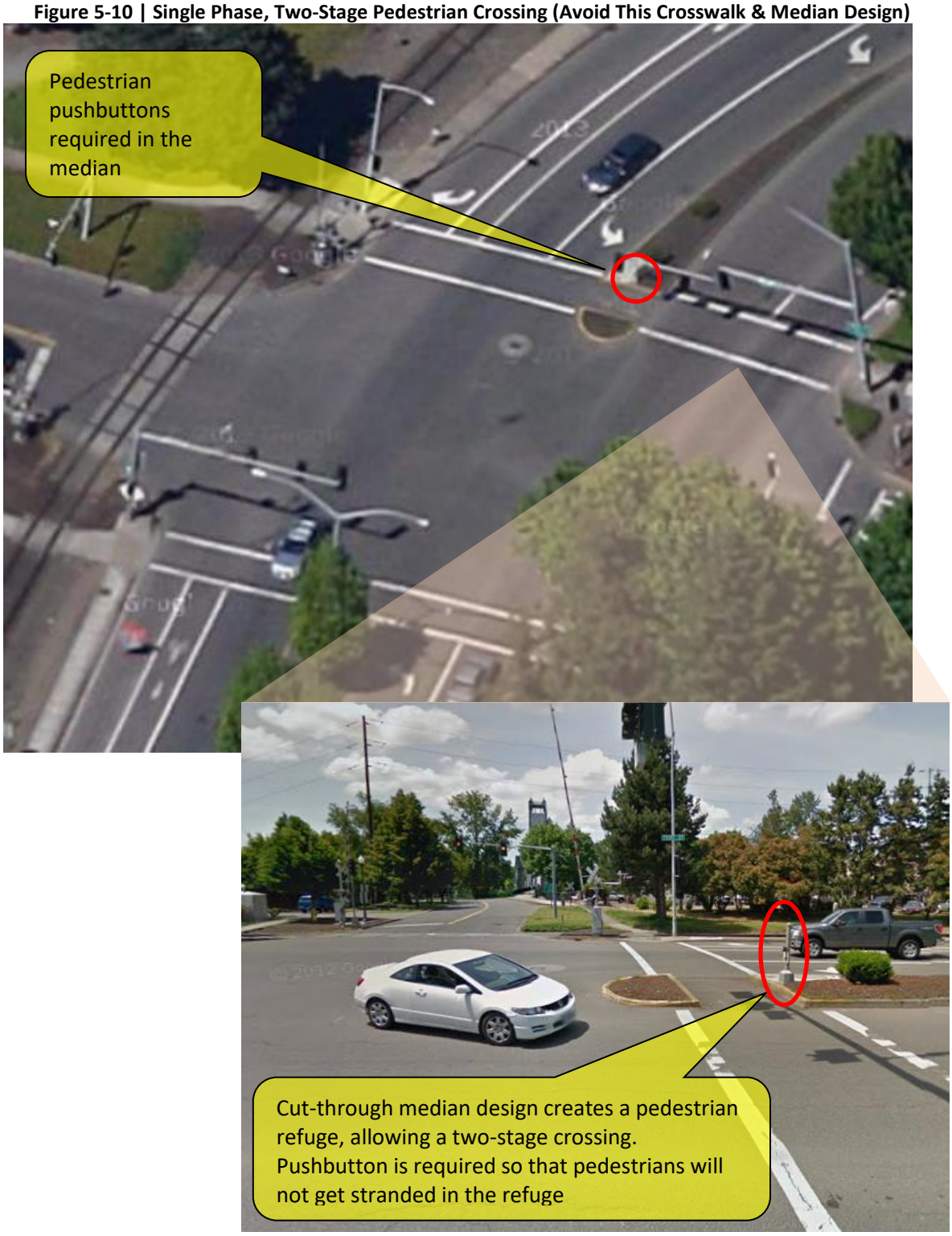


If the median is extended beyond the crosswalk with the cut-through style option, a pushbutton is required. See Figure 5-10. This is because the cut-through design is used to create a pedestrian refuge which allows pedestrians the option of a two-stage crossing, even though the pedestrian crossing is only a single phase (i.e. the pedestrian phase is timed to allow a pedestrian to cross the entire crosswalk, not just to the median). **A straight aligned crosswalk with a median cut-through should not operate as a two-phase pedestrian crosswalk (see Two-Phase Pedestrian Crossing requirements above).** Single phase, two-stage pedestrian crossings are not desirable and should be avoided for two reasons:

- The pushbutton in the median is often pushed by pedestrians even if they have no intention of making a two-stage crossing. This results in inefficient signal operations due to the pedestrian phase being serviced again in the next cycle when there is no demand. This is especially problematic if the signal is operating near, at, or over capacity.

- By placing a pedestrian refuge with a pushbutton in the median, pedestrians may be unsure if they should stop in the median and wait for the next WALK/FLASHING DON'T WALK to finish the crossing. However, the use of countdown pedestrian signal heads has largely eliminated this concern, as pedestrians now have info about how long the pedestrian phase will last and can make a more informed decision if they should wait in pedestrian refuge or not.

**Figure 5-10 | Single Phase, Two-Stage Pedestrian Crossing (Avoid This Crosswalk & Median Design)**



### 5.1.6 Driveway Approaches at Signalized Intersections

All approaches of an intersection shall be signalized, even if an approach is only a driveway or alley and serves a very limited amount of traffic. Figure 5-11 shows an example of a driveway forming the fourth approach of an intersection. Half signals or an unsignalized approach at the intersection are not allowed (this excludes right turn slip lanes which may be signalized, STOP or YIELD controlled as specified in the operational approval).

**Figure 5-11 | Signalized Driveway Example**

Typically a driveway approach is according to the roadway standard drawings RD715 (non-sidewalk driveways) or RD725 thru RD750 (sidewalk driveways). Sidewalk driveway options shown in RD725 thru RD750 should NOT be used when the driveway approach will be signalized. Instead, a small radius with sidewalk ramps (and standard crosswalk striping) as shown in RD756 should be used instead. A small radius with sidewalk ramp will make the approach look and feel like a typical signalized approach; drivers should be more likely to stop at the proper location and watch for pedestrians and pedestrians should be more likely to notice the pedestrian indications and comply. For comparison purposes, see Figure 5-12 showing the before photo of a signalized sidewalk driveway and
Figure 5-13 showing the after photo with a new small radius, sidewalk ramps and crosswalk striping.

**Figure 5-12 | Signalized Sidewalk Driveway (Before Photo) – Avoid This Approach Design**

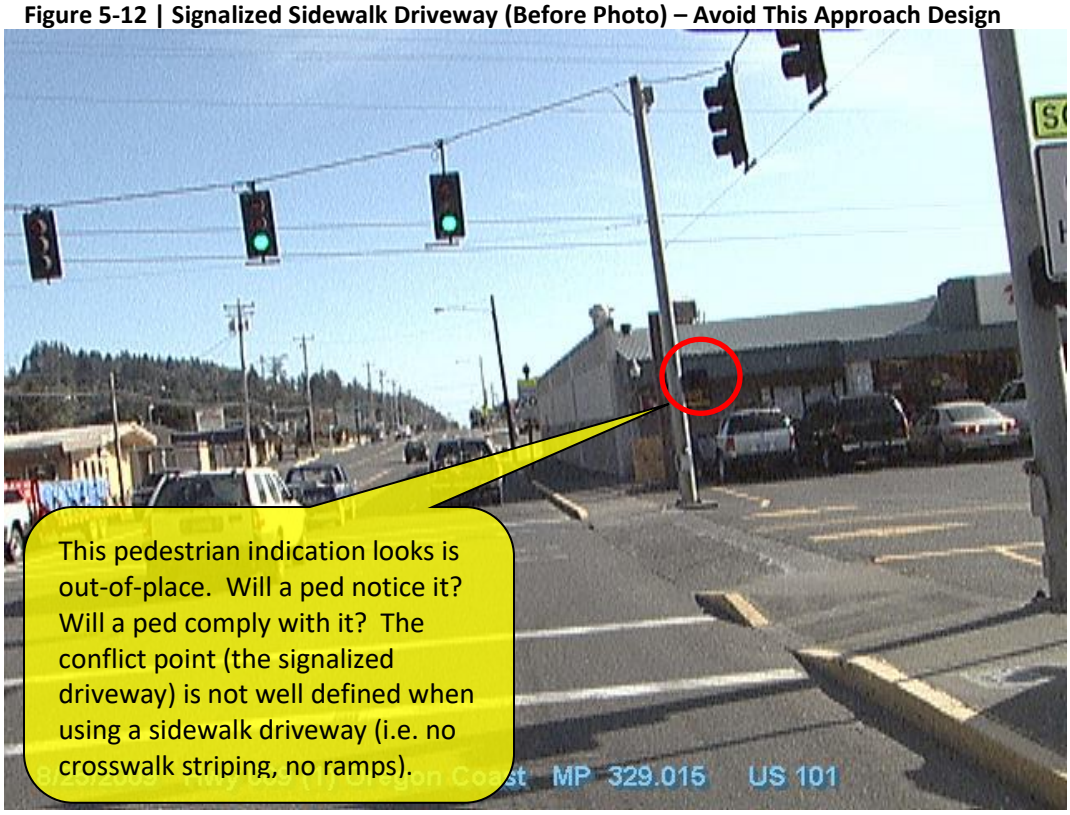
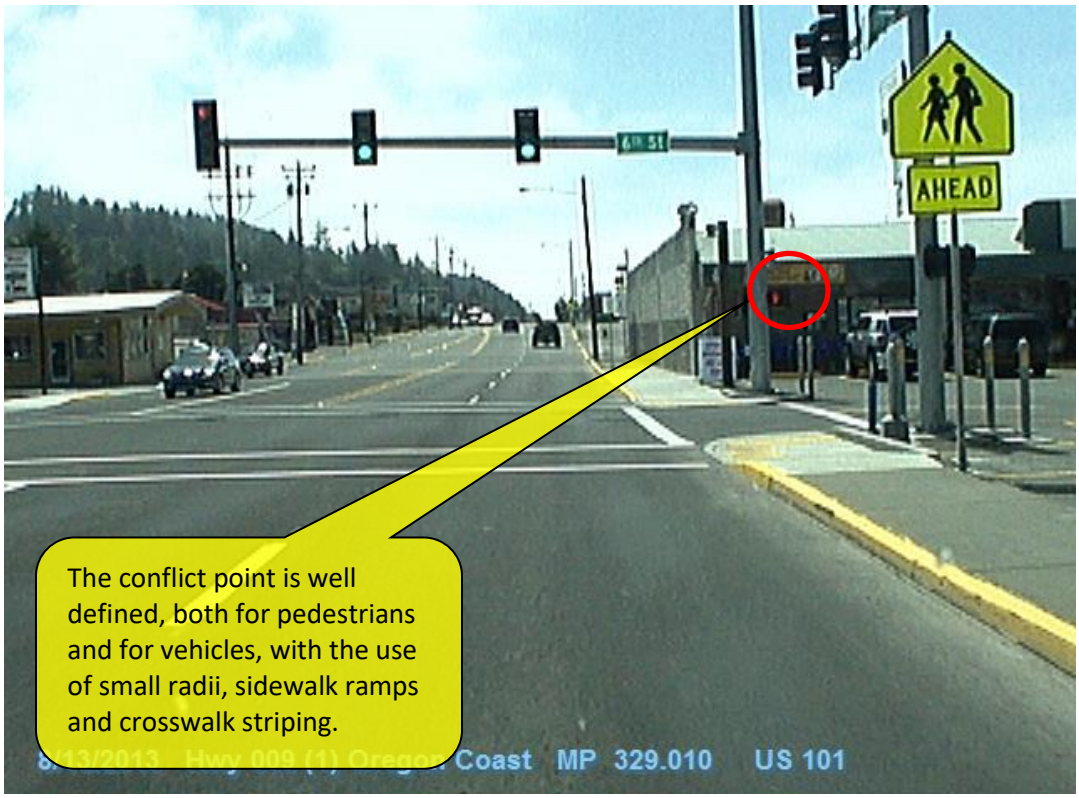



**Figure 5-13 | Signalized Driveway with small radius and sidewalk ramps (After Photo) – Use This Approach Design**



## 5.2 Vehicle Signal Head Layout

Signal head location is guided by the Manual on Uniform Traffic Control Devices (MUTCD) and the Oregon Supplements to the MUTCD. Once the number of lanes, lane use, location of crosswalks, signal phasing and roadway geometry are known, the vehicle signal heads can be laid out. This, in conjunction with the pedestrian signal equipment layout (Section 5.3), will be the basis for determining what type of signal support structures (mast arms, span wires, pedestrian pedestals, custom design, and/or pushbutton posts) should be used at the intersection.

**The Operational Approval and the Roadway Geometry MUST match!**

Some basic guidelines per approach:

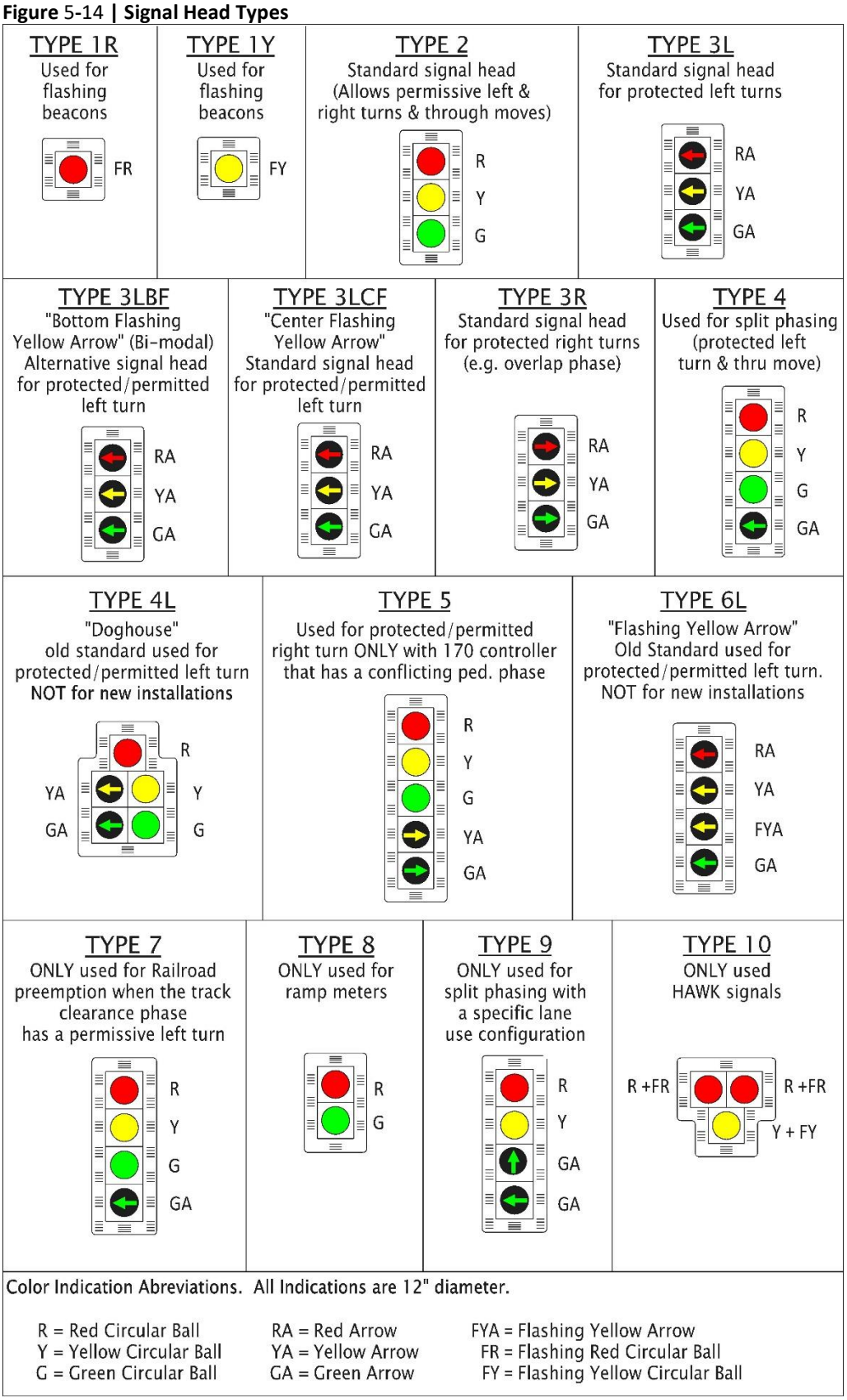
- Signal heads should be mounted over head on mast arms or span-wires for all movements. Supplemental signal heads may be ground mounted on vehicle pedestals.
- Signal heads should be aligned vertically (vs. horizontally)
- A minimum of two signal faces shall be provided for the through movement on the approach. If no through movement exists, a minimum of two signal faces shall be provided for the major movement from the approach.
- A signal face per lane shall be used when there are 3 or more through lanes on the approach.
- Heads for the same phase shall not be located closer than 8 feet apart (horizontally from each other). They should be located at least 10 feet apart when possible.
- Heads shall not be less than 45 feet (based on standard 18-19 foot mounting height) from the “STOP” line (or nearside crosswalk line if there is no stop line). Heads located greater than 180 feet from the “STOP” line require a near-side supplemental head.

### 5.2.1 Head Types

The type of signal heads that can be used are defined in Standard Drawing TM460 and shown in Figure 5-14. Head types are designated by a number or a combination of number and letter for the head type to be used. Each signal head type has a specific use.

If the need arises to use a signal head type or layout that that is not covered by this manual (such as bike, U-turn, flashing yellow right turn arrow, etc.), contact the Traffic Signal Engineer to discuss and resolve the unique situation. See Section 2.2 for more information on non-standard and experimental design.

**Figure** 5-14 **| Signal Head Types**



### 5.2.2 Head Placement

The even phases (ø2, ø4, ø6, and ø8) are typically the through movements. These phases typically require two Type 2 heads. The location of the heads in free space depends on the number of receiving lanes and the roadway geometry. See Table 5-1. The alignment of the through signal heads is based on the receiving lanes (Figure 5-15), NOT the projected approach lanes (Figure 5-16).

**Table 5-1 | Standard Signal Heads for Through Movement Phases**

| Standard Signal Heads for Through Movement Phases | |
|---|---|
| **Number of receiving lanes** | **Number and placement of signal heads** |
| Single receiving lane | Two Type 2 signal heads, placed one foot inside the projected receiving lane lines |
| Two receiving lanes | Two Type 2 signal heads, one placed in the center of each receiving lane |
| More than two receiving lanes | One Type 2 signal head for each receiving lane, placed in the center of each receiving lane |

**Signal head alignment for THROUGH movements are based on the RECEIVING lane lines (See Figure 5-15).**

**Signal head alignment for TURN movements are based on the PROJECTED lane lines (See Figure 5-19 and Figure 5-20).**

**Figure 5-15 | Signal Head Placement For Through Movement Using Receiving Lane Lines (CORRECT METHOD)**

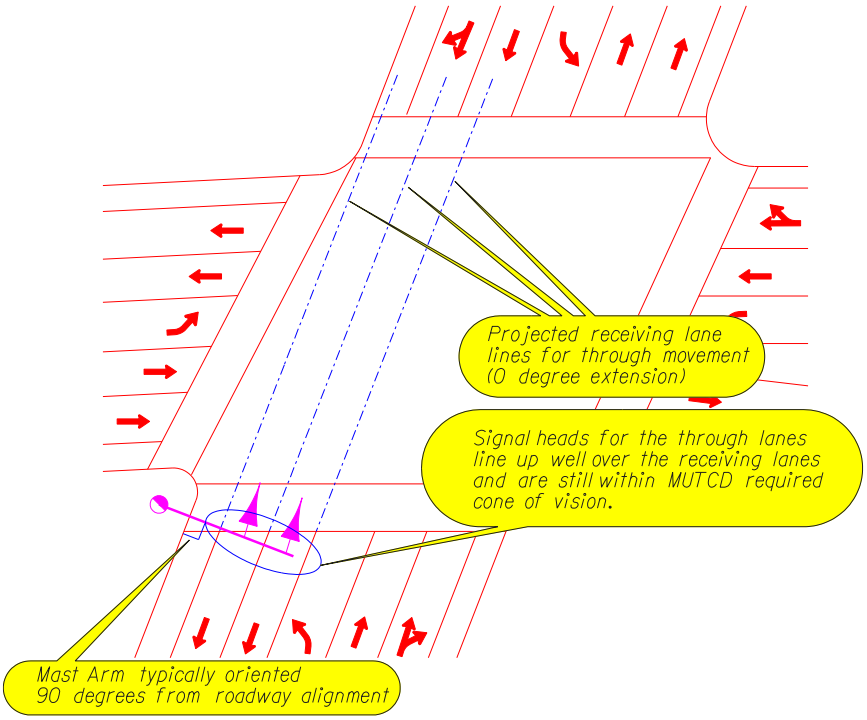
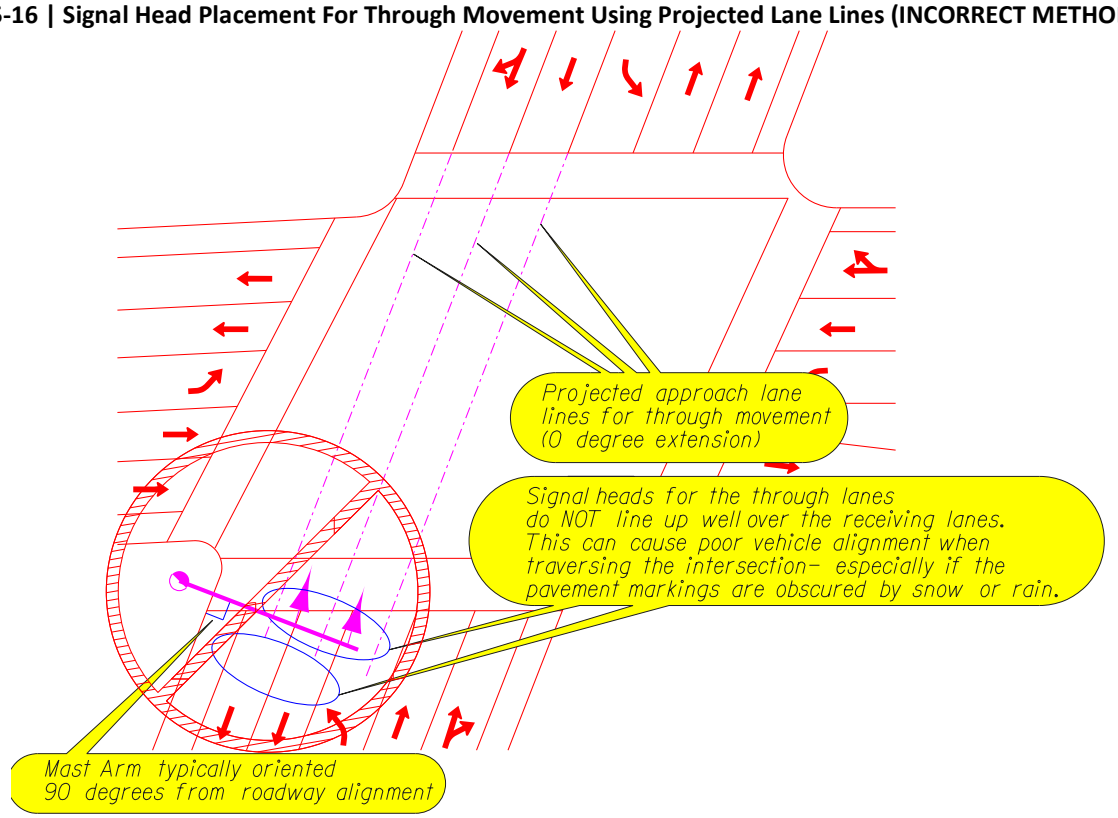
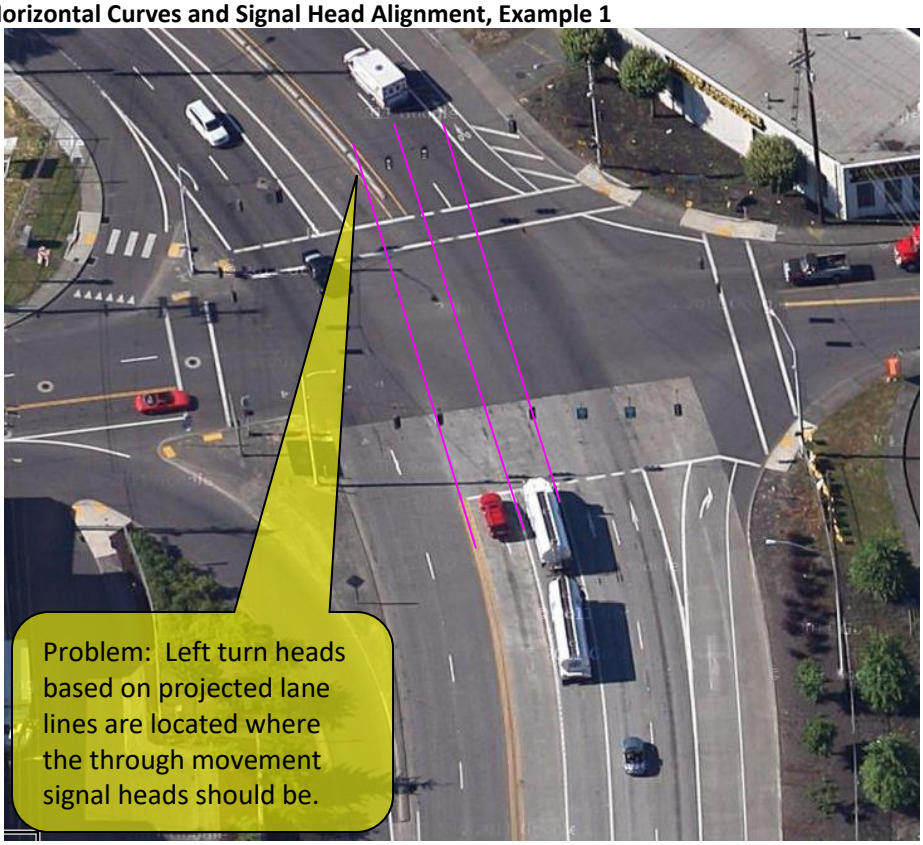



**Figure 5-16 | Signal Head Placement For Through Movement Using Projected Lane Lines (INCORRECT METHOD)**



When the intersection is located within a horizontal curve, strict adherence to signal alignment based on the receiving lane lines (through movements) and projected lane lines (turn movements) may not be possible; it could result in the left turn heads being located to the right of the through movement heads in one direction and the left turn heads being located to the left of the through movement heads by a ridiculous distance in the other direction. In these cases, the signal head alignment for the through phases takes precedence and should be determined first, according the receiving lane lines. This is because the through movements are more likely to be approaching and proceeding through the intersection at speed, while the turn movements are more likely to be coming to a stop and will proceed through the intersection at a slower speed. The turn signal head alignment is determined next, with the left turn head always located to the left of the through movement heads and the right turn heads always located to the right of the through movement heads, regardless of the projected lane lines. The turn signal heads should be kept within a reasonable distance of the through movement heads if possible, approximately 6 to 12 feet. See Figure 5-17 and Figure 5-18.

**Figure 5-17 | Horizontal Curves and Signal Head Alignment, Example 1**



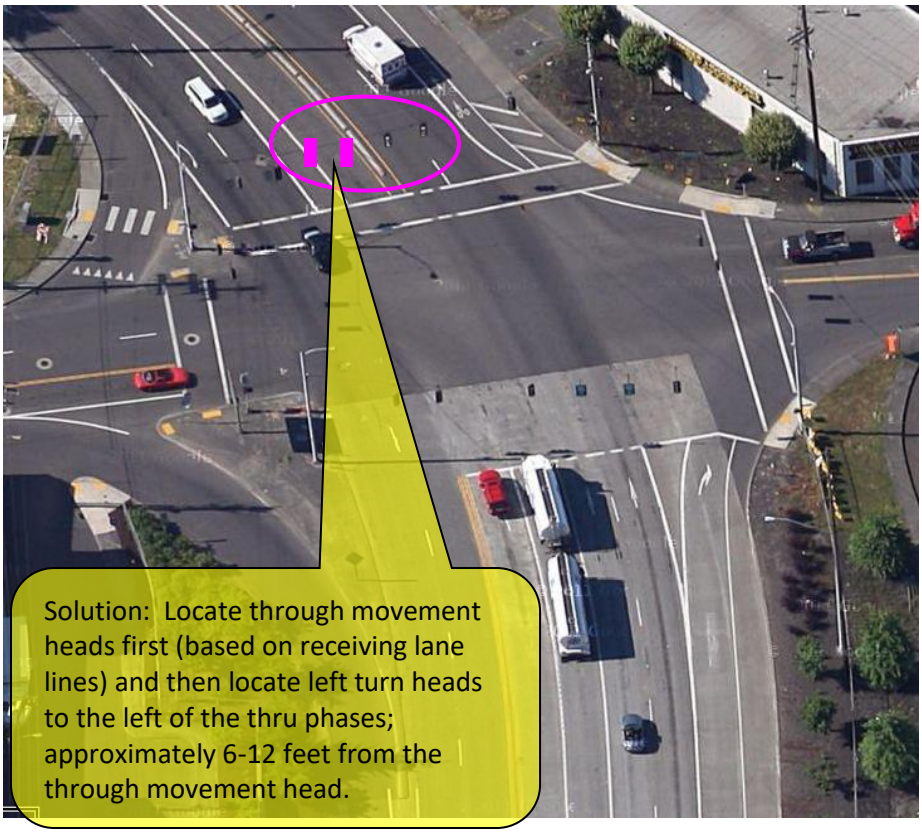
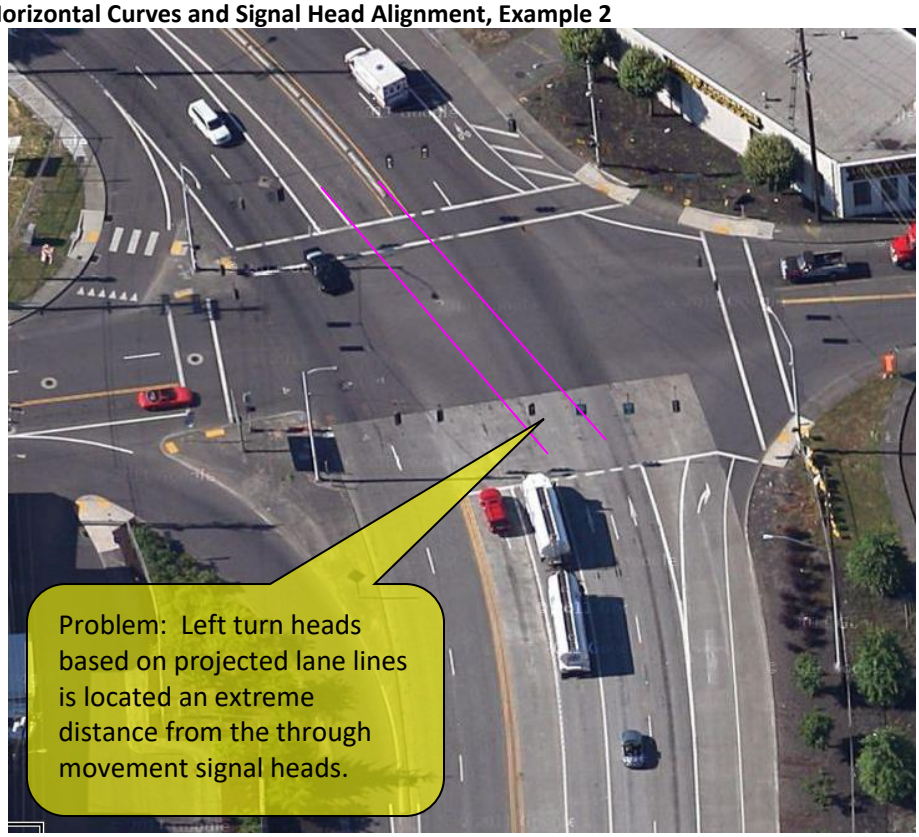
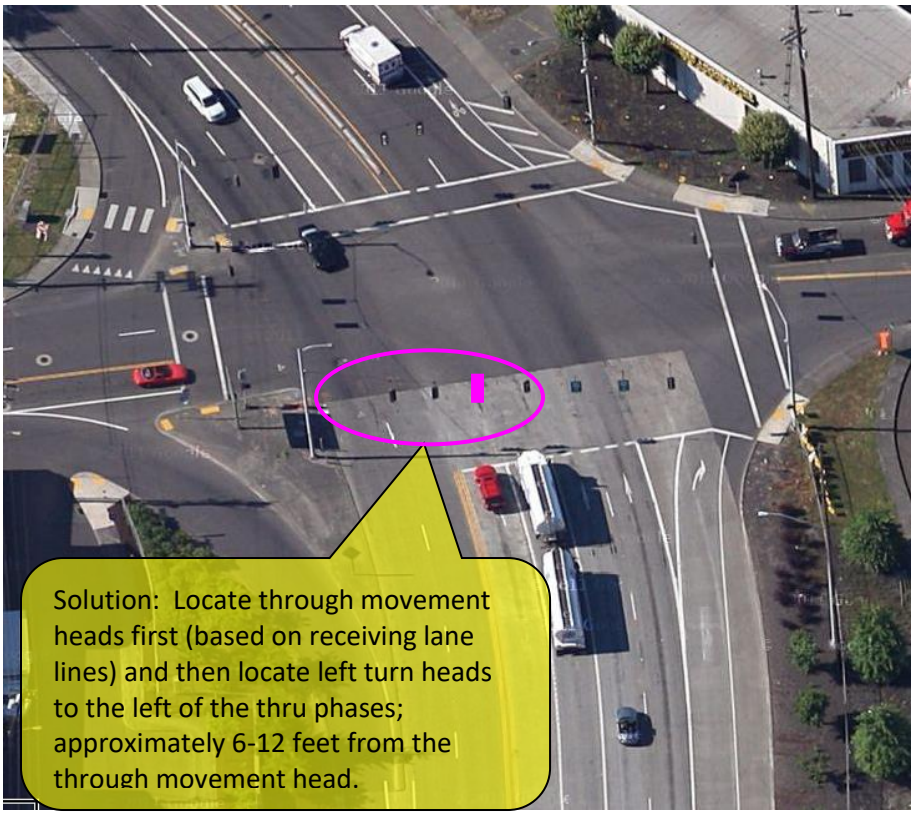



**Figure 5-18 | Horizontal Curves and Signal Head Alignment, Example 2**



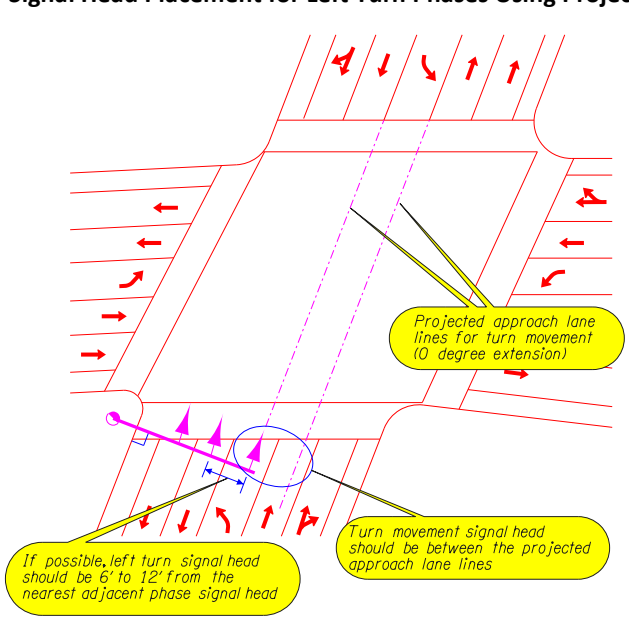
The odd phases (ø1, ø3, ø5, and ø7) are typically the left turn movements and would require one signal head. Dual turn movements, require two signal heads. The signal head type will depend on the desired operation of the left turn phase (as stated in the operational approval). The alignment of the left turn signal heads is based on the projected approach lanes. See Table 5-2 and Figure 5-19.

**Table 5-2 | Standard Signal Heads for Left Turn Phases**

| Standard Signal Heads for Left Turn Phases | |
|---|---|
| **Type of Operation** | **Number and placement of signal heads** |
| Protected Only Phasing | One Type 3L signal head, placed in the center of the projected lane lines* |
| Protected/Permitted Phasing | One Type 3LCF signal head, placed in the center of the projected lane lines.* The Type 4L and 6L head is no longer used. The location of the Type 3LCF needs to be inventoried by the State Traffic Operations Engineer. Use of Type 3LBF (bi-modal) heads is discouraged and should only be considered as a last resort (Section 4D.20 of the Oregon Supplement to the MUTCD). |
| Permissive Only Phasing | Signal head PROHIBITED from being located within the projected lane lines. Use signal head placement as described for through movement phases. |
| Dual Left Turns (typically protected only phasing) | Two Type 3L signal heads, one placed in the center of each projected lane lines* |

* If possible, left turn phase signal heads should be located within 6 to 12 feet of the nearest adjacent phase signal head.

**Figure 5-19 | Signal Head Placement for Left Turn Phases Using Projected Lane Lines**



Right turn movements are typically permissive only, and as such require no additional signal heads. However, if an exclusive right turn lane is to be operated other than permissive only, the signal head type will depend on the desired operation (as stated in the operational approval). The alignment of the signal heads is based on the projected approach lanes, with the exception of right turn slip-lanes. See Table 5-3 and Figure 5-20.

**Table 5-3 | Standard Signal Heads for Right Turn Phases**

| Standard Signal Heads for Right Turn Phases | |
|---|---|
| **Type of Operation** | **Number and placement of signal heads** |
| Overlap phasing (operating as protected only) | One Type 3R signal head, placed in the center of the projected lane lines*. This is the standard when using a 2070 controller (conflicting crosswalk phase must either be closed or use the "not ped" software feature) |
| 2-phase operation (operating as Protected/Permitted) | One Type 5 signal head, placed in the center of the projected lane lines*. This operation should ONLY be used 1.) when using a 170 controller AND the conflicting crosswalk phase cannot be closed or 2.) when the opposing left turn is PPLT or permissive only and there is a single receiving lane (MUTCD 4D.05, F, 1). |
| Permissive Only Phasing | No signal head required |
| Dual Right Turns (typically protected only phasing) | Two Type 3R signal heads, one placed in the center of each projected lane lines*. |
| Signalized right turn slip lanes, single lane (e.g. overlap phase) | Two Type 3R signal heads, placed one foot inside the approach lane line. The opposing left turn CAN NOT be a permissive left turn if there is a single receiving lane. |
| Signalized right turn slip lanes, dual lanes (e.g. overlap phase) | Two Type 3R signal heads, one placed in the center of each approach lane. The opposing left turn CAN NOT be a permissive left turn. |

* If possible, right turn phase signal heads should be located within 6 to 12 feet of the nearest adjacent phase signal head.

**Figure 5-20 | Signal Head Placement for Right Turn Phases Using Projected Lane Lines**

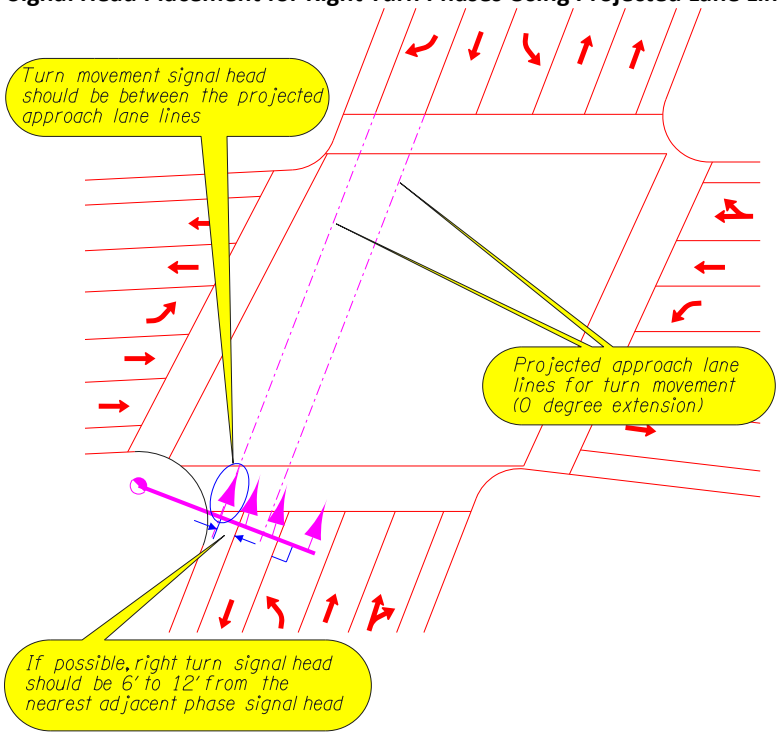
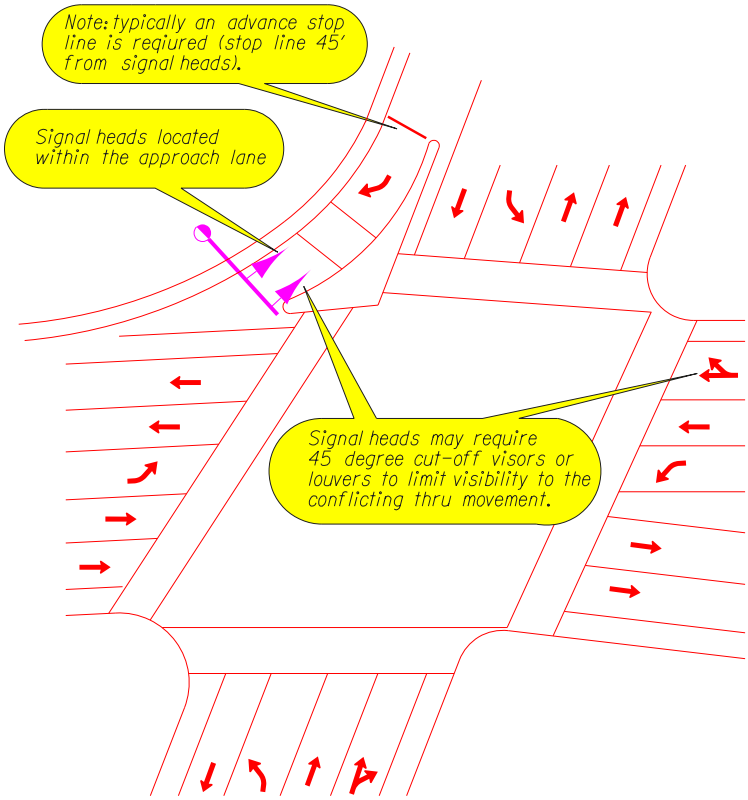



**Figure 5-21 | Signal Head Placement for Right Turn Phases –Right Turn Slip Lanes**



There are a few special signal phasing/lane configurations that noted below. While they are not used frequently, they are not uncommon and therefore have standards associated with them. See Table 5-4.

**Table 5-4 | Standard Signal Heads for Special Phasing/Lane Configurations**

| Signal Heads for Special Phasing/Lane Configurations | |
|---|---|
| **Type of Operation** | **Number and placement of signal heads** |
| Split phasing | A type 4, 3L or 9 is required if the approach has a left turn movement. The signal type is dependent on the lane use. See Figure 5-26 |
| Approach with a vehicle clear-out interval (railroad preemption) AND a permissive left turn phase. | A Type 7 signal is required, placed as shown in Figure 5-28 |
| Through-left turn lane with protected/permitted left turn phasing | A type 4L signal head is used for this unique phasing when an exclusive left turn lane is not available as shown in Figure 5-24 |

Figure 5-22 through Figure 5-28 show examples of typical signal head placements.

**Figure 5-22 | Signal Head Placement for Lanes Sharing the Same Phase**

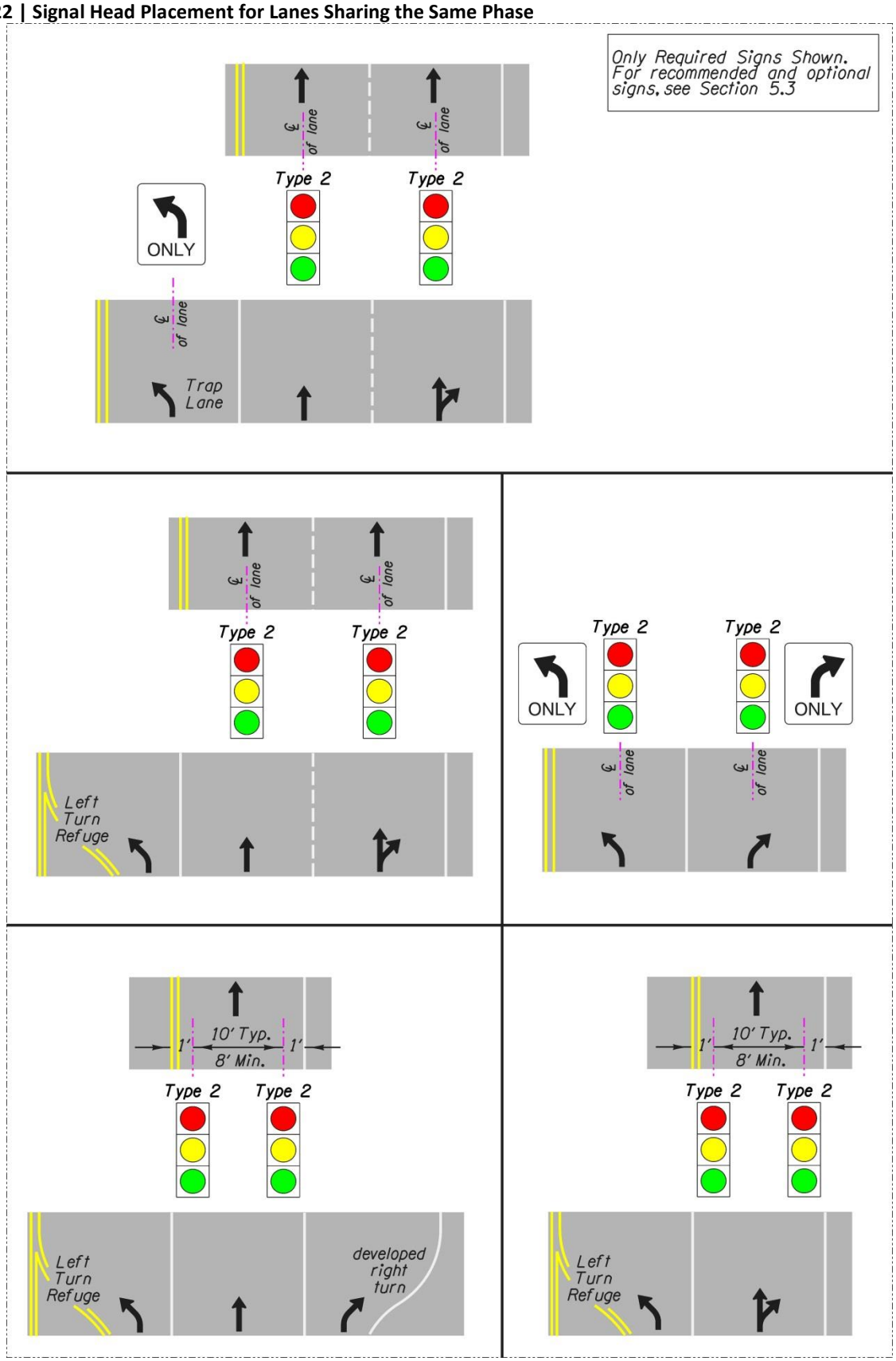


**Figure 5-23 | Signal Head Placement for Lanes Sharing the Same Phase (cont.)**

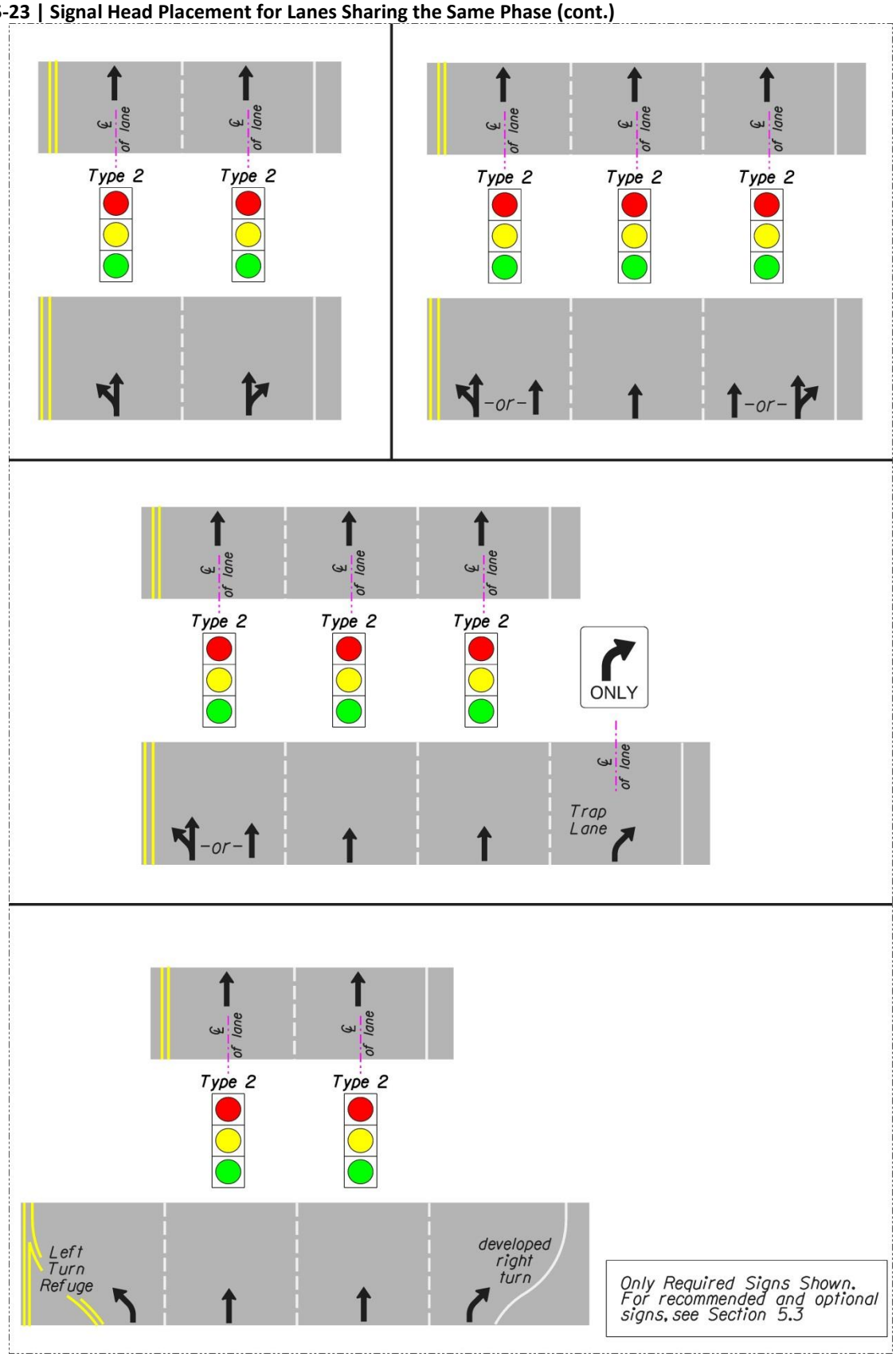


**Figure 5-24 | Signal Head Placement for Left Turn Phasing**

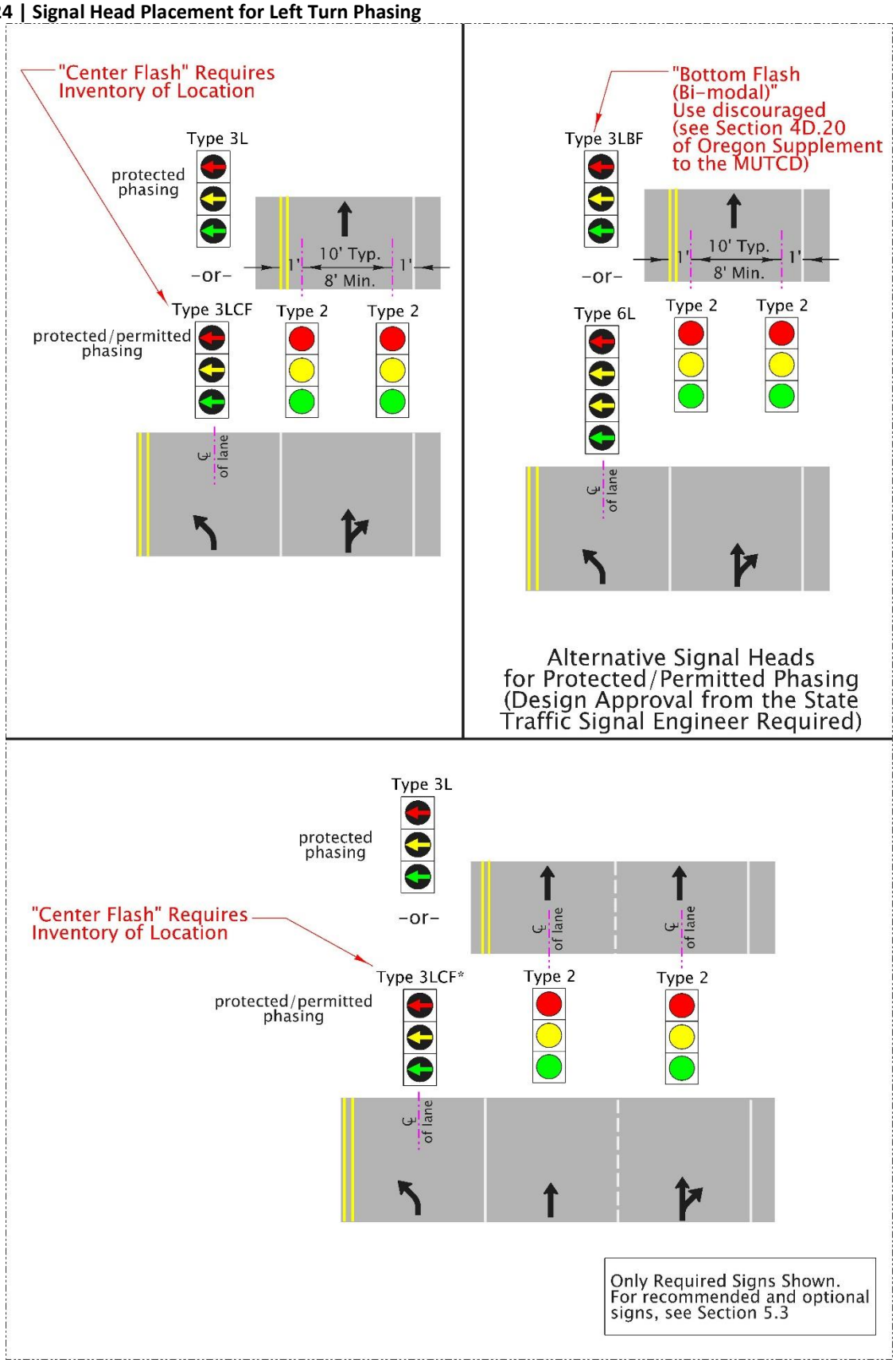


**Figure 5-25 | Signal Head Placement for Right Turn Phasing**

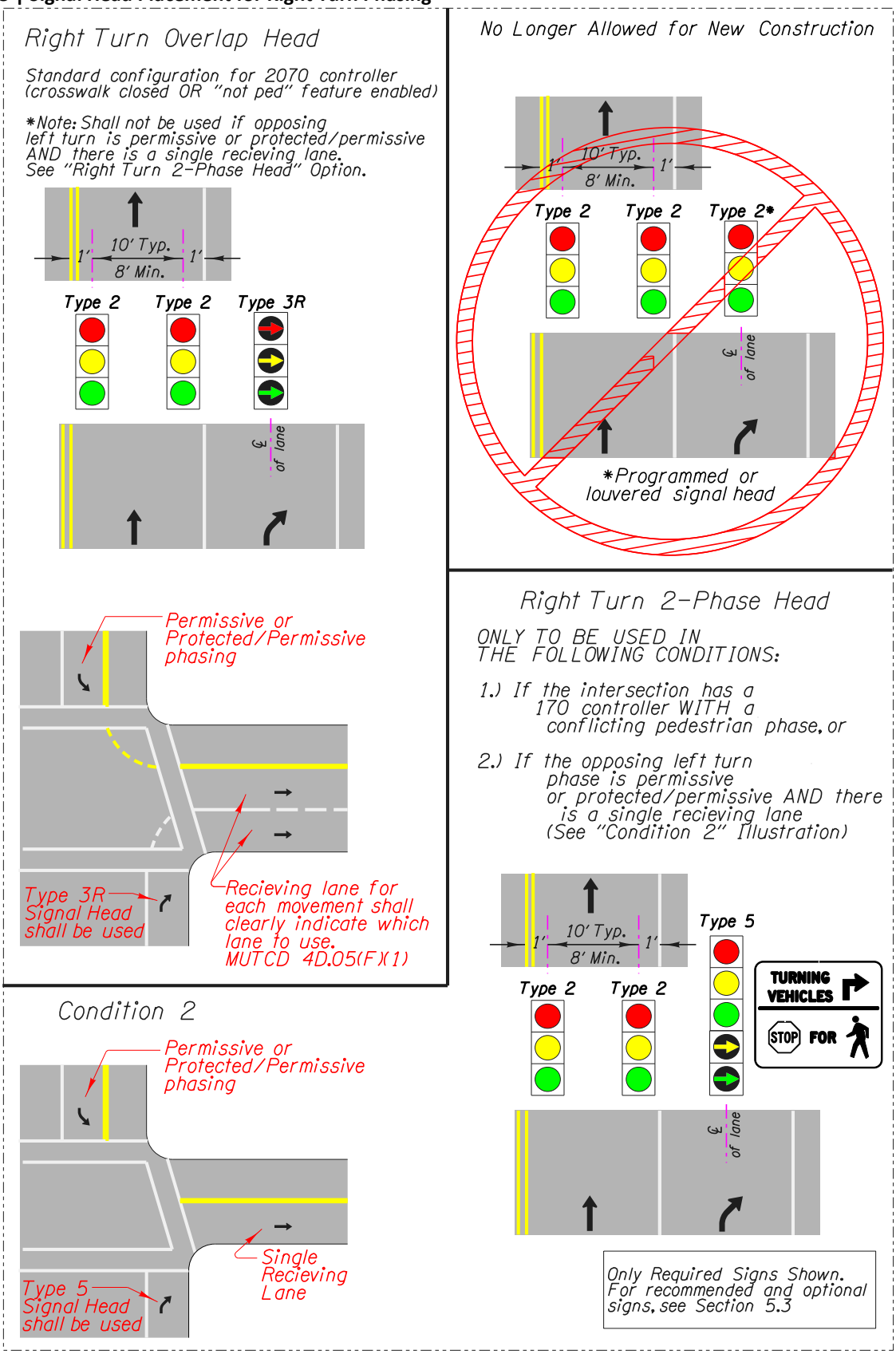


**Figure 5-26 | Signal Head Placement for Split Phasing**

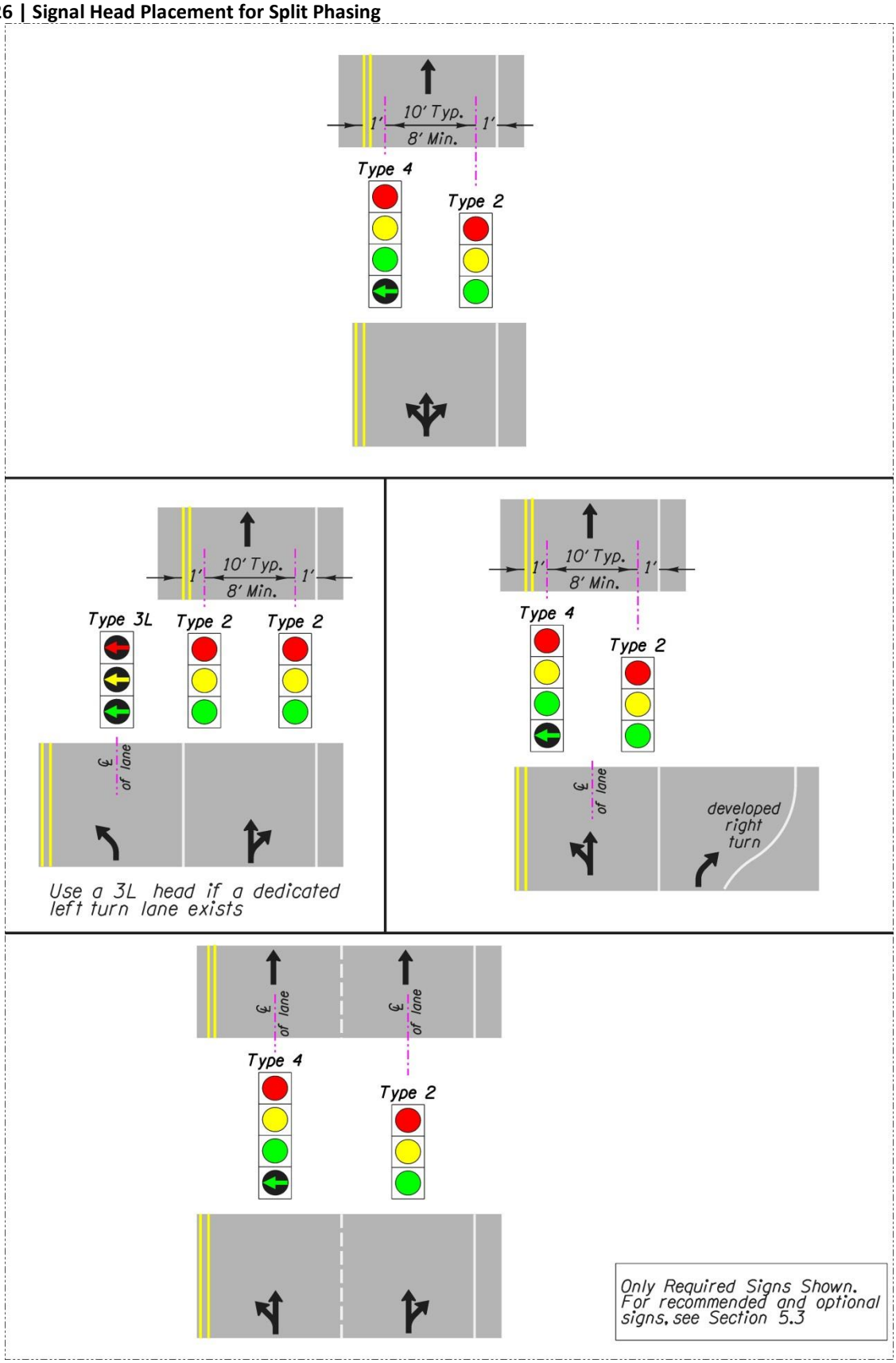


**Figure 5-27 | Signal Head Placement for Split Phasing (cont.)**

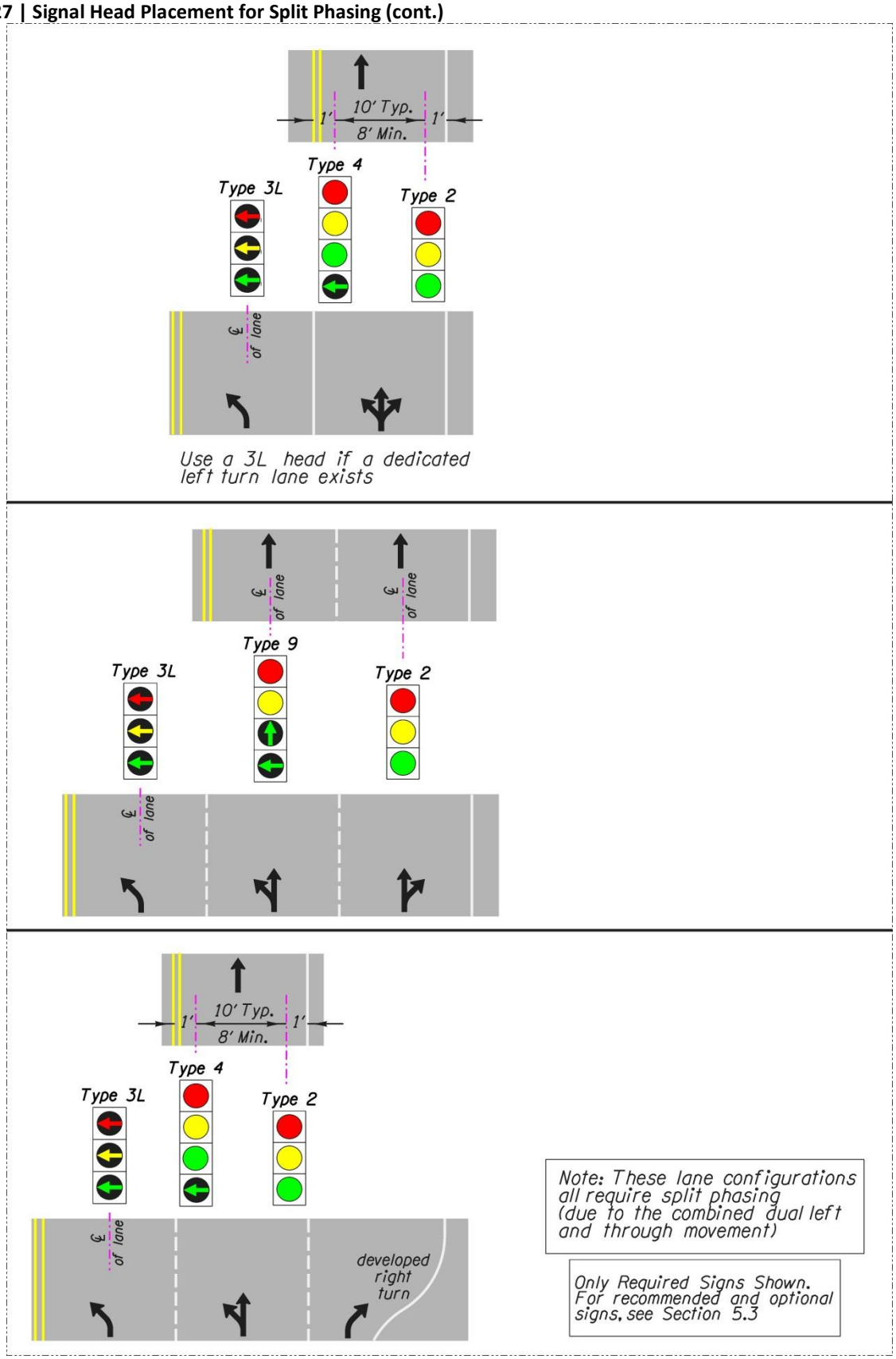
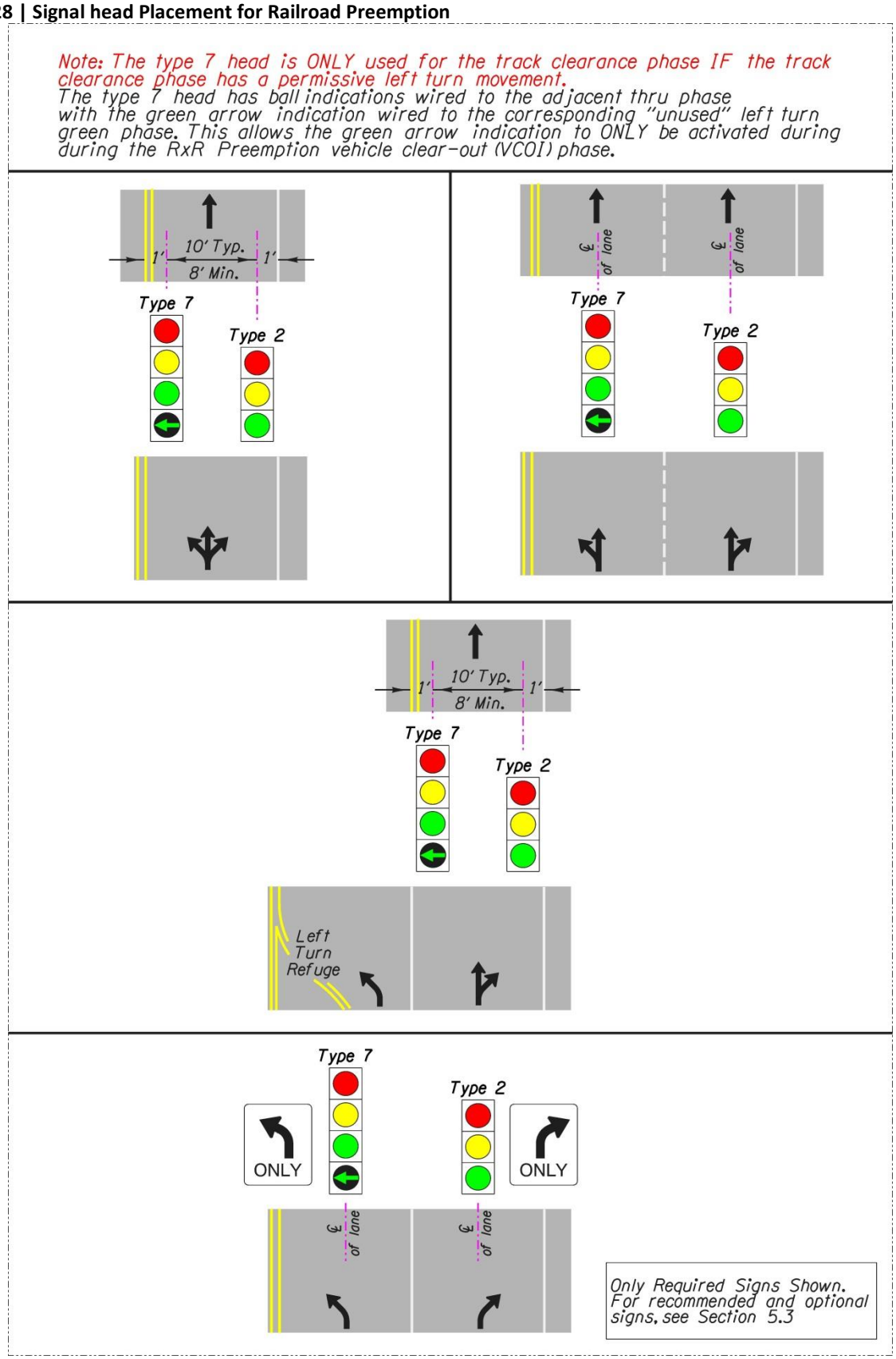


**Figure 5-28 | Signal head Placement for Railroad Preemption**



### 5.2.3 Supplemental signal heads

As per the MUTCD, supplemental near side signal heads are required when signal heads are located greater than 180 feet from the "STOP" line. They may also be used to improve conspicuity and visibility to the signalized intersection. There are two main locations where supplemental signal heads can be placed:

- Near-side supplemental heads: signal heads are located before the intersection. This is the most common location, and typically will be for the thru phase. See Figure 5-29. It may also be used for left turn phases. See Figure 5-30. The head will be on the vertical signal pole (left or right side of the road, depending on the roadway curvature) or overhead if the supporting structure allows proper alignment (i.e. the mast arm is long enough or a span wire is used).

- Far-side supplemental heads: signal heads are located across the intersection. This location is not as common as the near-side location. The typical application is for left turn phases. See Figure 5-32. It may also be for thru phases. See Figure 5-31. The head will be on the vertical signal pole (on the left side for a left turn phases, or on the right side for a thru phase).

**Figure 5-29 | Supplemental Near-side signal heads – Typical Placement for Thru Phase**

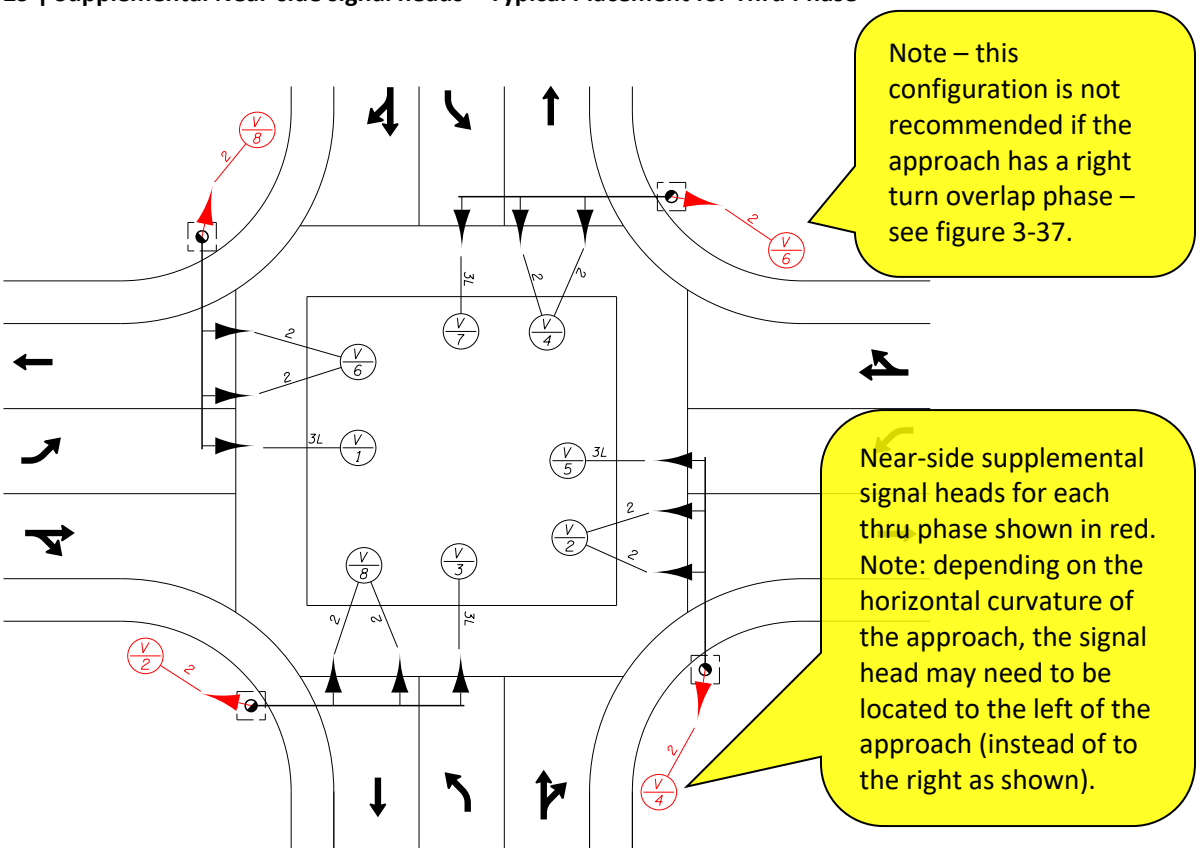



**Figure 5-30 | Supplemental Near-side signal heads – Typical Placement for Left Turn Phase**

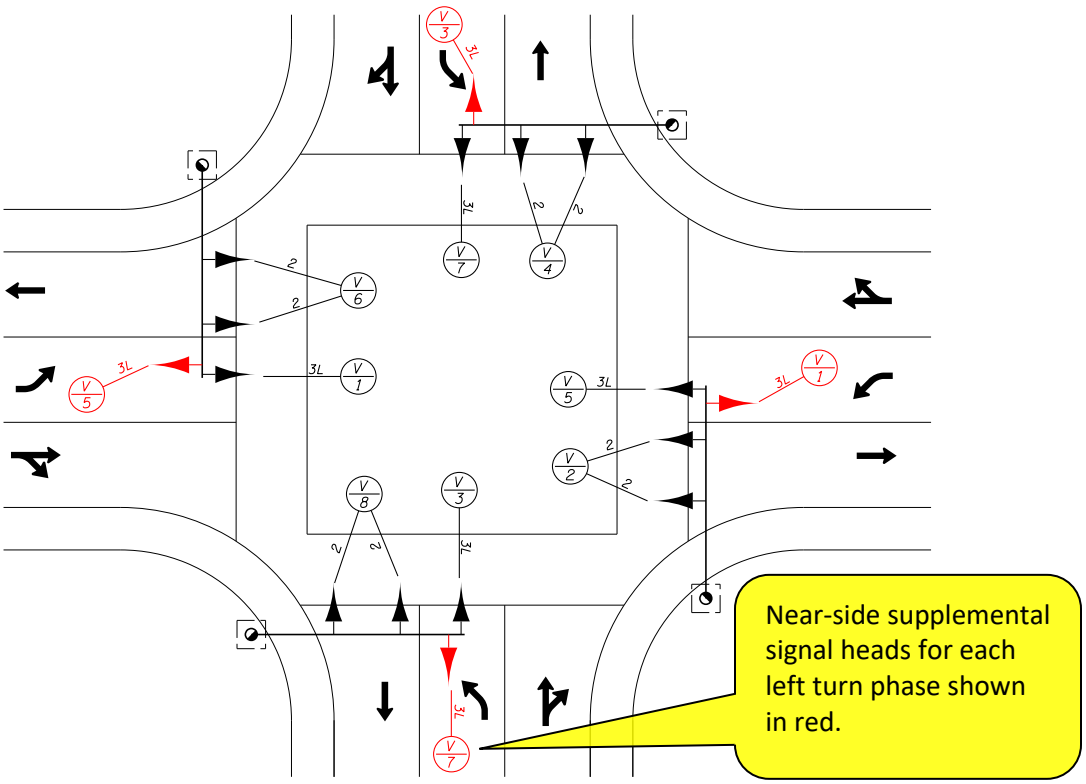


**Figure 5-31 | Supplemental Far-side signal heads – Typical Placement for Thru Phase**

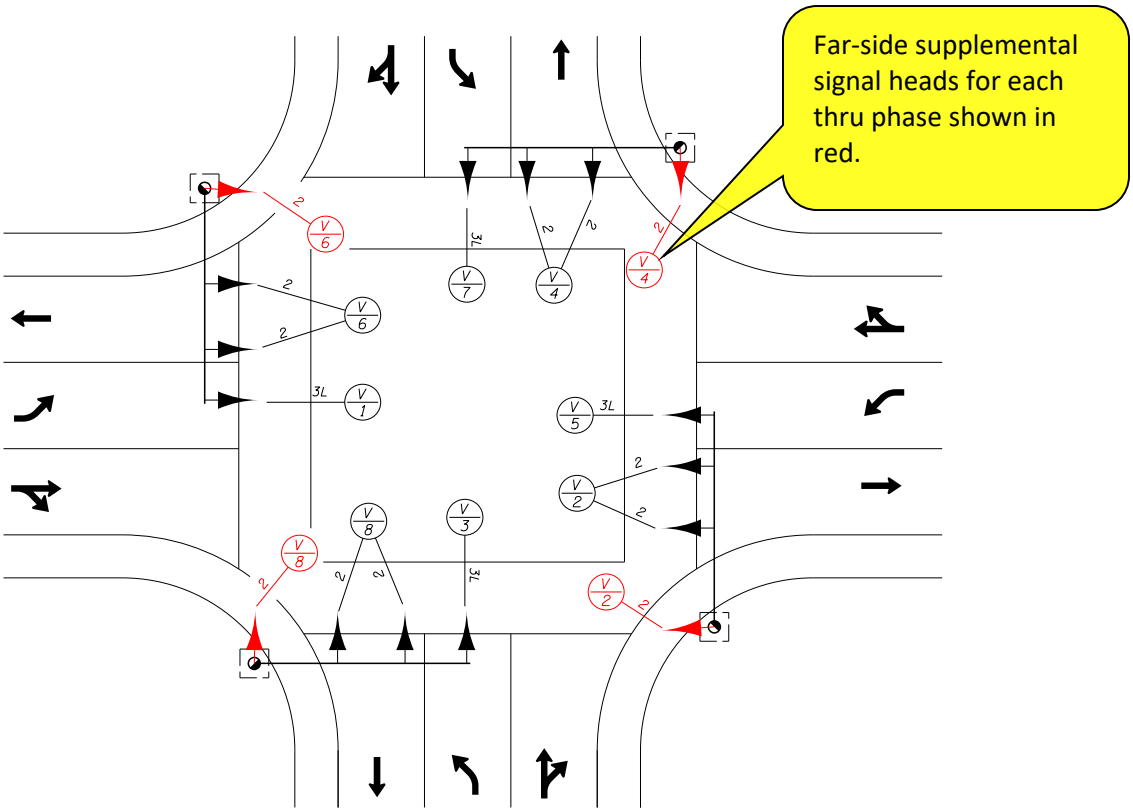
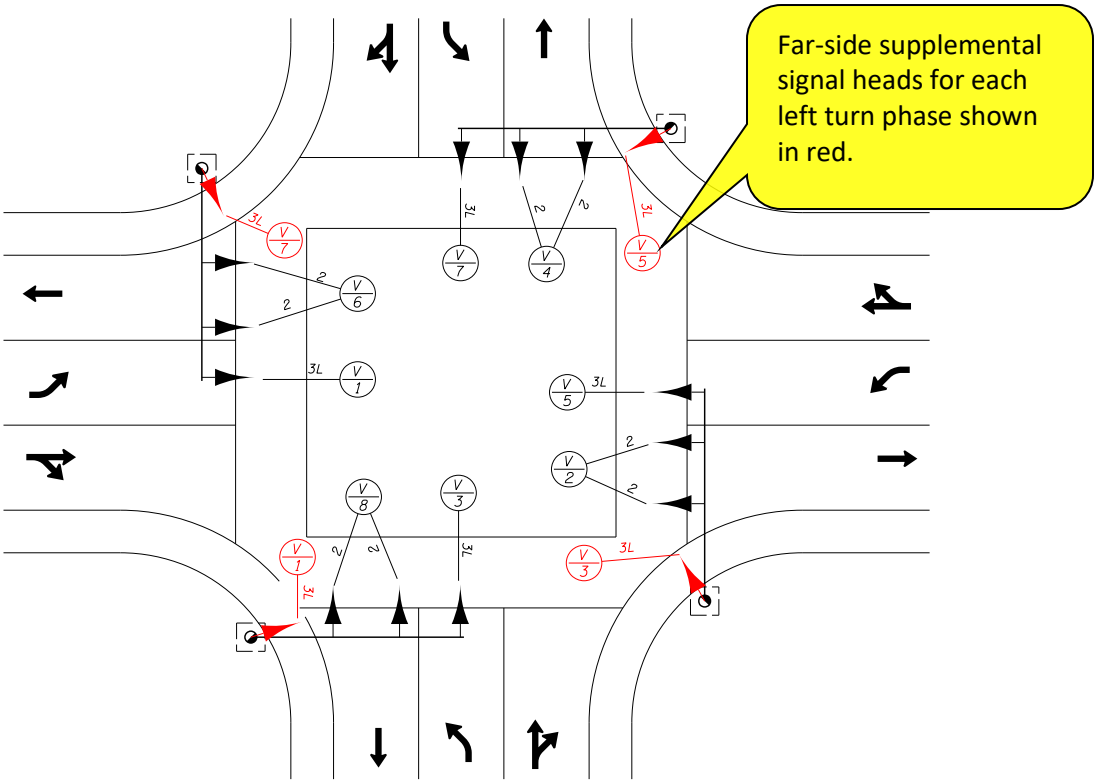



**Figure 5-32 | Supplemental Far-side signal heads – Typical Placement for Left Turn Phase**



The use and placement of supplemental heads needs to be careful considered to avoid motorist confusion. Supplemental signal heads can be very beneficial if the signal phasing and geometry allow proper placement. See Figure 5-33. However, there are situations where they should not be installed. For example, near-side supplemental heads should not be used for the right-hand side of the road for the thru movement on an approach that has a right turn only lane with overlap phasing (i.e. the right turn lane is phased differently than the thru phase). See Figure 5-34 which illustrates the potential confusion. Louvers and cut-off visors can help in some situations (see Section 5.2.5).

**Figure 5-33 | Supplemental near-side signal head placement: Example 1**

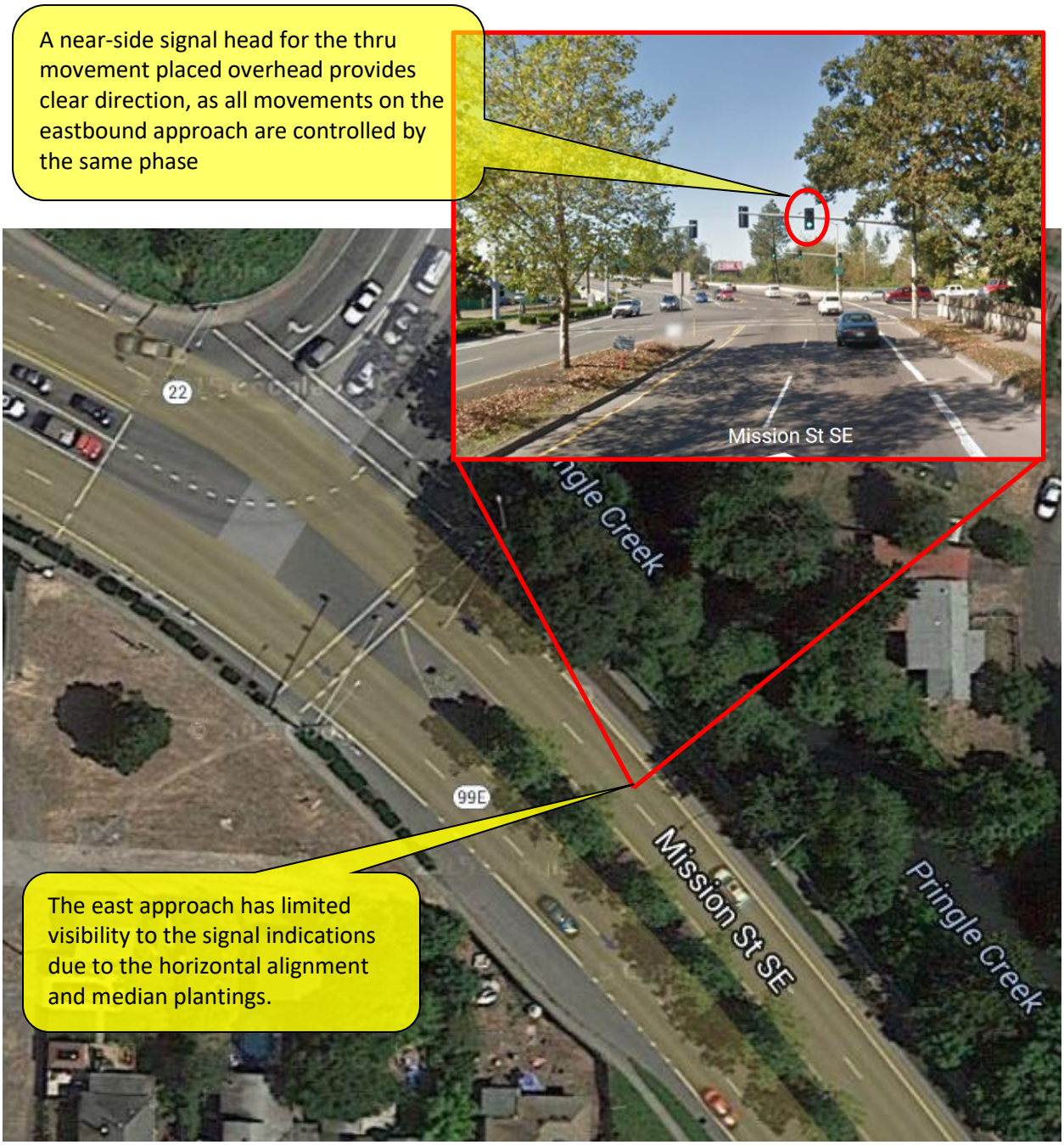
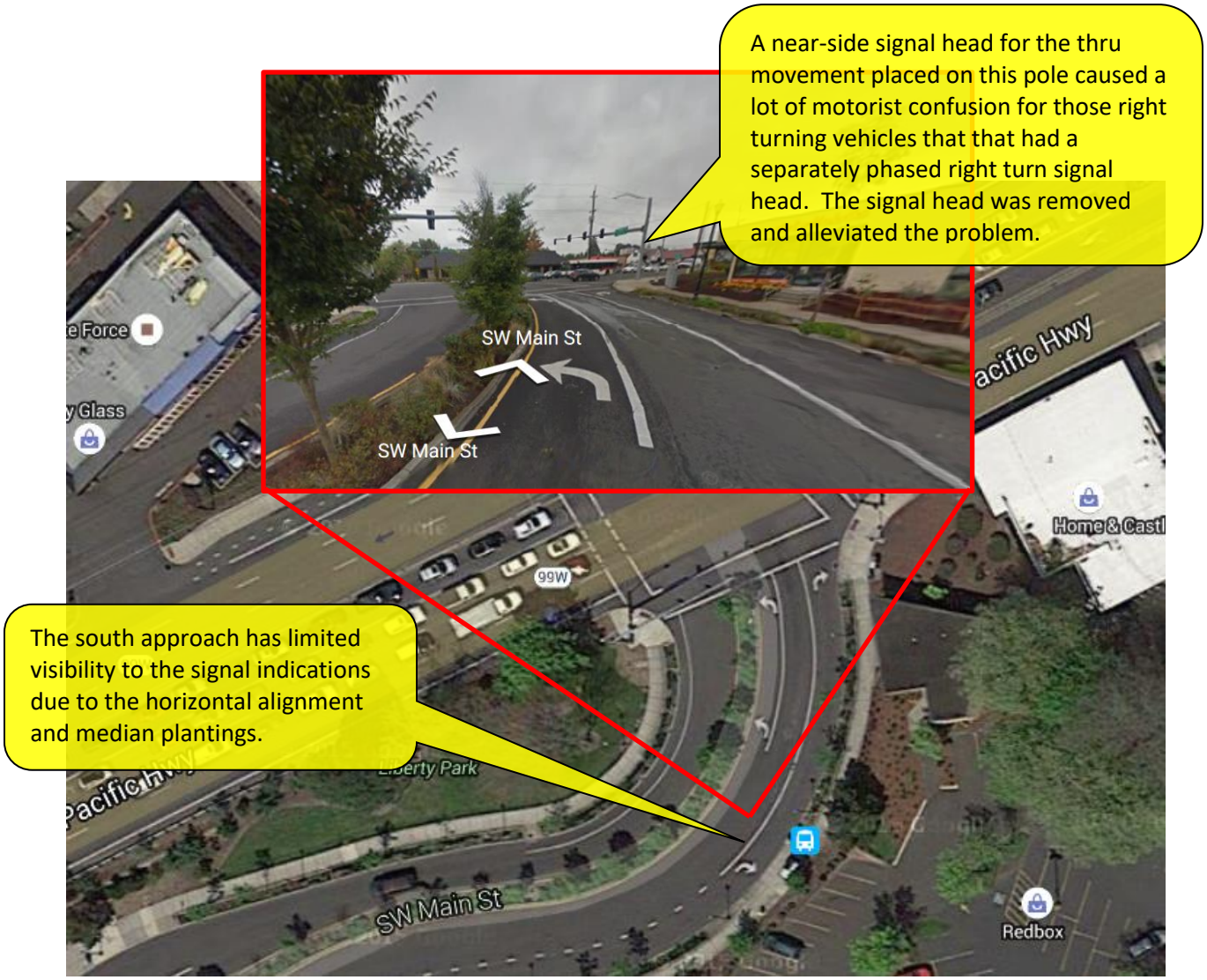
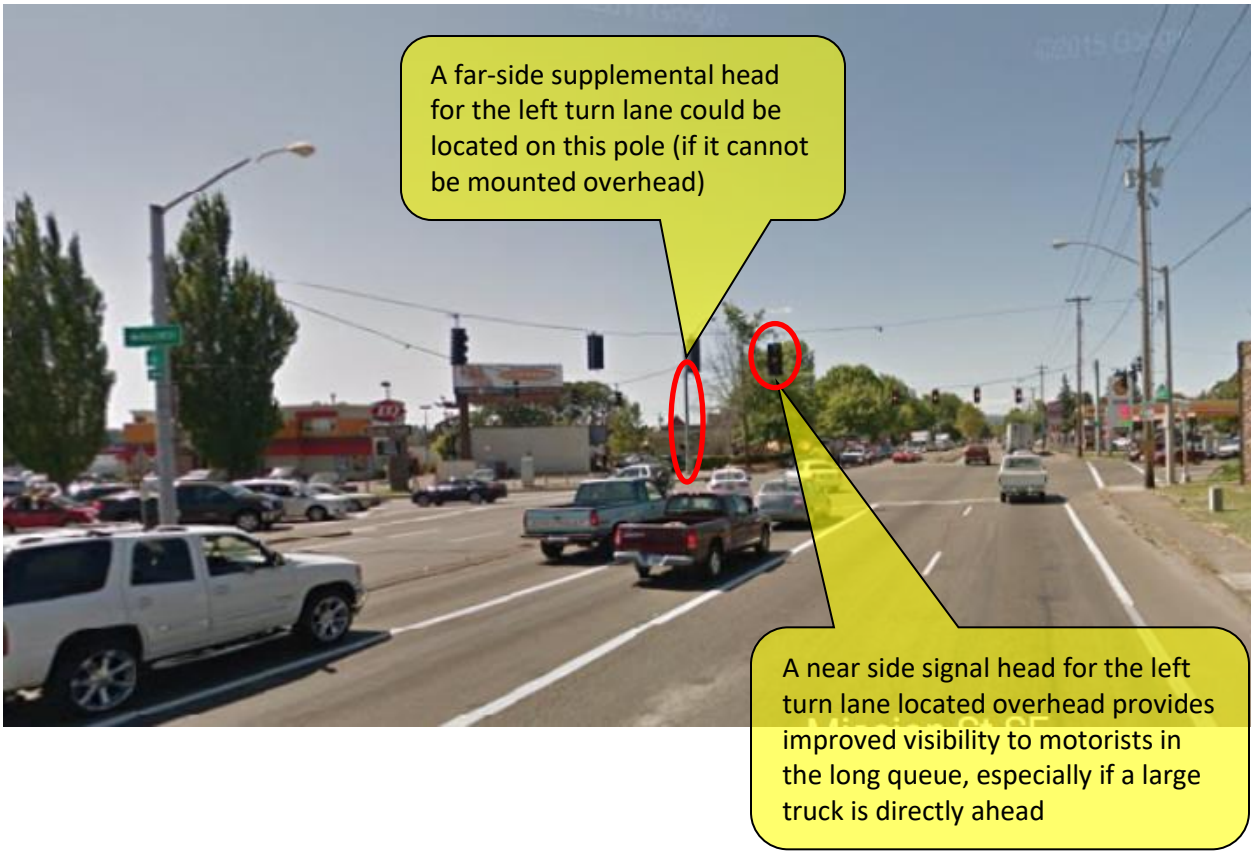


**Figure 5-34 | Supplemental near-side signal head placement: Example2**



Supplemental signal heads can help improve the operation and reduce the likelihood of red light running for minor phases under certain conditions. For example, a left turn phase that has a high volume (the phase typically maxes out rather than gaps out and has long queues) with a high volume of large trucks (cars behind the large truck have an obstructed view of the signal indications the closer you get to the intersection) can benefit from a supplemental left turn signal head located overhead (preferred) or on the far-side pole to the left of the left turn phase. See Figure 5-35.

**Figure 5-35 | Supplemental near-side signal head placement: Example 3**



Supplemental signal heads can be beneficial for locations with known sun glare issues where the east/west facing signal heads are in direct alignment with the sunrise or sunset during certain times of the year. Sun glare can make it difficult to maintain continuous visual contact with the signal indication while approaching the intersection (temporary blindness) or difficult to determine what signal indications are on or off. While current signal indication standards have helped solve the issue of sun reflection falsely "lighting up" indications that are not actually on (clear lens with only the LEDs providing the color vs. older versions indications where red/yellow/green colored lens were used with white incandescent bulbs), maintaining continuous visual contact still remains an issue. A supplemental signal head may be able to provide a better position or angle that helps direct the driver's eye away from the sun. See Figure 5-36.

**Figure 5-36 | Supplemental Signal Head Placement – Sun Glare Example**

### 5.2.4 Head Mounting

There are two approved ways to mount signal heads:

- Adjustable Bracket for attachment to a mast arm
- Spanwire Hanger for attachment to a span wire

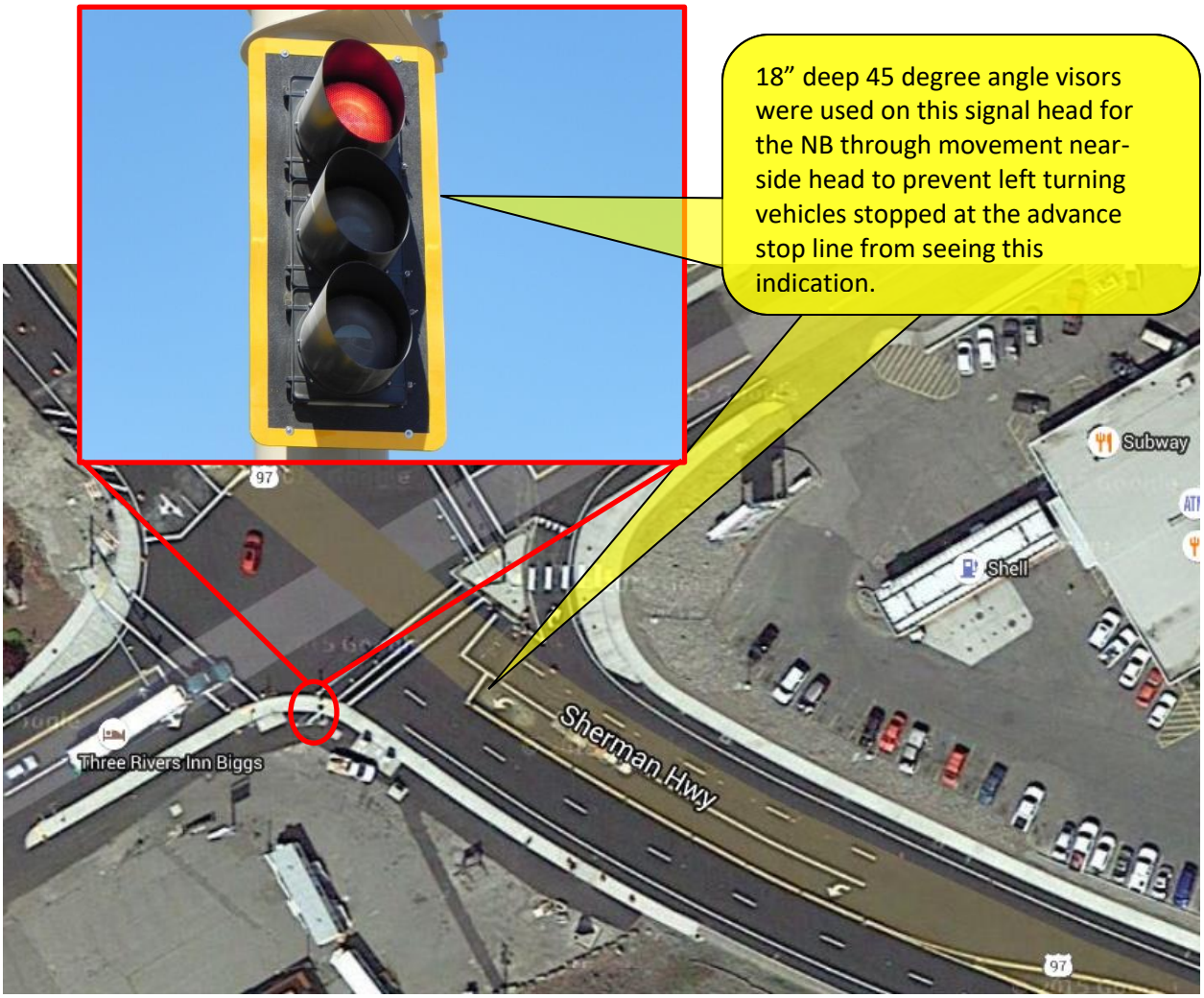
In the past, the use of plumbizers (and elevated plumbizers) to attach signal heads to mast arms was the standard, common practice. This practice required very precise control of vertical constraints, as plumbizers didn't allow much flexibility for installation. Adjustable Brackets, on the other hand, offer much more flexibility of the control of the vertical elevation.

### 5.2.5 Signal Head Louvers and Angle Visors

In situations where it is possible to view multiple conflicting phases of traffic signal indications, which may lead to motorist confusion, signal louvers and/or 18” deep 45 degree angle visors should be used. See Figure 5-37.

Programmed signal heads were used in the past, but are no longer an option.

**Figure 5-37 | Cut-off visor Example**



## 5.3 Sign Requirements and Layout

Depending on the operation of the intersection and type of signal heads used, certain signs may be required. Other signs may be recommended or optional. The following figures show common signs associated with traffic signal control. Note that positive symbol signs (i.e. "THROUGH ONLY" sign, which tells the motorist what to do) are preferred over negative word signs (i.e. "NO RIGHT TURN" sign, which tells the motorist what NOT to do).

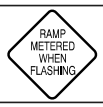
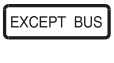
All the signs listed in Figure 5-38 and Figure 5-39 are typically shown and detailed on the signal plan sheet, NOT on the signing plan sheet.

**Note for signs mounted on signal structures: When showing and detailing design items on signal plan sheets that have the potential to also be shown and detailed in other discipline's plan sheets (e.g. Signs, Bollards, Illumination, ITS), always coordinate with the other discipline to ensure that the design item is only detailed in one plan sheet, not both. If the item is detailed in both plan sheets, it causes confusion during construction as to how the design item is paid for. This can result in paying twice for the same item or extra paperwork and time to define how the item will be paid for.**

**Figure 5-38 | Common Signs Used for Traffic Control**

| SIGN NUMBERS & SIZE (signs beginning with an "O" are Oregon specific) | SIGN TYPES: Aluminum | SIGN TYPES: Part Time Restriction | RECOMMENDED OR REQUIRED |
|---|---|---|---|
| R6-2L 30"x36" | AL 1L | | Required for one-way streets. One way signs can be installed on the mast arm (R6-2L) OR ground mounted (R6-1L). See MUTCD 2B.40(P10) |
| R6-2R 30"x36" | AL 1R | | Required for one-way streets. One way signs can be installed on the mast arm (R6-2R) OR ground mounted (R6-1R). See MUTCD 2B.40(P10) |
| R10-11A 30"x36" | AL 3 | | Region Traffic Engineer Operational Approval Required |
| OR3-12 30"x36" | AL 3U | | StateTraffic-Roadway Engineer Operational Approval Required |
| R5-2 30"x30" | AL 3T | | StateTraffic-Roadway Engineer Operational Approval Required (typically used in conjuction with U-turn permitted sign) |
| OR3-5TD 30"x36" | AL 4 | | |
| R3-6L 30"x36" | AL 4L | | |
| R3-6R 30"x36" | AL 4R | | |
| OR3-5TT 30"x36" | AL 4T | | |
| R3-5L 30"x36" | AL 5L | | Required for a trap lane (where a through lane becomes a mandatory turn lane at the intersection) if the trap lane does not have a signal head with arrow indications |
| R3-5R 30"x36" | AL 5R | | Required for a trap lane (where a through lane becomes a mandatory turn lane at the intersection) if the trap lane does not have a signal head with arrow indications |
| R3-5A 30"x36" | AL 5T | | |
| R3-3 36"x36" | AL 6 | | Use of appropriate lane use signs is preferred over R3-3 |

**Figure 5-39 | Common Signs Used for Traffic Control (Cont.)**

| SIGN NUMBERS & SIZE (signs begining with an "O" are oregon specific) | SIGN TYPES: Aluminum | SIGN TYPES: Part Time Restriction | RECOMMENDED OR REQUIRED |
|---|---|---|---|
| R3-2 36"x36" | AL 6L | PR 6L | Use of appropriate lane use signs is preferred over R3-2. PTR version used for RxR applications |
| R3-1 36"x36" | AL 6R | PR 6R | Use of appropriate lane use signs is preferred over R3-1. PTR version used for RxR applications |
| R5-1 36"x36" | AL 7 | | |
| R10-28 24"x30" | AL 8 | | For overhead mounting |
| OR20-1 24"x12" | AL 8s | | |
| R10-6 24"x36" | AL 9 | | |
| R10-12 30"x36" | AL 11 | | Required with a Type 4L signal head. Recommended when a permissive left turn phase has an exclusive left turn lane. Optional otherwise. |
| OR10-15 30"x36" | AL 12 | | Required with a Type 5 signal head |
| W3-8 36"x36"   | AL 16 | | |
| OR20-5 24"x30" | AL 17 | | |
| W3-4 36"x36" | AL 18 | | |
| W16-13p 24"x18" | AL 19 | | |
| OR3-7a 30"x9"   | AL 20 | | |

### 5.3.1 Layout of Regulatory Signs

Regulatory signs installed on mast arms or span wires should either be located near the signal head that they apply to or centered within the lane that they apply to. For example, the "TURNING VEHICLES YIELD TO PEDS" sign should be placed near the right turn signal head and the "LEFT TURN YIELD ON green ball" sign should be centered within the left turn lane. When placing signs next to signal heads, they will need to be a minimum of 3 feet apart (measured for the center of the signal head to the center of the sign). This accommodates placement of a standard regulatory sign next to all signal indications except for a type 4L (doghouse) head. If placing a sign next to a type 4L head, the sign needs to be a minimum of 4 feet apart.

In the situation where the signal head and the sign should both be centered over the lane (i.e. three through lanes each with a "THROUGH ONLY" sign), the location of the signal head takes precedence (center over lane) and the sign should be located just to the left or right of the signal head. The message on sign will help determine which side of the signal head to place it on. For example, in the left-most through only lane, the "THROUGH ONLY" sign would be more beneficial if placed to the left of the signal head where it is more in the motorist's line of sight if they attempt to make an incorrect left turn. In the right-most through only lane, the "THROUGH ONLY" sign would be more beneficial if placed to the right of signal head for the same reason. In the center through only lane, the placement of the sign to the left or right of signal head would both be equally beneficial.

Occasionally, there are times when two regulatory signs may be desired for one lane. For example, an exclusive right turn lane with a type 5 signal head; The "RIGHT TURN YIELD TO PEDS ON green ball" sign is required and the "RIGHT TURN ONLY" sign may also be appropriate to install. In this case, it is recommended to install one sign to the left of the signal head and one sign to the right of the signal head.

Some signs are applicable to all lanes of traffic, such as the "ONE WAY" signs. In this case, the sign should be placed in the location where the information would be the most critical. For example, on a three lane approach where a "ONE WAY left arrow" sign is required, the location where this information is most critical is the right-most travel lane (of the three approach lanes, a motorist in the right-most lane is most likely to make wrong-way movement).

For large and/or complex intersections, locating the appropriate signing can sometimes be challenging and ideal spacing and location of signs and signal heads may not always be achievable. In these cases, aligning all of the necessary equipment becomes a bit of an art, but the final product should broadcast clear, unmistakable information to the approaching motorist.

### 5.3.2 Street Name Signs and Guide Signs (Custom Designed Signs)

Street name signs and guide signs are custom designed signs (vs. standard MUTCD regulatory signs). Custom designed signs that are mounted to signal poles, mast arms or span wires are detailed on a separate sign plan sheet and only referenced on the signal plan sheet (see the ODOT Traffic Signal Drafting Guide for how to reference custom signs). Custom signs are NOT part of the lump sum traffic signal bid item; they are paid for under the signing bid items (type of sign by the square foot and sign mount type).

Street name signs are required at each intersection, for each approach leg. The standard location for the street name sign is on the mast arm or span wire. If possible, the street name sign should be the sign located closest to the signal pole. All other appurtenances on the mast arm should be located to the left of the street name sign.

Standard signal pole design, as per Standard Drawings TM650 and TM660, allows a maximum street name sign area of 21 square feet (mounted on the mast arm or span wire) and a maximum guide sign of 60 square feet (mounted on the signal pole). Always verify the size of custom signs to ensure they do not exceed the maximum dimensions. If a sign does exceed the maximum dimensions, there are a couple of solutions that can work (listed in order of preference):

1. Contact the sign designer and request a re-design of the sign to fall within maximum dimensions.
2. Ground mount the sign near the signal pole
3. Contact the Traffic Structures Engineer and request an analysis/recommendation for the oversized sign. A non-standard signal pole (SMX) will likely be required.

### 5.3.3 Part Time Restriction Signs (PTR)

Part Time Restriction (PTR) signs are sometimes used depending on the desired operation (see the operational approval). PTR signs are electronic signs that appear black (blank-out) when not in use and display text/symbols when in use. The most common applications for use of a PTR sign includes signals with railroad/light rail preemption. Other unique applications include restricting turning movements by time-of-day/day-of-week or during certain portions of the signal phasing.

### 5.3.4 Materials and Mounting

The standard material for small signs mounted on signal structures (poles, mast arms, span wires, pedestals) is sheet aluminum. Extruded aluminum is used for larger signs. In the past, interior illuminated signs were used on signal installations due to the poor performance of sign sheeting when signs were mounted overhead. However, with the vast improvement of modern sign sheetings, coupled with the effort to be more energy efficient, interior illumination is no longer necessary or desirable. Modern sign sheetings are extremely effective and visible when mounted overhead and do not have

the extra maintenance and power costs that are associated with interior illuminated signs.

There are two approved ways to mount signs:

- Adjustable Bracket for attachment to a mast arm
- Spanwire Hanger for attachment to a span wire

## 5.4 Pedestrian Signal Equipment Layout

Pedestrian signal equipment location is guided by the Manual on Uniform Traffic Control Devices (MUTCD), the Oregon Supplements to the MUTCD, Americans with Disabilities Act Accessibility Guidelines (ADAAG), and Public Rights of Way Accessibility Guidelines (PROWAG). It should be determined in conjunction with the curb ramp and crosswalk layout. This is an iterative process, typically requiring adjustments of each feature (i.e. curb ramp, crosswalk, and pedestrian equipment) to achieve the best possible design. This process should coordinated with the Roadway Designer and be done early in the design process (i.e. DAP plans) so that right-of-way needs can be addressed in a timely manner.

If raised medians are present, additional pushbuttons and/or pedestrian signal equipment may be required depending on the configuration of the median and the crosswalk. See Section 5.1.5 for requirements.

### 5.4.1 Use of Pedestrian Detection

Pedestrian detection is required for all crosswalks except when the pedestrian phase will be recalled at all times. Pedestrian recalled phases are common in central business districts.

### 5.4.2 Pushbutton Requirements

Pushbuttons shall meet the following criteria. Note: A Roadway Design Exception is required if unable to meet any of these requirements. Contact Roadway Designer for assistance.

- Horizontal reach to the pushbutton shall be 10 inches maximum. See Figure 5-40.
    - Pedestal cannot be located behind a curb. See Figure 5-42.
- Clear Space to access the pushbutton shall be within the 10 inch horizontal reach and unobstructed. The Clear Space is 30”x48” for a parallel approach or 36”x48” for a head-in/back-in maneuver with a maximum design slope of 1.5% (Max. 2.0% finished slope surface). See Figure 5-40 and Figure 5-45 thru Figure 5-51.
    - Pedestal foundation shall be installed on a level surface (1.5% max. design slope, max. 2.0% finished slope surface). See Figure 5-43 and Figure 5-44.
- Turning Space is 4.5’ x 5.5’ (Signal Equipment is an obstruction). See Figure 5-54.
- Vertical reach to the pushbutton is 36” to 48” from the adjacent finish grade. See Figure 5-55 and Figure 5-56.

Pushbuttons should meet the following criteria:

- Mounted on a pedestrian pedestal or pushbutton post
- 15 feet maximum from the pushbutton to the edge of the ramp. See Figure 5-57.
- 8 foot minimum separation between buttons (i.e. one pushbutton per pedestal). Note this criterion doesn’t apply to (See Section 5.4.6):
    - Diagonal ramps allowed by Design Exception
    - Two ramps that share a single turning space

### 5.4.3 Deviations from Pushbutton Location Requirements

Meeting all of the criteria listed in Section 5.4.2 may be impossible at certain locations and compromises in the design will need to be made. The "shall" criteria are the highest priorities and should be met before attempting to meet any other criteria, as not meeting these criteria requires a roadway design exception. The "should" criteria, while important, are a lower priority and can usually be acceptably mitigated by the deviations discussed in Sections 5.4.5, 5.4.6, and 5.4.7.

If unable to meet any of the above listed criteria in Section 5.4.2, deviations may be considered. Common deviations are listed below. Any deviations require approval of the State Traffic Signal Engineer during the Design Approval process.

- Pushbutton mounted on a large pole. See Section 5.4.5.
- Two pushbuttons per pedestal/pole (note: this is the preferred solution for diagonal ramps and two ramps that share a single turning space). See Section 5.4.6.
- Use of an extension bracket mount. See Section 5.4.7.

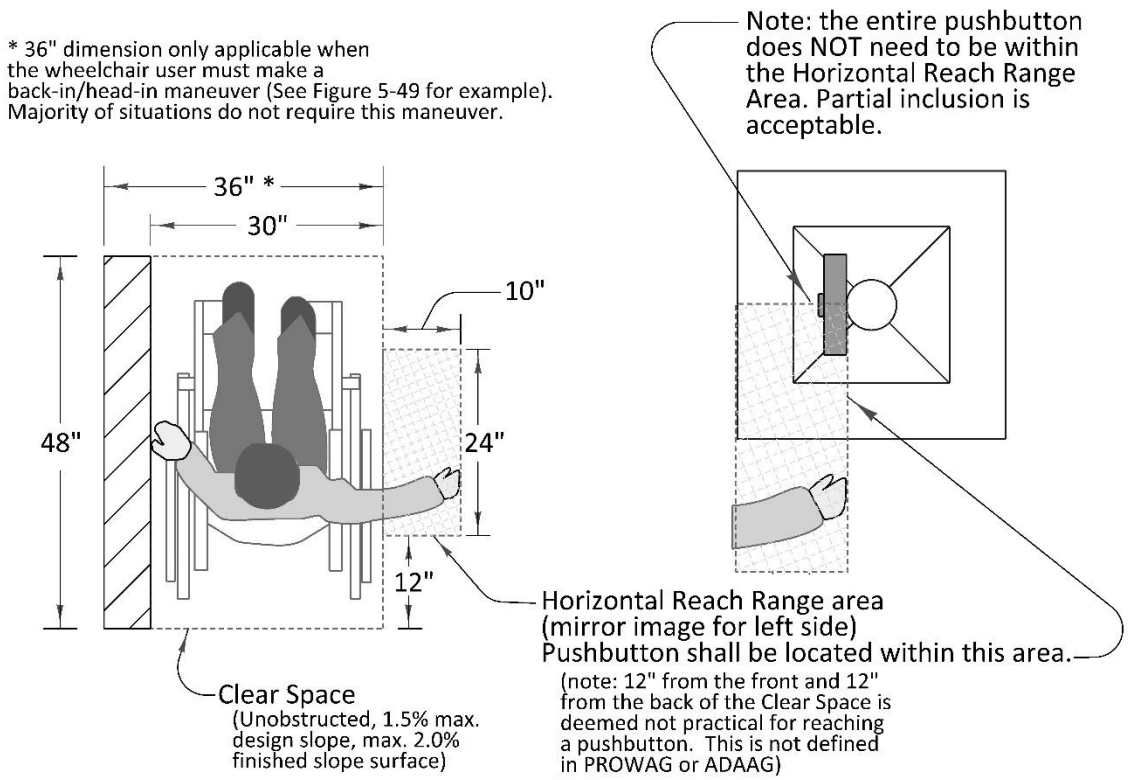
### 5.4.4 Verifying Pushbutton Requirements

Pushbuttons are mounted with the face of the pushbutton parallel to crosswalk it serves (it should be in-line with the crosswalk striping). It can be mounted on either side of the post as long as all the requirements in Section 5.4.2 are met.

During design, the horizontal reach and Clear Space requirements for the pushbutton should be verified using the "Design Vehicle" (i.e. a wheelchair user) in CADD. See Figure 5-40. The design vehicle should be simulated for each pushbutton in both approach directions. The results of each simulation shall accompany the plan sheets when submitted to the State Traffic Signal Engineer for Design Approval.

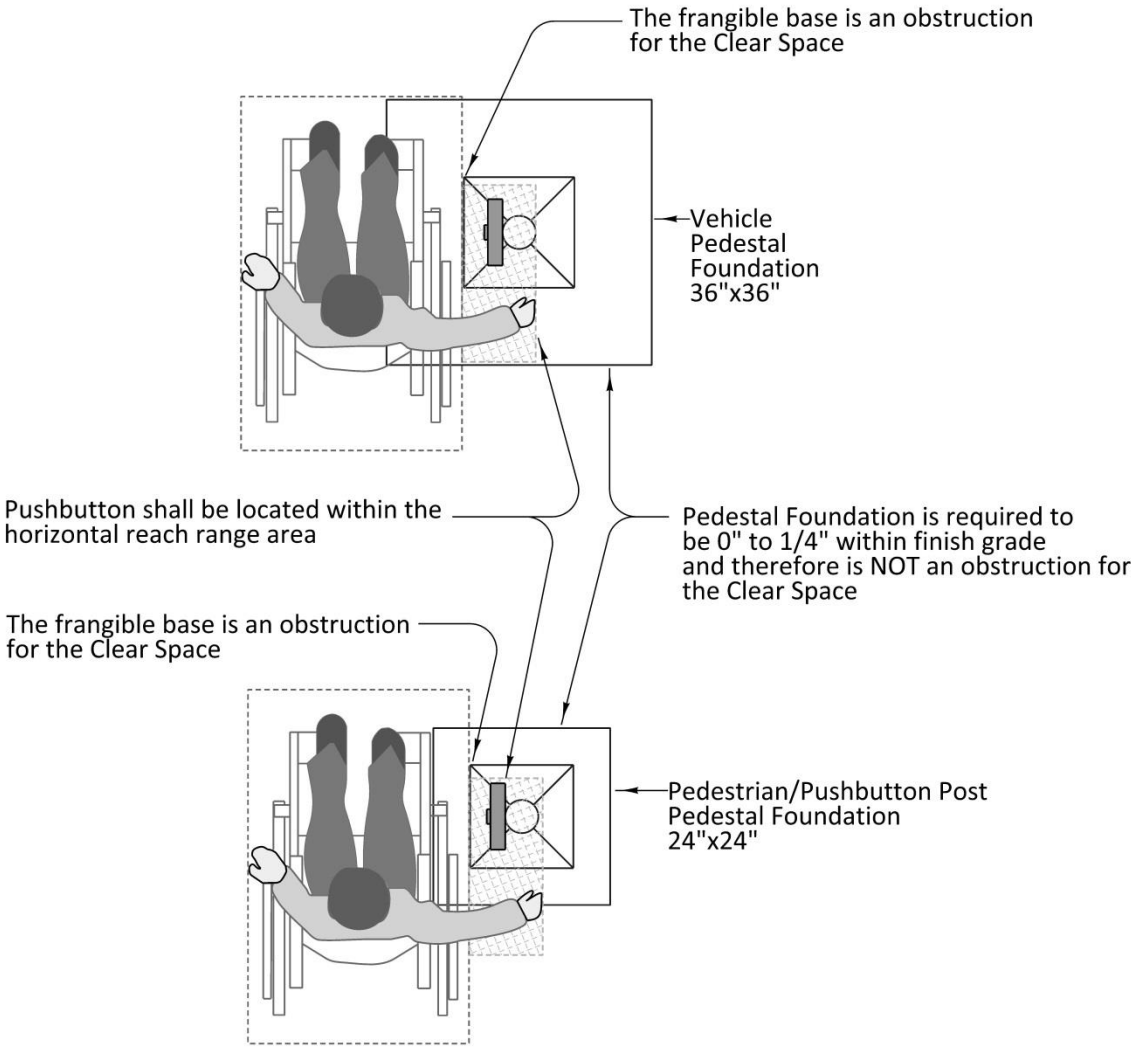
An obstruction to the Clear Space is defined as any vertical difference that is greater than ¼" or any slope that is designed at greater than 1.5% (Maximum 2.0% finished slope surface). When running simulations at each pushbutton, the Clear Space shall be unobstructed.

**Figure 5-40 | Design Vehicle (Clear Space with 10" Max Horizontal Reach)**



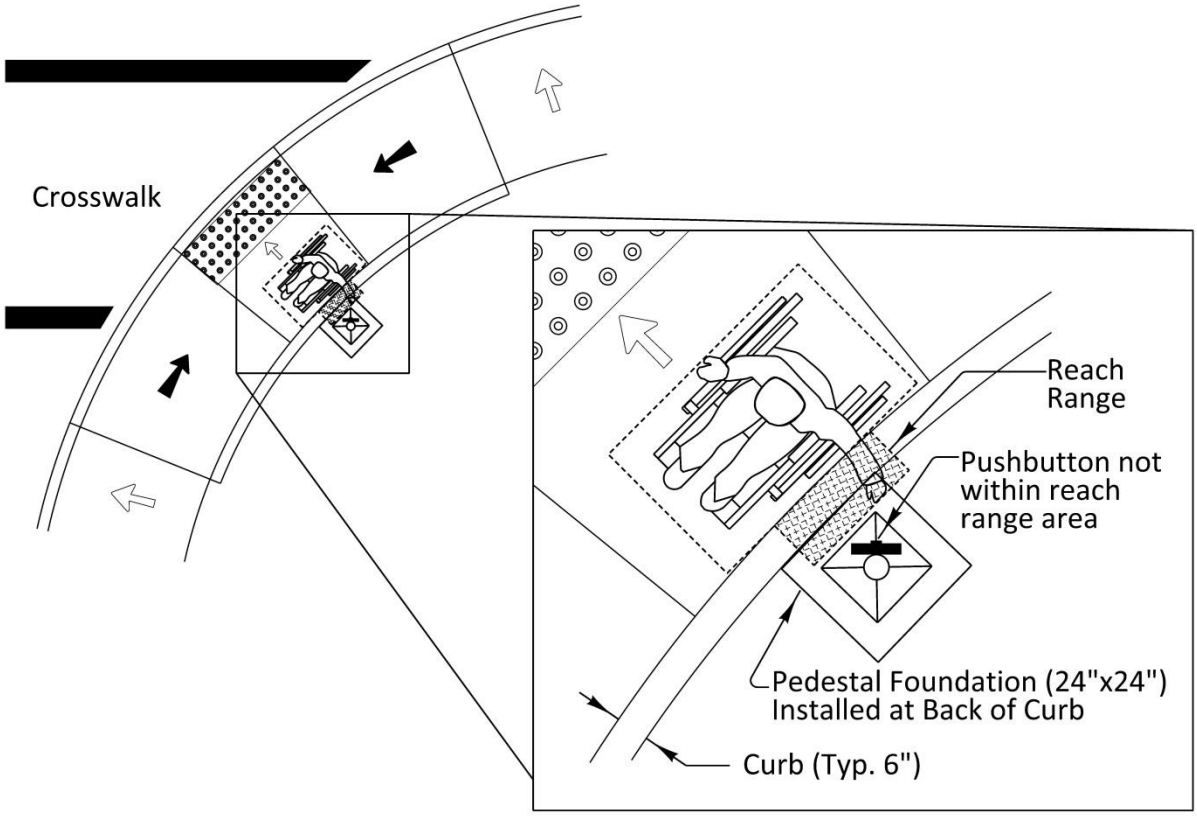
The horizontal reach is measured from the obstruction to the pushbutton. For a pedestrian pedestal or pushbutton post, the obstruction is the edge of the frangible base. The foundation edge is not considered an obstruction as standard drawing TM457 requires the top of foundation to be flush with finish grade (0” to ¼” vertical tolerance). See Figure 5-41.

**Figure 5-41 | Measuring Horizontal Reach to Pushbutton Mounted on Pedestal**



The 10 inch horizontal reach eliminates the placement of the pedestal behind curbs. Curbs are typically 6 inches wide and with a standard construction of the foundation against the back-of-curb, the horizontal reach becomes approximately 13 inches. See Figure 5-42. While it may be possible to integrate the pedestal foundation with the curb installation to achieve the 10 inch horizontal reach, is not recommended due to the increased the complexity of construction (requires custom design details and excellent coordination and cooperation between subcontractors).

**Figure 5-42 | Pedestals Located Behind Curbs Do NOT Meet 10 Inch Horizontal Reach Requirement**



Pedestal foundations must be placed on a level surface (1.5% max. design slope) in order to meet the requirements for the 10 inch horizontal reach and Clear Space. See Figure 5-43. Do not place a pedestal foundation across more than one plane. See Figure 5-44.

**Figure 5-43 | Pedestal Foundation Placement – Example 1**

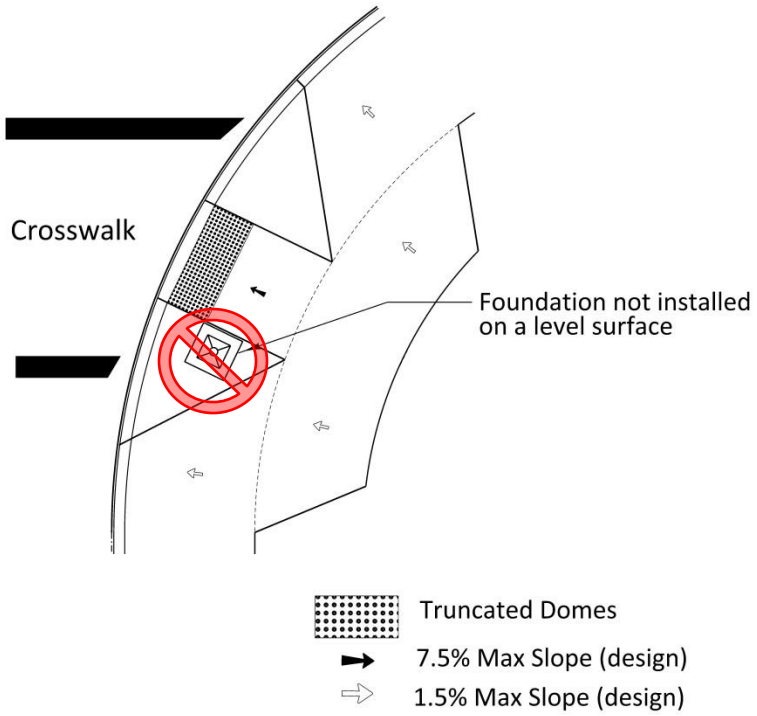
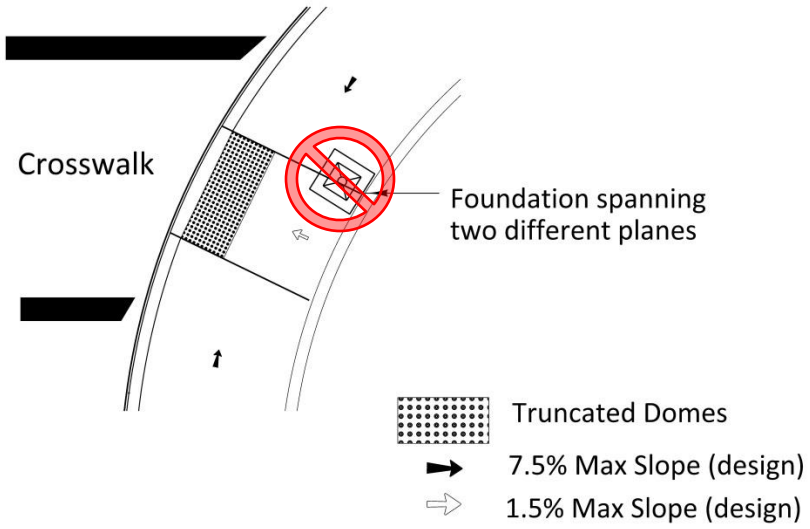



**Figure 5-44 | Pedestal Foundation Placement – Example 2**

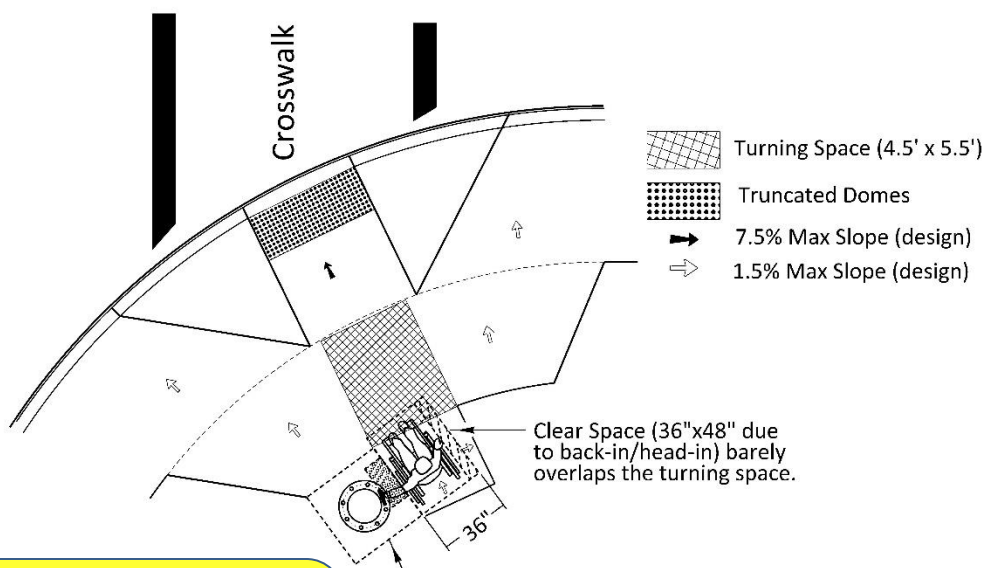


The Clear Space is the area defined as being level (having a maximum design slope of 1.5% or less) and is 30”x48” for a typical parallel approach. If the wheelchair user has to back-in/head-in to access the pushbutton, the clear space requirement becomes a little larger: 36”x48”. Typically the only time a wheelchair user will have to back-in/head-in is when the pushbutton is located on a large pole at perpendicular style ramp. See Figure 5-45. Due to the additional effort required for a back-in/head-in maneuver, ramp design and pushbutton locations that require this maneuver should be avoided.

The ramp Turning Space (with an obstruction at back-of-walk, such as pedestal or signal pole) is defined as the 4.5’x 5.5’ unobstructed area located in front of the ramp, with the longer dimension towards the ramp. The Clear Space and Turning Space are independent of each other; they may coincide, overlap, or not touch depending on the ramp type and geometrics. **The ideal pushbutton location occurs when the Turning Space and Clear Space coincide or have a large overlap for the following reasons:**

- The path the Wheelchair user takes to push the button and use the curb ramp is the most direct path
- The pushbutton location is more likely to meet the other ODOT and MUTCD Section 4E.08 criteria (i.e. distance from crosswalk: See Figure 5-70, distance from edge of curb ramp: see Figure 5-57, etc.)
- Typically easier to meet the sidewalk and curb ramp slope requirements

**Figure 5-45 | Turning and Clear Space – Back-in/Head-in Maneuver Required**




Note: Back-in/Head-in maneuvers should be avoided. See Section 5.4.5 for more info on mounting pushbuttons on large poles.

Figure 5-46 through Figure 5-48 show pushbutton placement examples for a parallel approach that meets the "Shall" requirements for horizontal reach and Clear Space for the three standard types of ramps (Perpendicular, Parallel, and Combo), while also showing how the Clear Space and turning space relate to each other.

**Figure 5-46 | Turning and Clear Space – Perpendicular Ramp (Parallel Approach)**

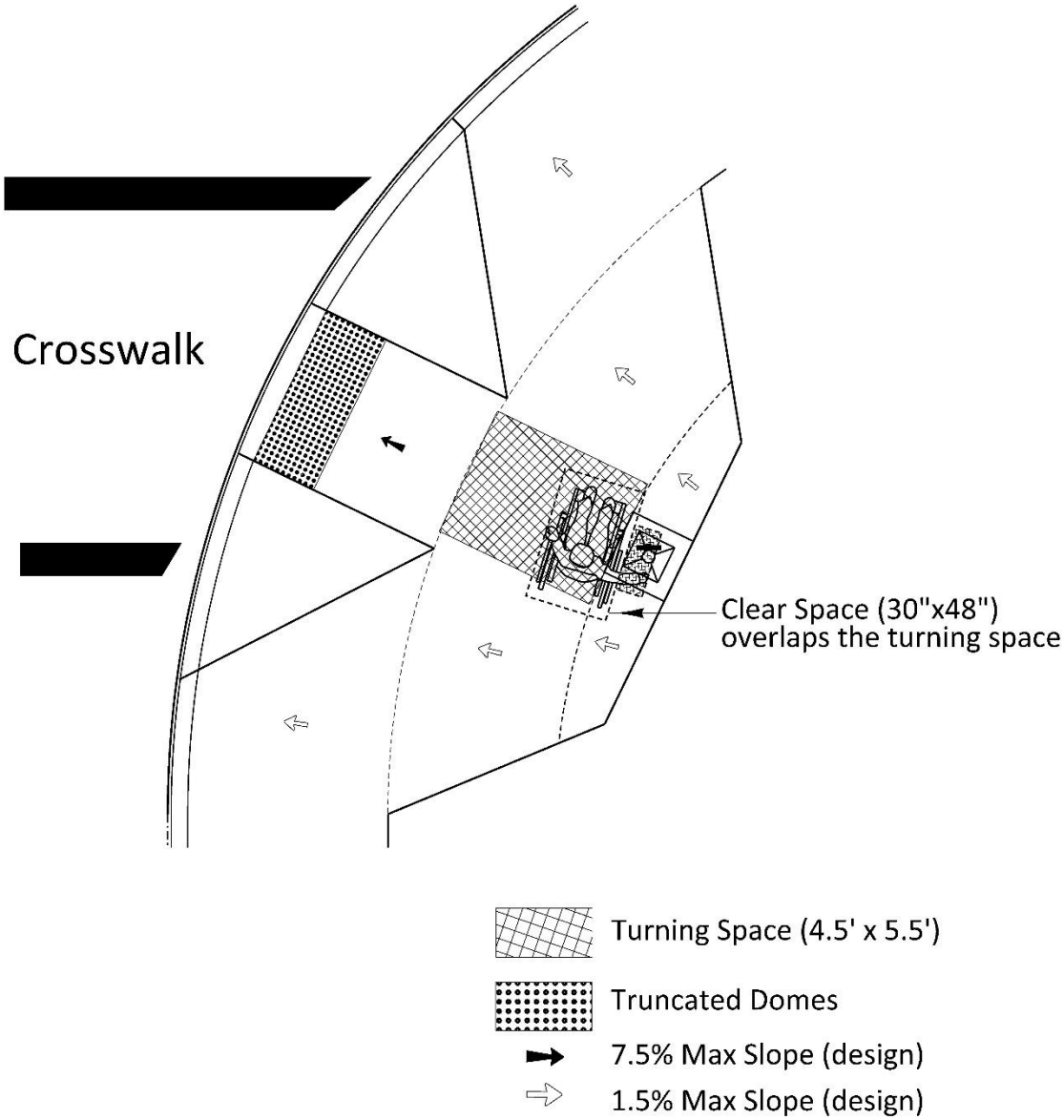


**Figure 5-47 | Turning and Clear Space – Parallel Ramp (Parallel Approach)**

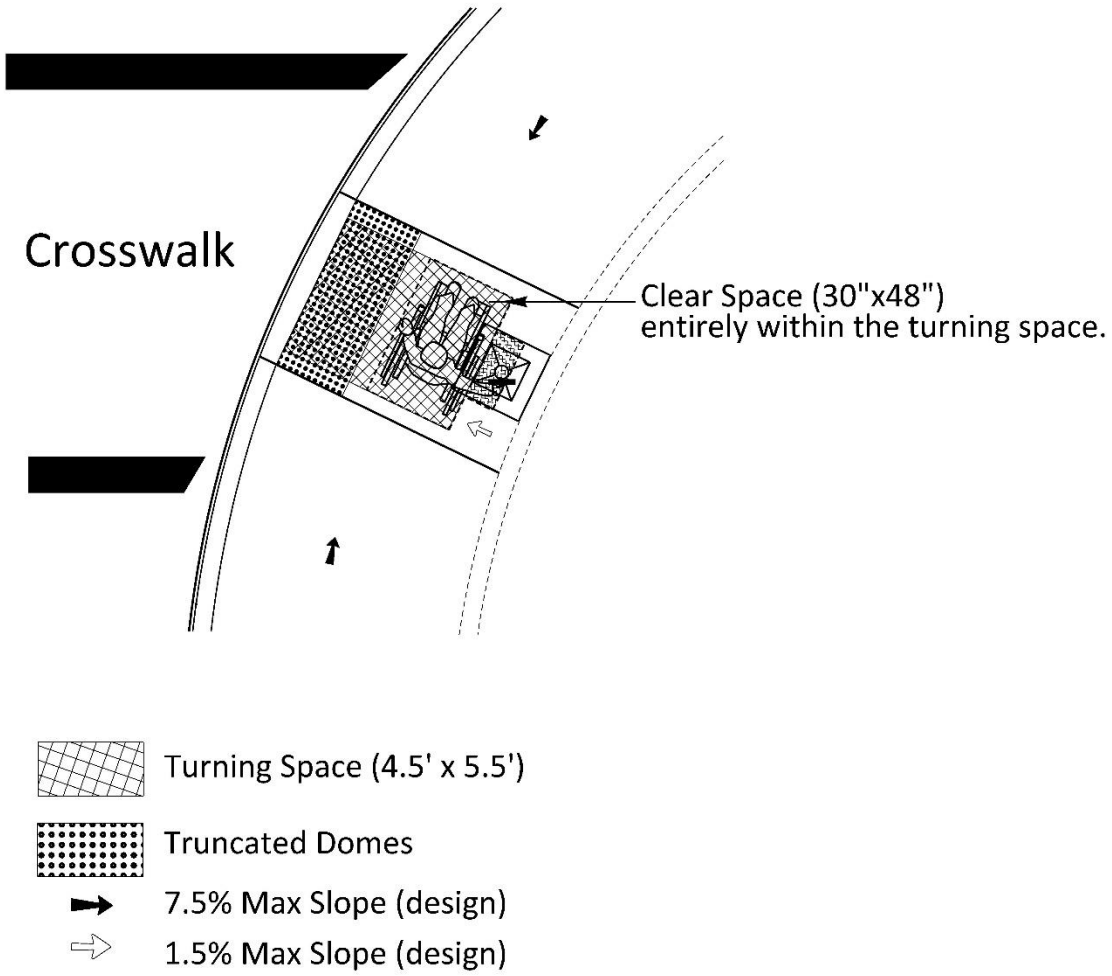
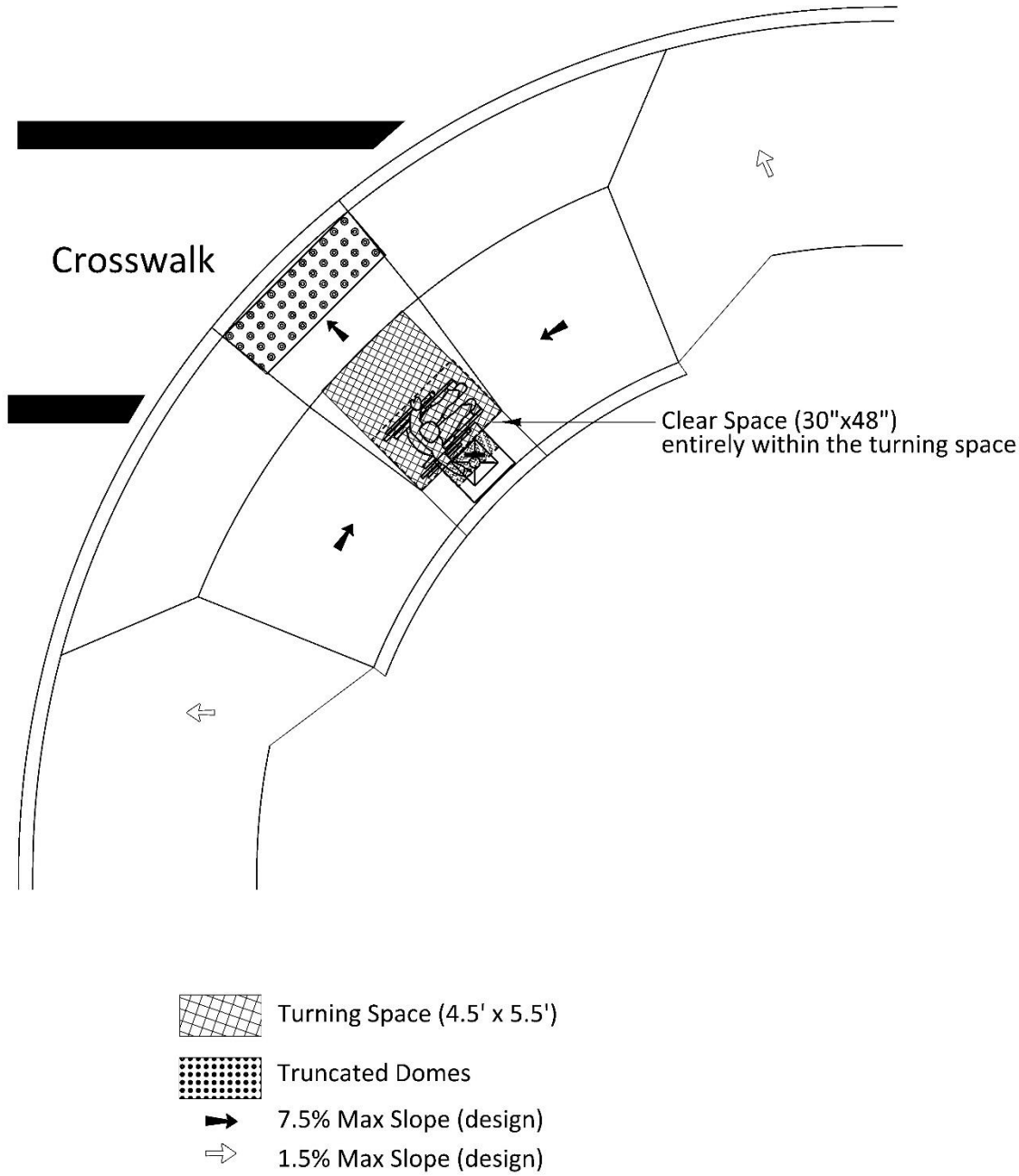


**Figure 5-48 | Turning and Clear Space – Combo Ramp (Parallel Approach)**



When a wheelchair user is accessing the pushbutton, the Clear Space (30”x48” or 36”x48” as required) cannot be located within any surface that has a designed slope greater than 1.5% (max. 2.0% finished slope surface). See Figure 5-49 through Figure 5-51.

**Figure 5-49 | Accessing the Pushbutton – Clear Space within 1.5% Slope (design), Example 1**

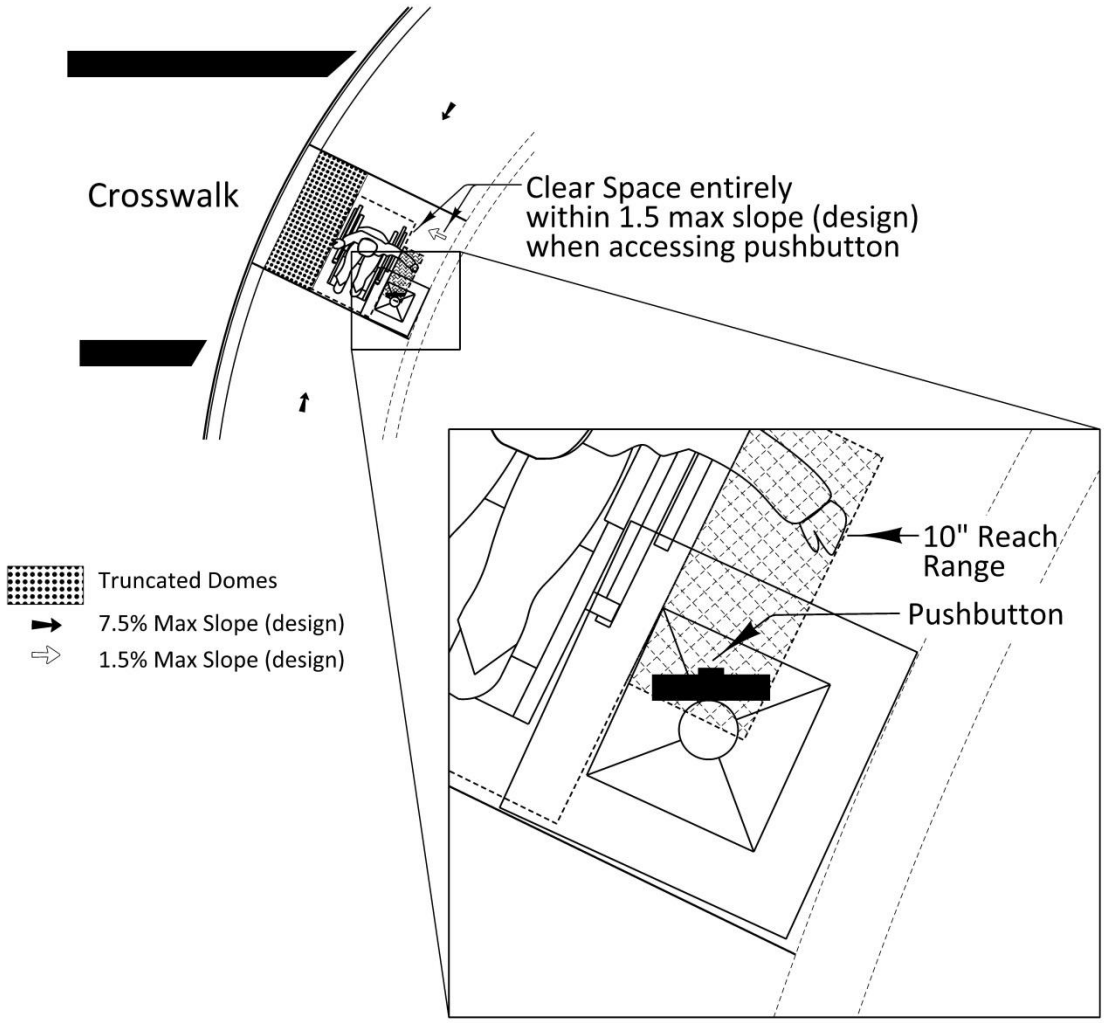


**Figure 5-50 | Accessing the Pushbutton – Clear Space within 1.5% Slope (design), Example 2**

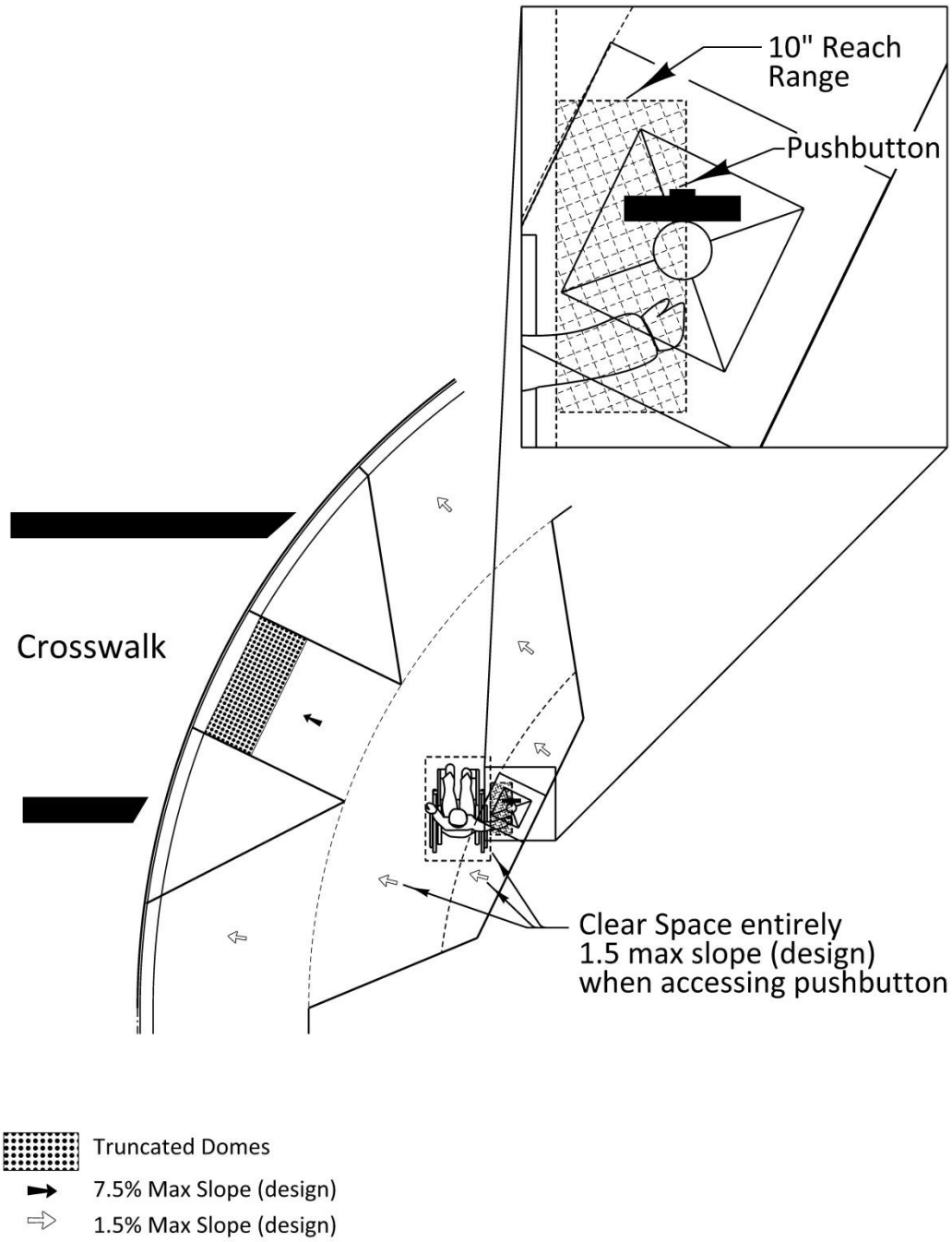
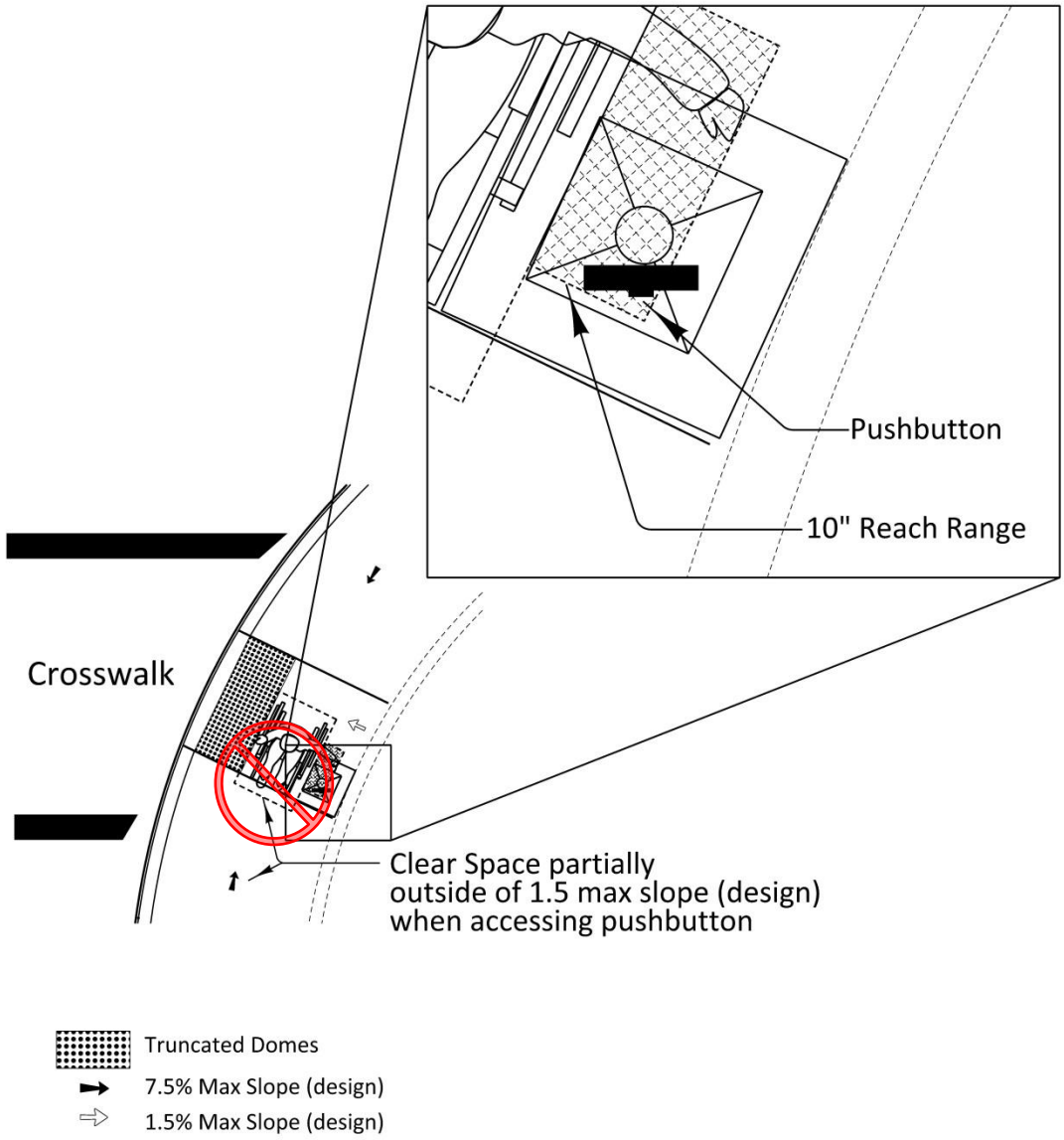


**Figure 5-51 | Accessing the Pushbutton – Clear Space NOT within 1.5% Slope (design)**

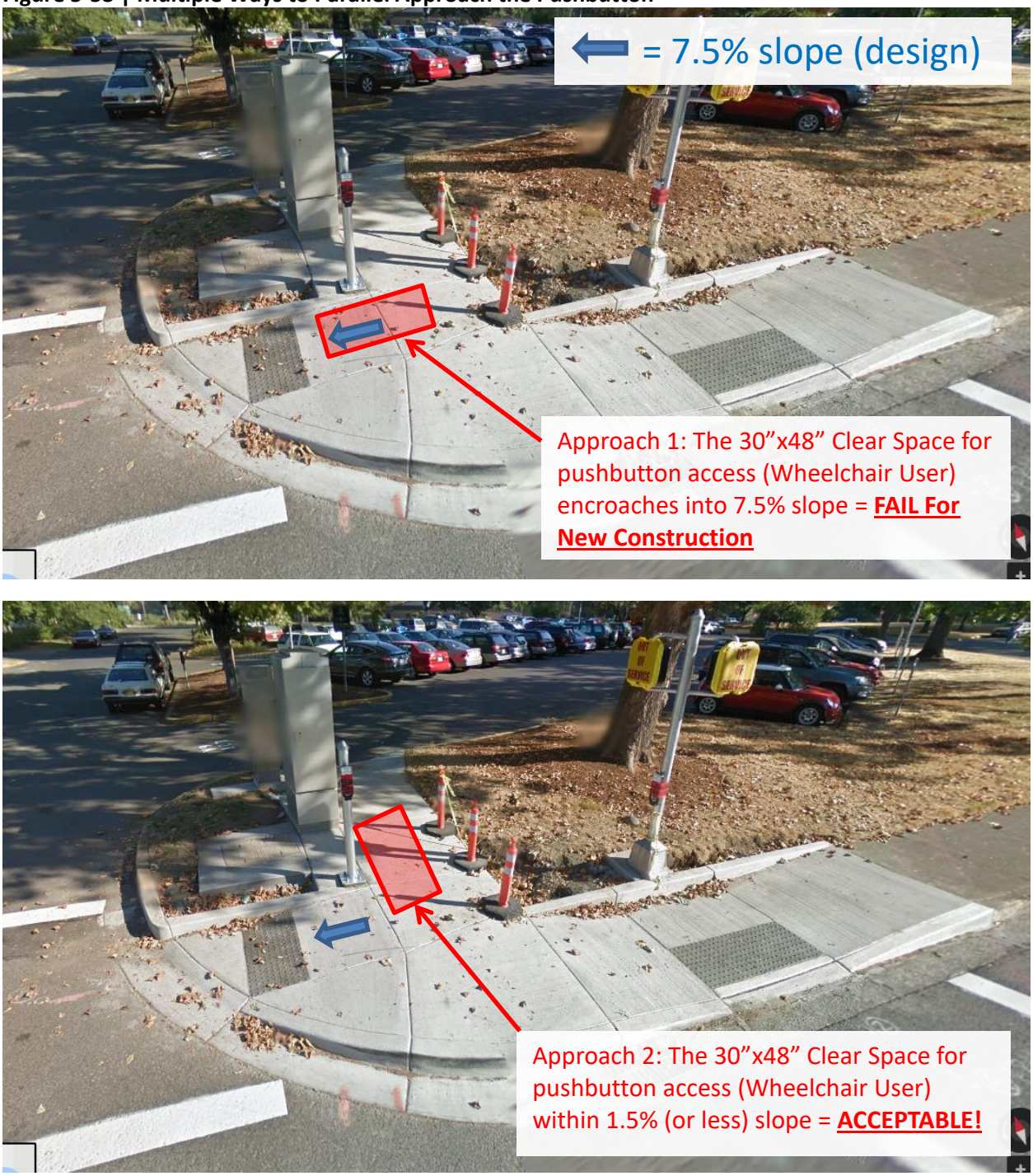


The Clear Space surface shall be comprised of a material that is solid (i.e. concrete, asphalt). Use of a poorly compacted material (pea gravel, uncompacted aggregate or soil) will make it difficult or impossible for a wheelchair user to access the pushbutton. This is especially important to consider for temporary signals. See Figure 5-52.

**Figure 5-52 | Poorly Compacted Material Example**

Depending on the ramp geometry, there may be multiple ways to parallel approach the pushbutton, which can mean the difference between meeting or failing the Clear Space slope requirement (1.5% design slope). See Figure 5-53. Be sure to verify the Clear Space from all possible approaches with the Wheelchair Design Vehicle in CADD. While only one approach is required to meet the requirements, accessing each approach to the pushbutton can lead to a better overall design that minimizes the amount of maneuvering for the wheelchair user.

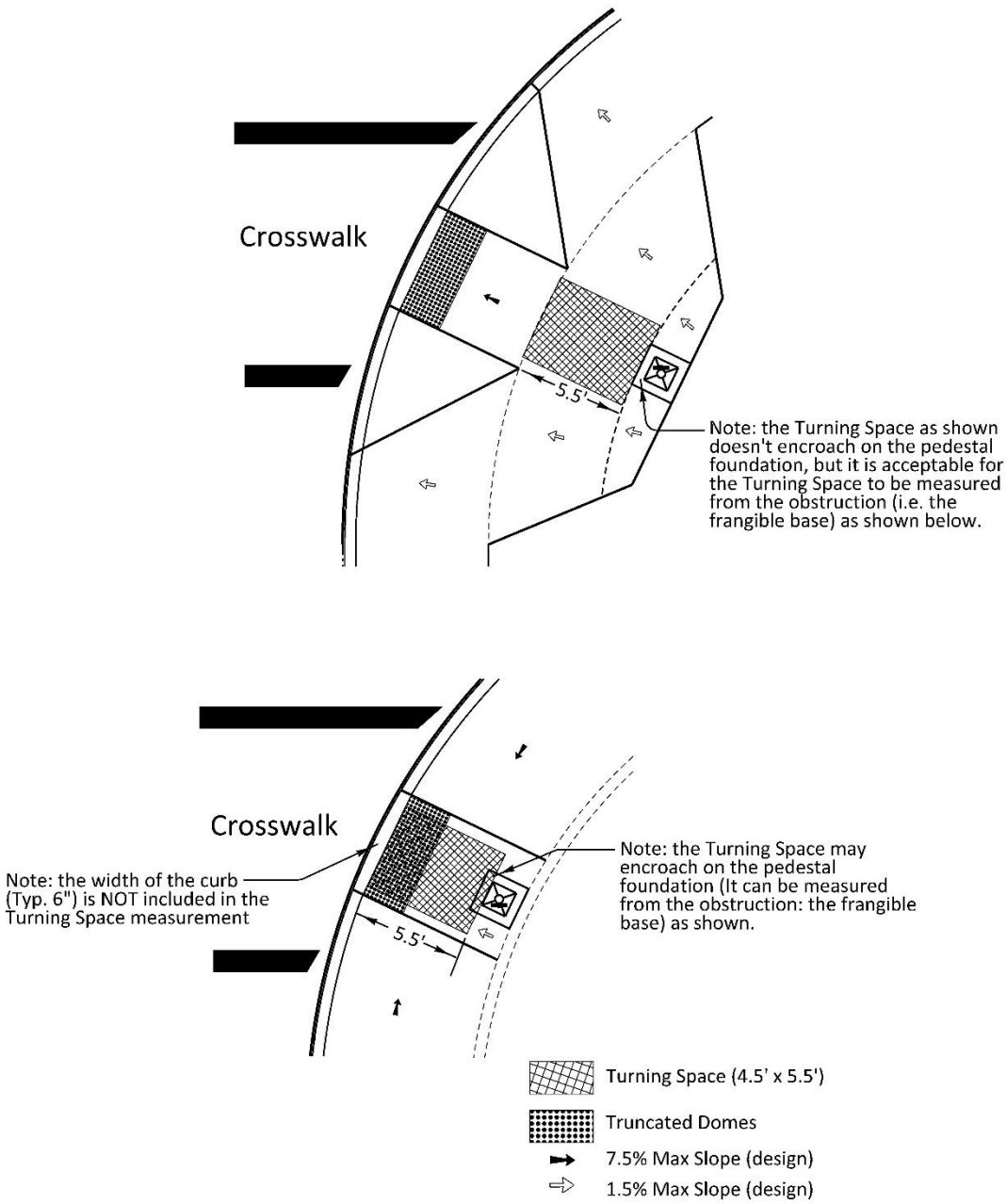
**Figure 5-53 | Multiple Ways to Parallel Approach the Pushbutton**



The Turning Space for a ramp with pedestrian pedestals or signal poles (i.e. an obstruction) is required to be 4.5’ x 5.5’ with the 5.5’ dimension measured from the obstruction towards the ramp. The width of the curb shall NOT be included in the measurement. An obstruction to the Turning Space is defined as any vertical difference that is greater than ¼” or any slope that is designed at greater than 1.5% (Maximum 2.0% finished slope surface). See

**Figure** 5-54.

**Figure 5-54 | Turning Space Measurement for Ramp with Signal Equipment**



The vertical reach requirements for the pushbutton will typically always be met when using standard traffic signal pedestals, poles, and pushbuttons. Pushbuttons mounted to non-standard equipment, structures, or in unusual locations require verification of the vertical requirements. This includes poles with ornamental bases and poles located behind or above barriers. See examples shown in Figure 5-55 and Figure 5-56.

**Figure 5-55 | Verification of Pushbutton Vertical Height Required (Non Std. Equipment) – Example 1**

**Figure 5-56 | Verification of Pushbutton Vertical Height Required (Non Std. Equipment) – Example 2**

Pushbuttons should be located no more than 15 feet from the access to the crosswalk (edge of ramp). See Figure 5-57. This distance should be measured going through the middle of the turning space to the edge of the ramp, which may not always be a straight line. See Figure 5-58. In order to achieve the most direct measurement (straight line) the Clear Space and the Turning Space should coincide or have a large overlap.

Note that the MUTCD section 4E.08 states that the pushbutton should be 1.5 feet to 6 feet from the edge of ramp and allows up to 10 feet when physical constraints make closer placement impractical. While it is desirable to follow the MUTCD guidance and stay within 6 feet, we know that many ramps designed using ODOT standards will not even allow the placement of a pushbutton within 10 feet due to the slope requirements and the 7 inch standard curb exposure. Therefore, ODOT allows up to 15 feet to accommodate the majority of ramp designs.

If it is not feasible to place the pushbutton within 15 feet, adjustments to the signal timing WALK phase can be made to mitigate the longer distance. Be sure to coordinate with the Region Signal Timer if this distance will exceed 15 feet.

**Figure 5-57 | Distance from Pushbutton to Crosswalk (Edge of Ramp)**

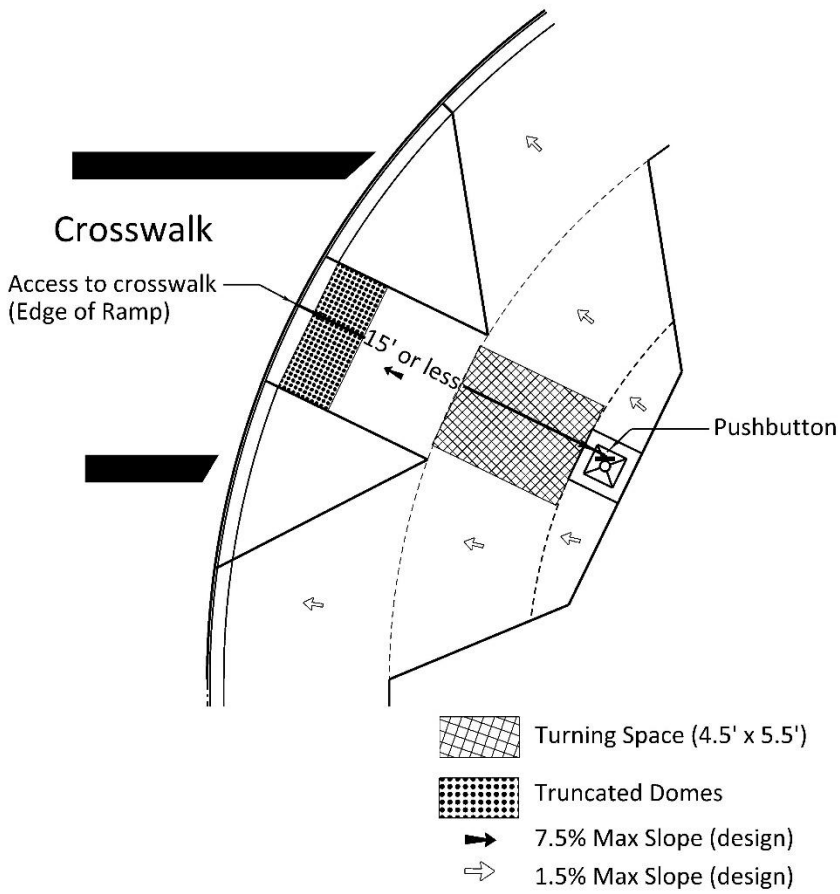
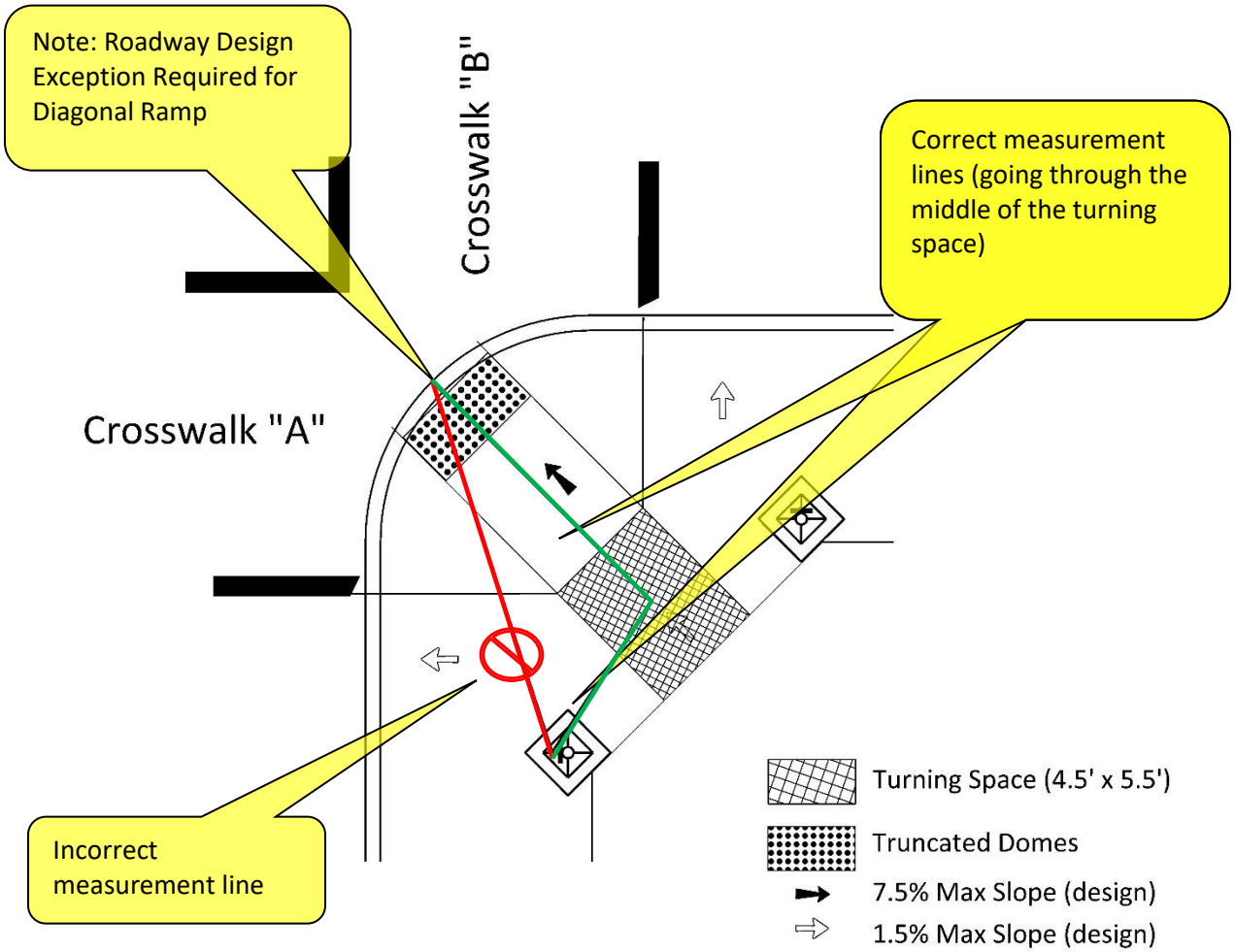


**Figure 5-58 | Measuring Distance from Pushbutton to Crosswalk (Edge of Ramp) Example**

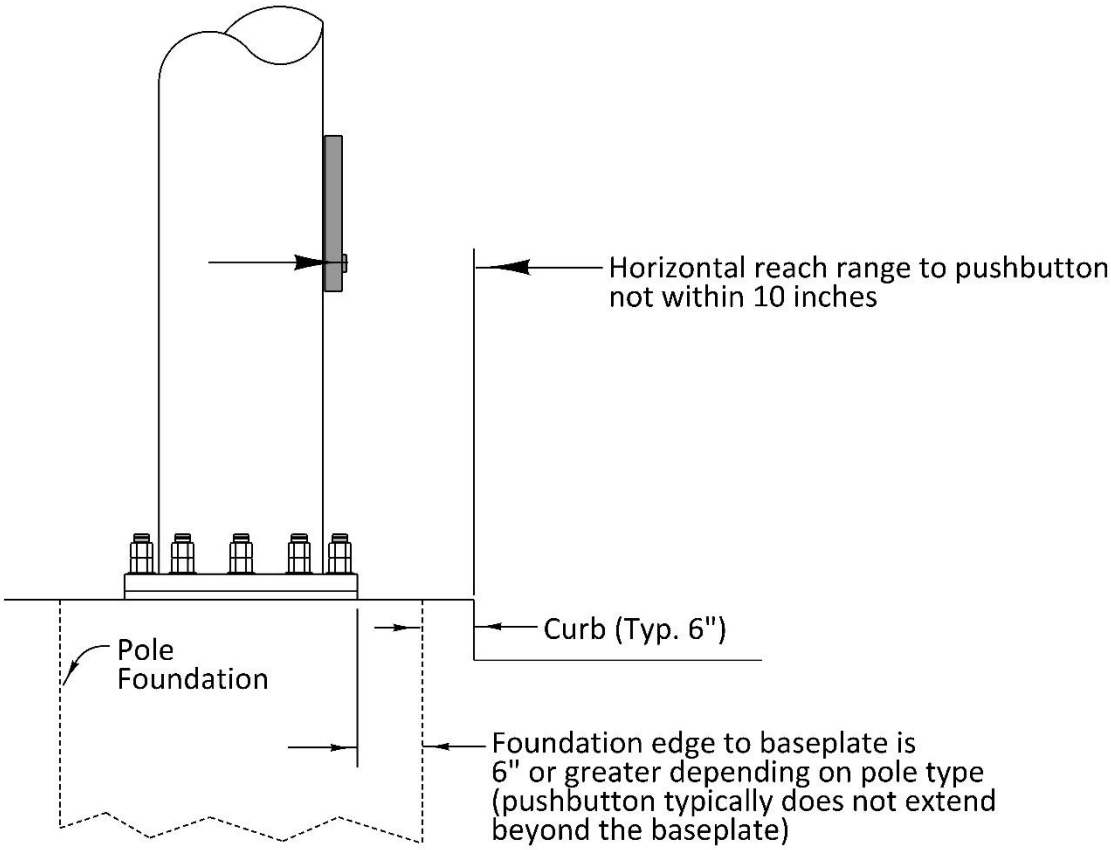


### 5.4.5 Deviation: Pushbutton Mounted on a Large Pole

Pushbuttons mounted on large poles are discouraged due to the tight tolerances for the 10 inch horizontal reach and high probability of requiring an extension bracket mount. As such, pushbuttons mounted on a large pole should only be considered in rare cases where a pedestal/pushbutton post cannot be installed (i.e. areas with limited right-of-way, utility conflicts, etc.).

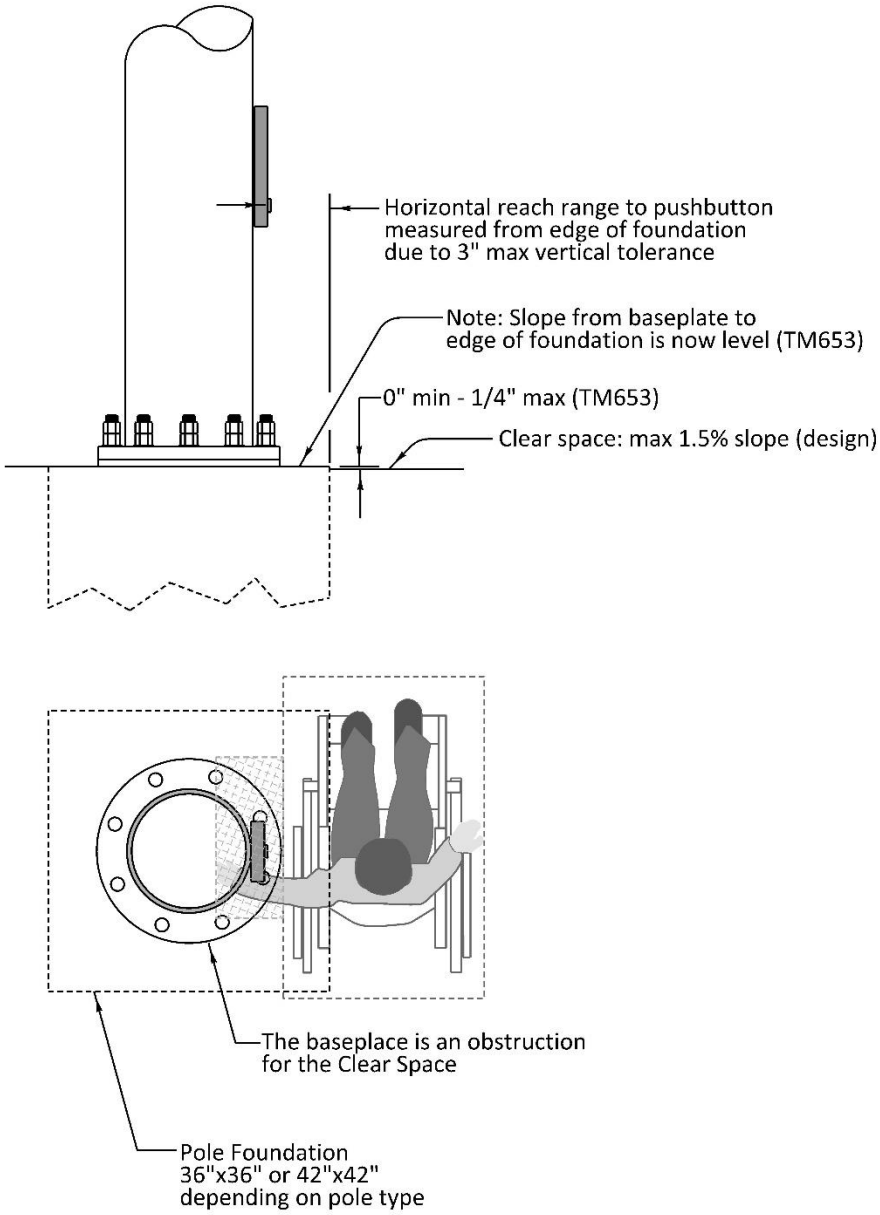
Mounting a pushbutton to a large pole limits the type of ramp that may be used. Typically only a perpendicular ramp style will work, with a larger clear space to accommodate the back-in/head-in maneuver. See Figure 5-45. The two other ramp styles (parallel and combo) both include a curb which will not meet the 10 inch horizontal reach if the pole is placed behind the curb. See Figure 5-59. Unlike a pedestal foundation, it is typically not practical to place the large pole foundation in front of the curb. Integrating the pole foundation with the curb installation, to achieve the 10 inch horizontal reach, is also not recommended due to the increased the complexity of construction (requires custom design details and excellent coordination/cooperation between sub-contractors).

**Figure 5-59 | Poles Located Behind Curbs Do NOT Meet 10 Inch Horizontal Reach Requirement**



The foundation of the large pole is no longer an obstruction to the clear space due to recent changes to standard drawing TM653 (the slope from baseplate to edge of foundation is now level and the vertical tolerance of the foundation to the adjacent asphalt or concrete finish grade is now 0” to ¼”). For large poles constructed after January 2020, the baseplate is the obstruction to the Clear Space. See Figure 5-60.

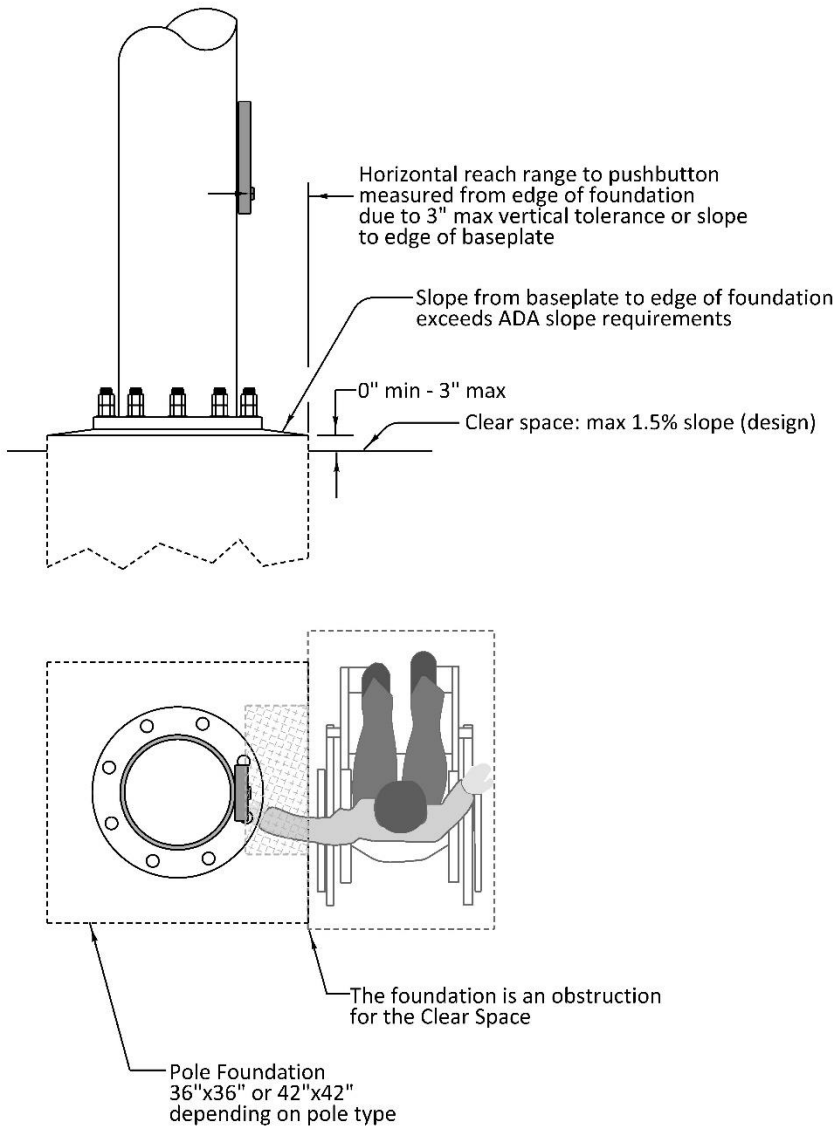
**Figure 5-60 | Measuring Horizontal Reach to Pushbutton Mounted on Large Pole (POLES CONSTRUCTED AFTER JANUARY 2020)**



For poles constructed before January 2020, the foundation is likely an obstruction to the clear space for two reasons (see Figure 5-61):

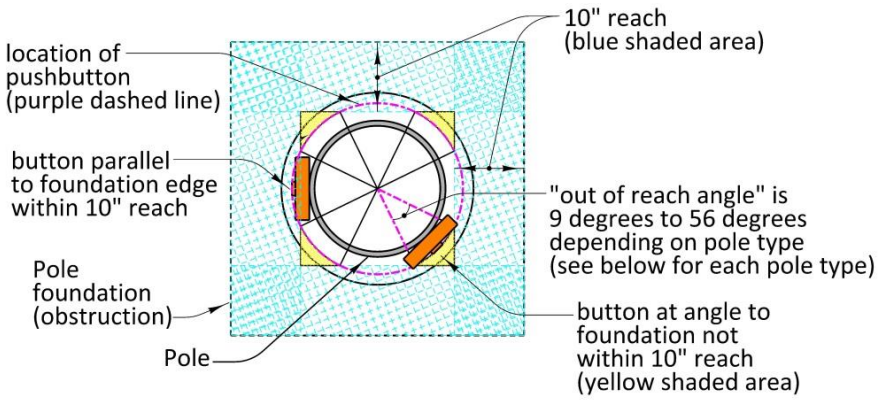
- the 3 inch max vertical tolerance for foundation exposure with respect to the adjacent finish grade, or
- the slope from the foundation control point to the edge of the baseplate exceeds ADA slope requirements.

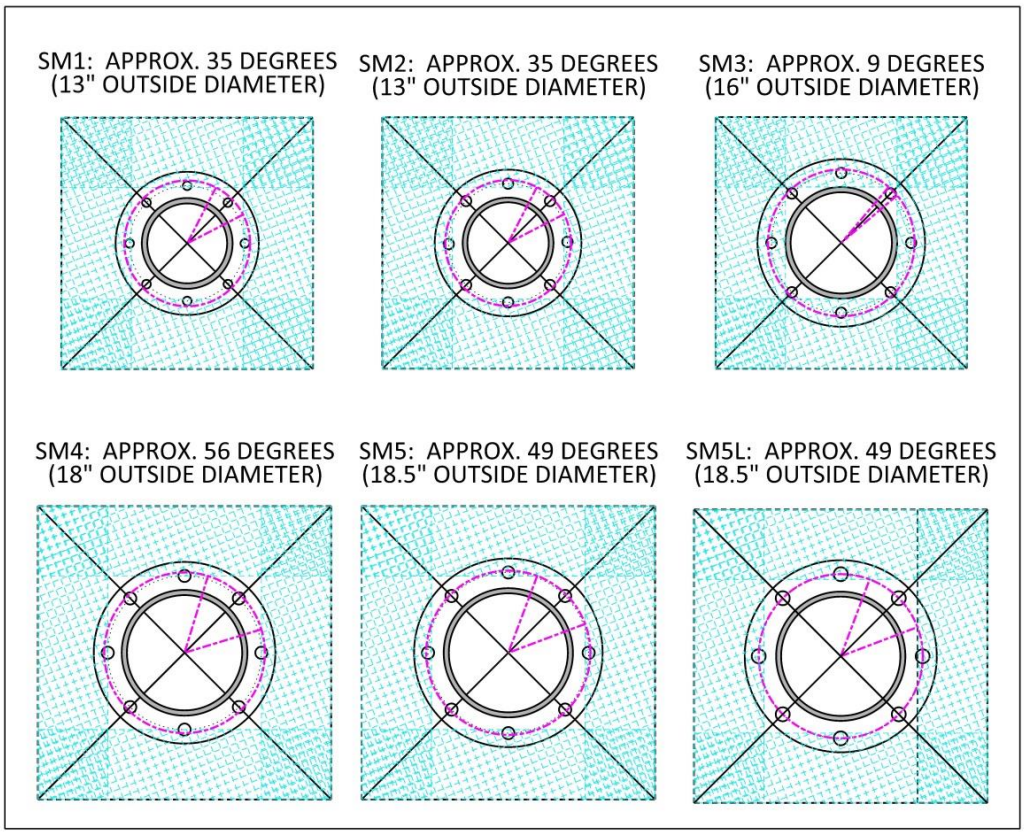
**Figure 5-61 | Measuring Horizontal Reach to Pushbutton Mounted on Large Pole (POLES CONSTRUCTED BEFORE JANUARY 2020)**



For poles where the foundation is an obstruction for the clear space (typically poles constructed before January 2020), the reach distance measured from the edge of the signal pole foundation to the pushbutton will just barely meet the 10 inch horizontal reach for MOST all pole types and pushbuttons listed on the approved Blue Sheets IF THE PUSHBUTTON IS MOUNTED PARALLEL TO THE EDGE OF THE FOUNDATION. See Figure 5-61. If the pushbutton is installed at an angle to the foundation, there is a point where it will fall outside the 10 inch horizontal reach (i.e. "out-of-reach angle"). See Figure 5-62.

**Figure 5-62 | Out-of-Reach Angle for Pushbuttons Located on Large Poles (POLES CONSTRUCTED BEFORE JANUARY 2020)**



### 5.4.6 Deviation: Two Pushbuttons Mounted on a Single Pedestal

Two pushbuttons on the same pedestal is the preferred solution for two scenarios:

- For two ramps that share a single turning space
- When a roadway design exception has been granted for a diagonal ramp (one ramp that will serve two crosswalks)

Trying to accommodate the 8 foot button separation for these two scenarios is not recommended due to the following drawbacks:

- The Turning Space and the Clear Space would separated by a large distance. This creates a longer (and unnecessary) path for the wheelchair user in certain directions. For example, a parallel style diagonal ramp the wheelchair user would have to traverse the 7.5% slope three times if approached from a certain direction. See Figure 5-63

- Unable to meet the MUTCD requirement of 60 inch maximum from the outside edge of the crosswalk striping to the pushbutton in the majority of cases. When Pedestrian signal indications are mounted on the same pedestal as the pushbutton, they would likely be blocked from the pedestrian's view by cars stopped at the intersection. See Figure 5-63

- If the buttons are placed adjacent to the turning space (so that the clear space will coincide with or overlap the turning space), typically only 5 to 6 feet of separation can be achieved. Short separation distances are not desirable as they can create an "obstacle course" on the sidewalk that may be difficult for the sight impaired to navigate. See Figure 5-64

Note that the MUTCD section 4E.08 states that the pushbuttons should be separated by 10 feet and allows the pushbuttons to be placed closer or on the same pole when it is impractical to achieve the 10 foot separation. While it is desirable to follow the MUTCD guidance and separate the pushbuttons by 10 feet, we have encountered enough locations where pushbutton separation between 8 to 10 feet provides the best access to the pushbuttons within the site constraints. Pushbutton separation of 8 to 10 feet still allows a reasonable amount of separation to avoid creating an "obstacle course" and alternative audible pedestrian messages for buttons less than 10 apart are allowed as per the MUTCD. Therefore, ODOT allows a minimum pushbutton separation of 8 feet. If it is not feasible to separate the pushbutton 8 feet, both pushbuttons should be mounted on a single pedestal.

**Figure 5-63 | Drawbacks to the 10 foot Separation of Pushbuttons at Diagonal Ramps**

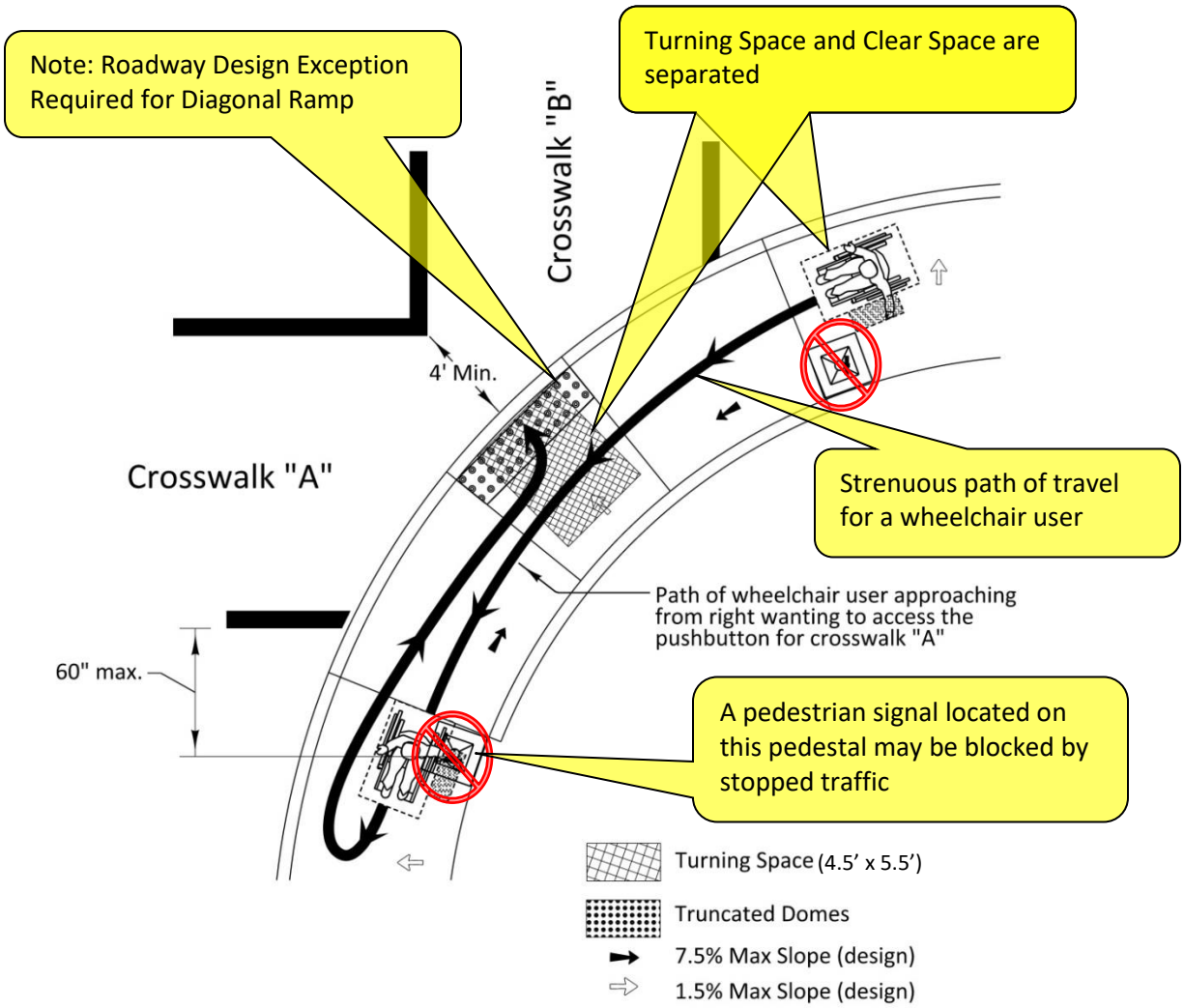
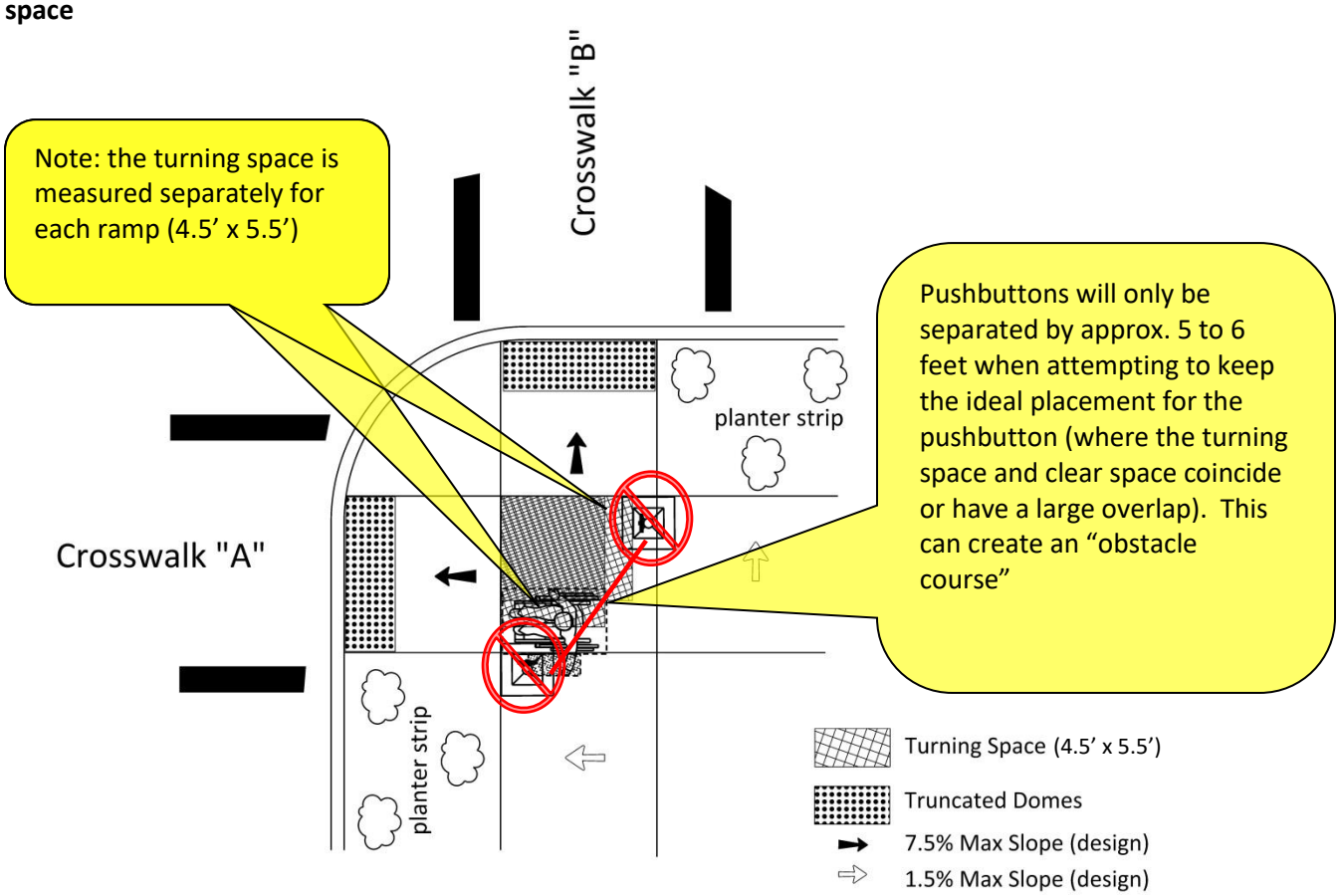


**Figure 5-64 | Drawbacks to the 10 foot Separation of Pushbuttons at two ramps that share a turning space**



See Figure 5-65 for an example of the preferred placement for two ramps that share single turning space and Figure 5-66 through Figure 5-69 for the preferred placement for common styles of diagonal ramps.

**Figure 5-65 | Preferred Pushbutton Placement for two ramps that share a turning space (Two Buttons on Pedestal)**

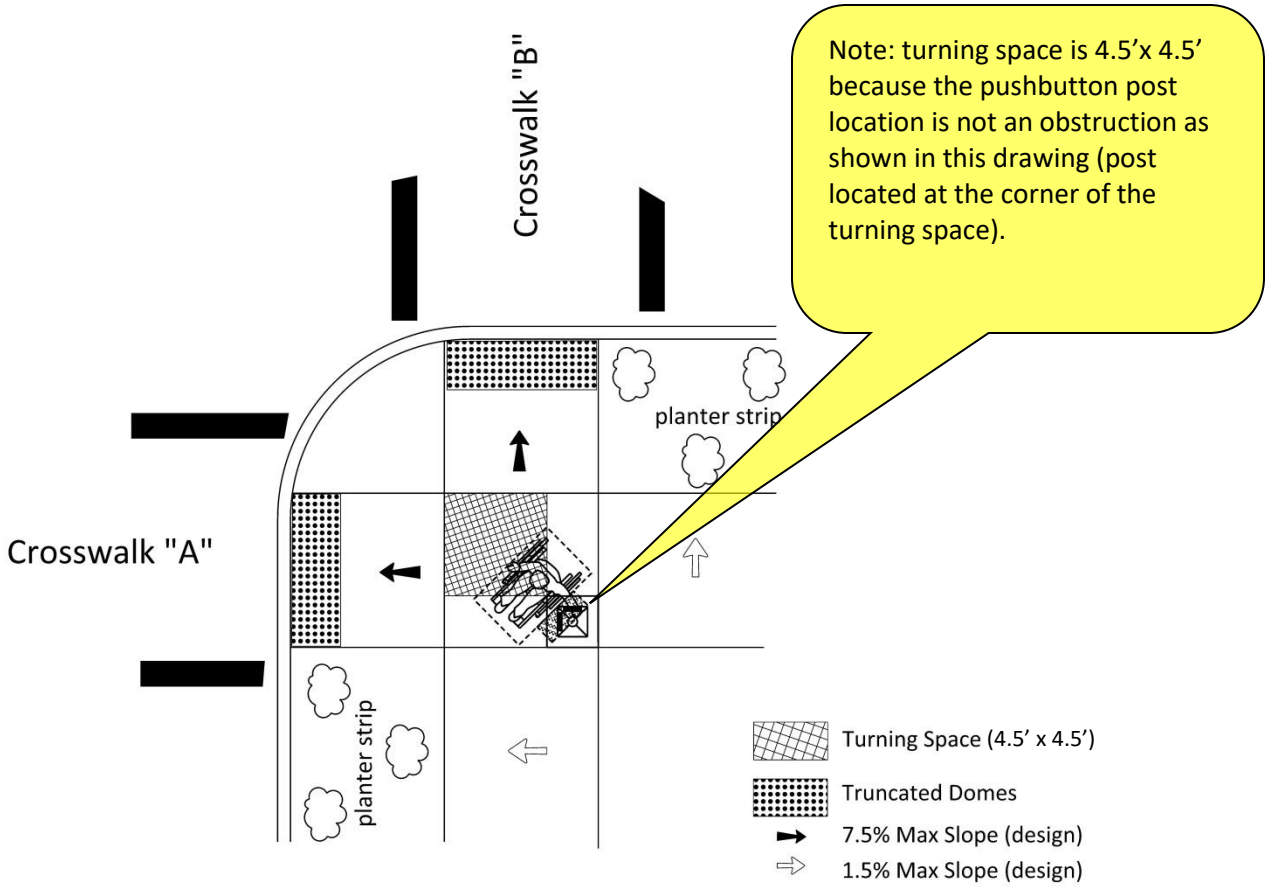


**Figure 5-66 | Preferred Pushbutton Placement for Diagonal Perpendicular Style Ramp (Two Buttons on Pedestal)**

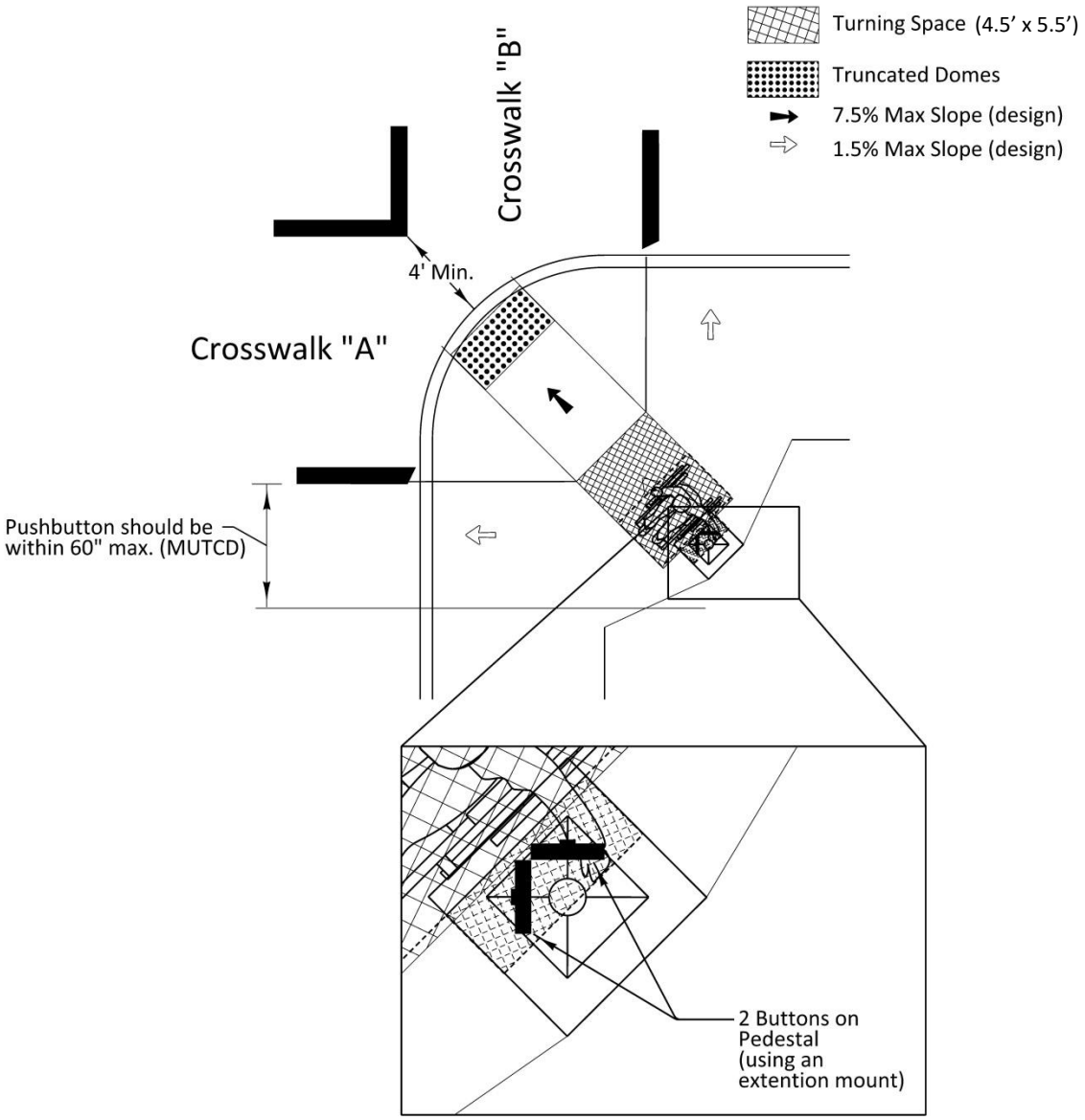


**Figure 5-67 | Preferred Pushbutton Placement for Diagonal Parallel Style Ramp (Two Buttons on Pedestal) – Example 1**

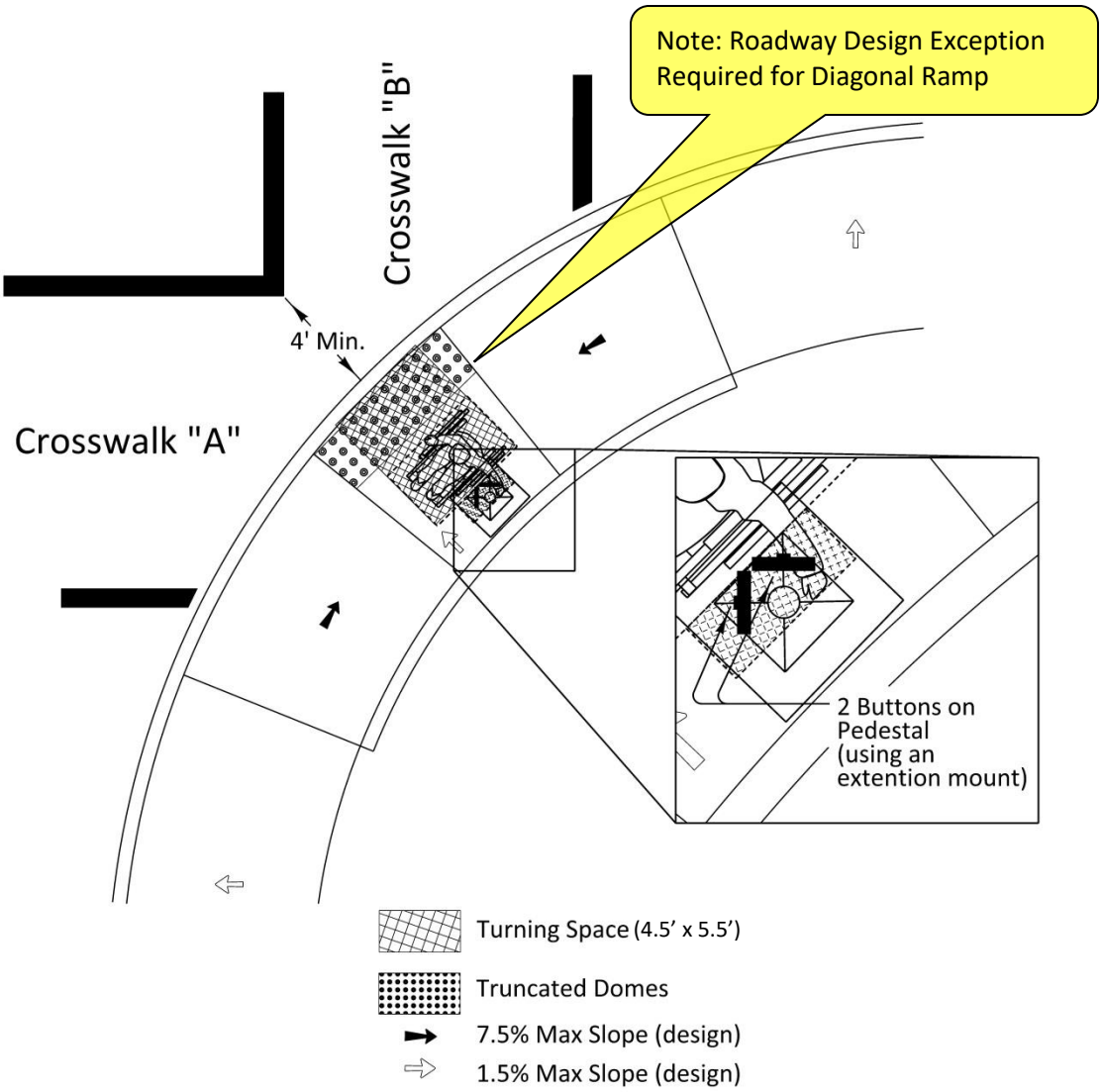


**Figure 5-68 | Preferred Pushbutton Placement for Diagonal Parallel Style Ramp (Two Buttons on Pedestal) – Example 2**

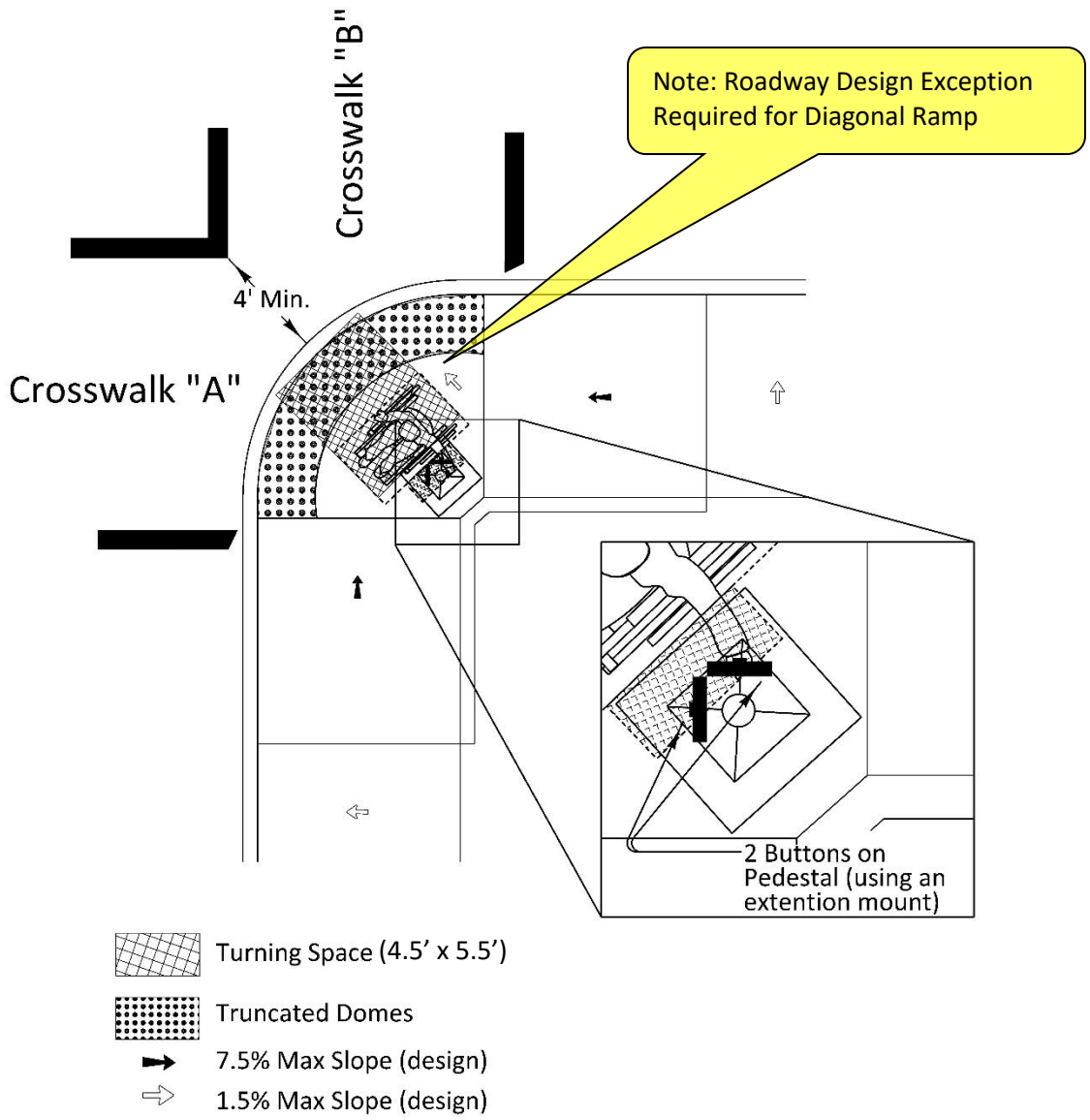
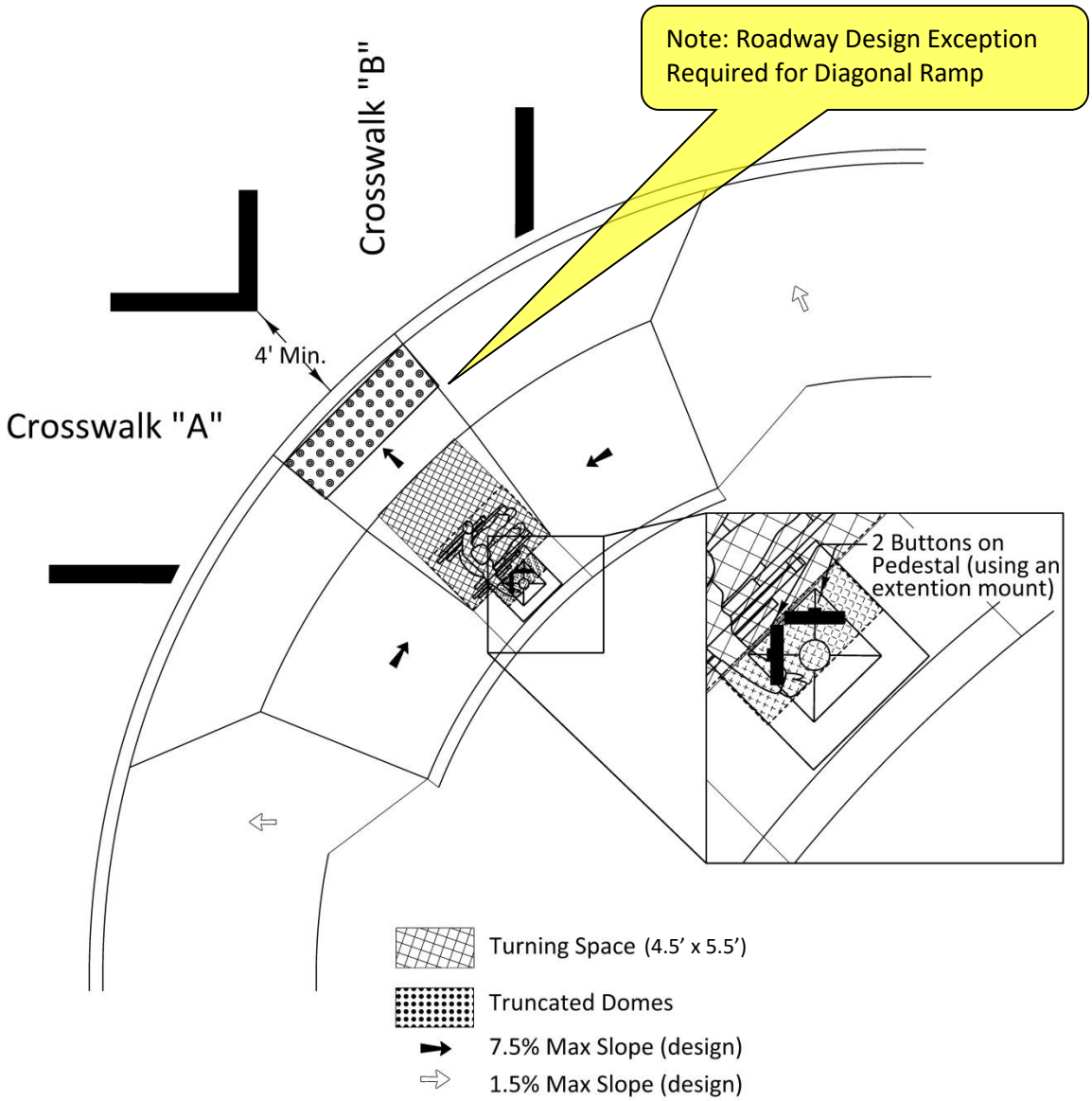


**Figure 5-69 | Preferred Pushbutton Placement for Diagonal Combo Style Ramp (Two Buttons on Pedestal)**



Several items need extra attention when a diagonal ramp serves two crosswalks. Verify the following:

- The pushbutton is located within 60 inches of the outside edge of the crosswalk striping. See Figure 5-70.
- The location of the pedestrian indications will not be blocked by from view by traffic stopped at the stop line. This can be challenging when the radius is small. Advance stop lines may be an appropriate solution to preserve the pedestrian's line of sight to the pedestrian indications.
- There is 4' minimum between the curb ramp and the inside crosswalk striping. This distance provides the wheelchair user a location to maneuver to the desired crosswalk and should be outside of the travel way (including bike lanes). Note that meeting this 4' minimum dimension may not be possible with a small radius. See Figure 5-71.

**Figure 5-70 | Pushbutton 60" From Outside Edge of Crosswalk Striping at Diagonal Ramp**

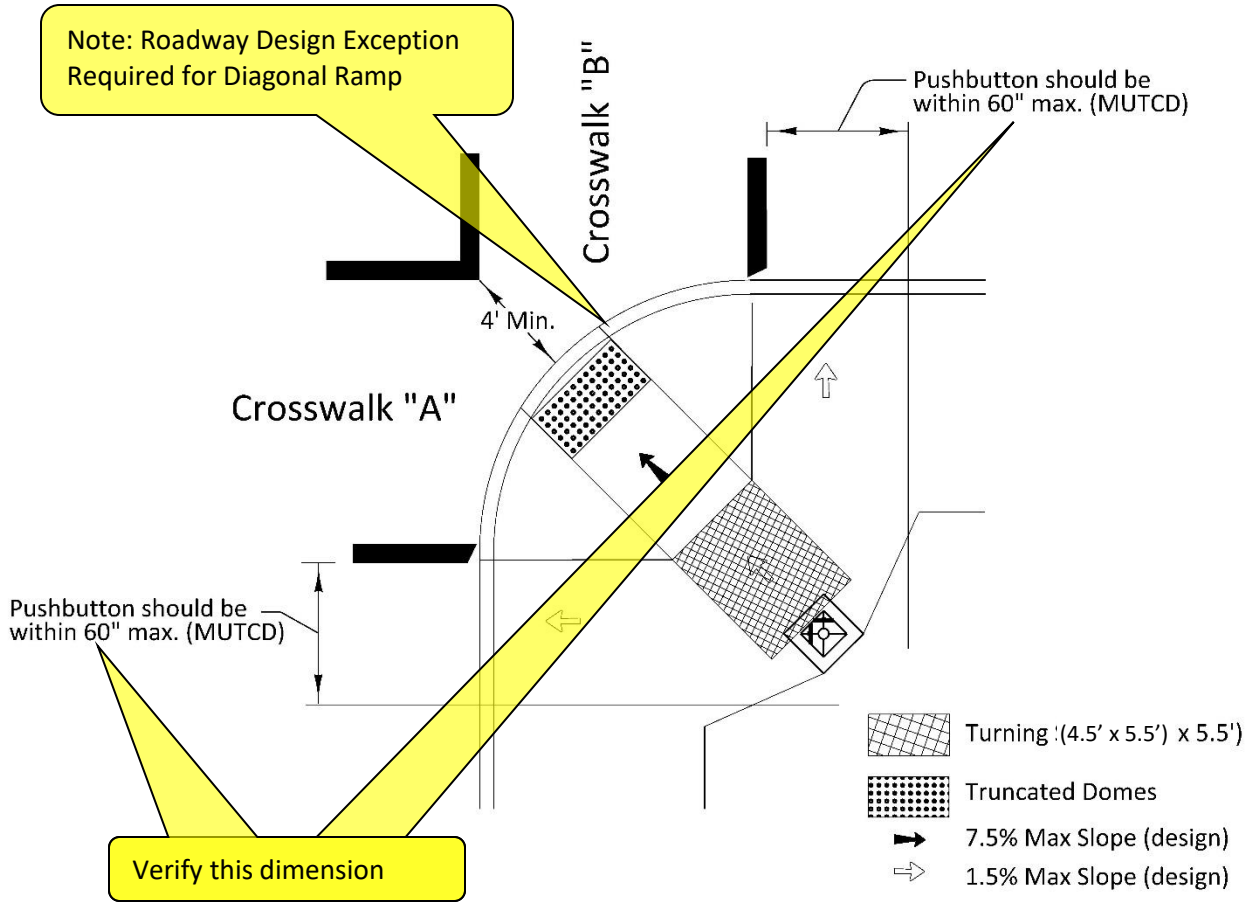
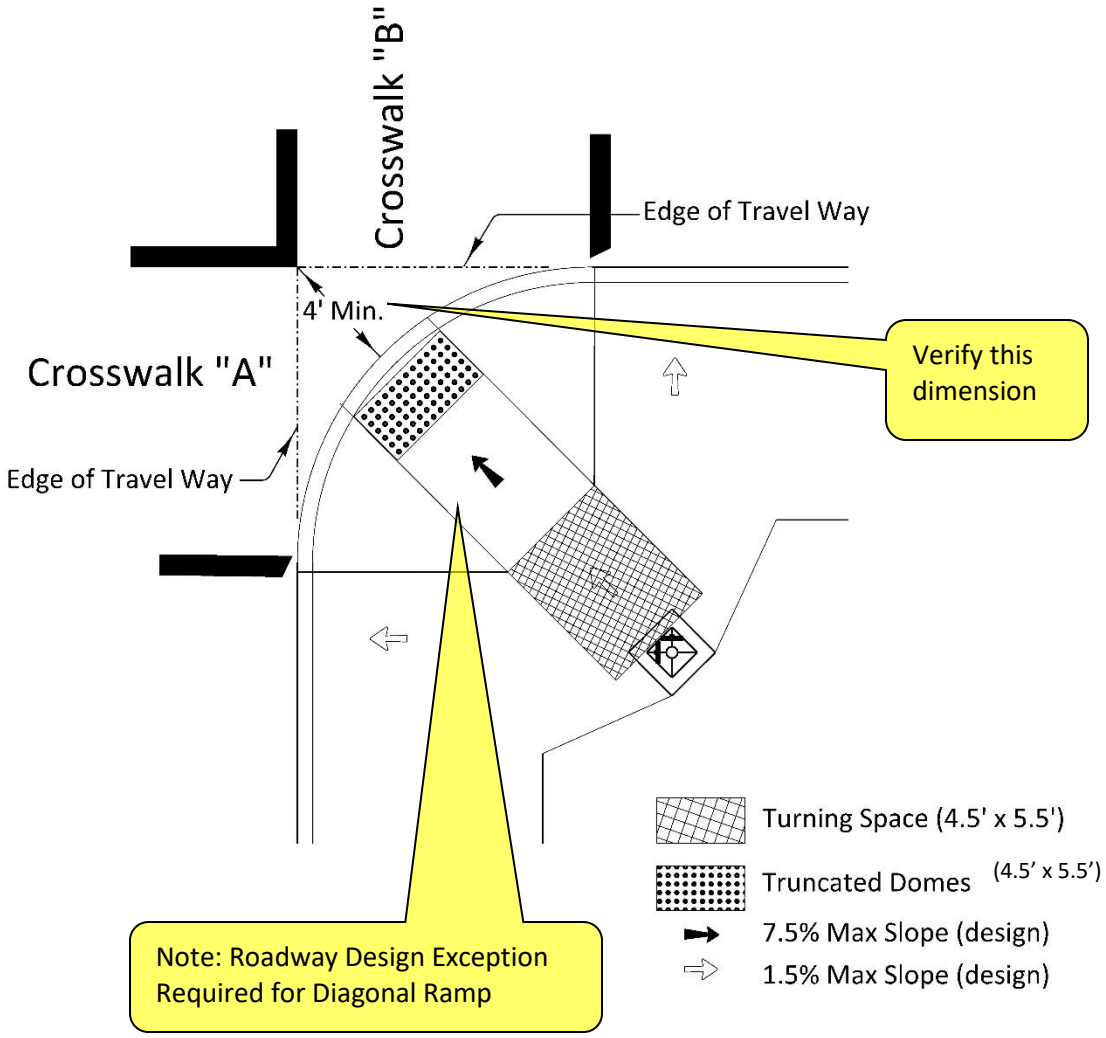


**Figure 5-71 | 4' Minimum Distance Between Curb Ramp and Inside of Crosswalk Striping at Diagonal Ramp**



### 5.4.7 Deviation: Use of an Extension Bracket Mount

Pushbuttons mounted on extensions are discouraged due to the potential for increased maintenance problems and they can also be a potential hazard for the blind that use caning for navigation if they protrude into the clear circulation path. Pushbuttons using an extension bracket may not extend more than 4 inches into the clear circulation path (see standard drawing RD720). As such, they should only be used in two specific cases:

- When two pushbuttons must be mounted on 4” diameter pole. See Figure 5-72.
- Retro-fitting existing installations that do not meet the 10 inch horizontal reach. See Figure 5-73 and Figure 5-74.

**Figure 5-72 | Extension Bracket Mount for Two Pushbuttons on 4 Inch Diameter Pole**

**Figure 5-73 | Extension Bracket Mount Example – Standard Button Style**

**Figure 5-74 | Extension Bracket Mount Example – H-Frame**

### 5.4.8 Pushbuttons Located behind Guardrail

While not ideal, pushbuttons may be located behind guardrail if they meet the criteria specified in Section 5.4.2. This can be accomplished by positioning the pedestrian pedestal or pushbutton post between the guardrail posts. Additional coordination between the guardrail installer and the signal installer during construction will be necessary to ensure compliance.

### 5.4.9 Extended Pushbutton Press Feature

The extended pushbutton press feature provides slower pedestrians an opportunity to request and receive a longer pedestrian clearance time. The Traffic Signal Operations Engineer will determine if this feature is needed. If this feature is used, an additional sign PUSH BUTTON FOR 2 SECONDS FOR EXTRA CROSSING TIME (R10-32P) is required to be mounted adjacent to the pedestrian pushbutton (see Figure 5-75). The Oregon specific sign shown in Figure 5-76 combines the two required federal signs and is preferred over installing the two federal signs.

**Figure 5-75 | Extra Crossing Time Sign R10-32P**

**Figure 5-76 | Extra Crossing Time Sign OR-32**

### 5.4.10 Pedestrian Signal Location

All pedestrian signals shall have clear line of sight from within the crosswalk lines from one end of the crosswalk to the pedestrian signal at the other end of the crosswalk (see Figure 5-77).

**Figure 5-77 | Good Pedestrian Signal Visibility**

### 5.4.11 Indication Type

All pedestrian signal indications installed on new projects shall be the countdown type. See Figure 5-78. If the scope of the project impacts an existing non-countdown indication (e.g. adjustment of the head due to curb ramp changes) or necessitates the need to install only one new pedestrian signal indication, all pedestrian signal indications for the entire intersection should be updated at the same time. The reason for doing this is to provide uniformity and consistent information to the pedestrian at that particular location.

**Figure 5-78 | Countdown pedestrian signal Indications**

White

Portland Orange

### 5.4.12 Audible Pedestrian Signals

The Operational Approval for the traffic signal will state if audible pedestrian signals are required. Verify with the Region Traffic Engineer. See the Traffic Signal Policy and Guidelines for additional information.

## 5.5 Pole Selection and Placement

ODOT's standard is the use of mast arm poles in all new signal and retrofit installations. Span wire installations are allowed if standard length mast arms will not allow for proper signal head placement. Local jurisdictions may also request strain poles. Custom supports (other than mast arm or span wire) should only be considered if standard supports are not feasible.

### 5.5.1 Right-of-Way

All equipment (including foundations) must be located within right-of-way or permanent easements and shall not overhang private property.

### 5.5.2 Overhead Structures and Vertical Clearance Standards

Contact the Region Mobility Liaison when any proposed project (new construction, reconstruction, preservation, or maintenance) adds a new or modifies an existing overhead structure (Truss Sign Bridge, Monotube Cantilever, Signal Mast arm, and Signal Strain Pole) regardless of meeting the existing minimum vertical clearance standards. In addition, contact the Region Mobility Liaison for any project that reduces the existing vertical clearance regardless of meeting the minimum vertical clearance standards. The Region Mobility Liaison will provide the appropriate coordination with the Region, and MCTD. This coordination should address not only project specific mobility requirements, but also any corridor level vertical clearance and mobility needs. Vertical clearance greater than 19'-0" for sign, VMS, and signal support structures are considered non-standard and require a design exception. The Traffic designer is to follow the procedures outlined in Chapter 14 of the HDM. The design exception request process for increasing the vertical clearance greater than the above mentioned 19'-0" will need to consider safety, operations, and impact to other design features in order to support the approval of the design exception.

### 5.5.3 Height Restrictions

When working on signals located near airports, there is the possibility of height restrictions which can have an impact on pole selection, especially poles with illumination. Permitted high loads and oversized truck routes should also be considered. Check with the airport in question regarding flight paths and any height restrictions and with the ODOT Trucking Industry Representative regarding permitted route issues.

### 5.5.4 Utility Conflicts

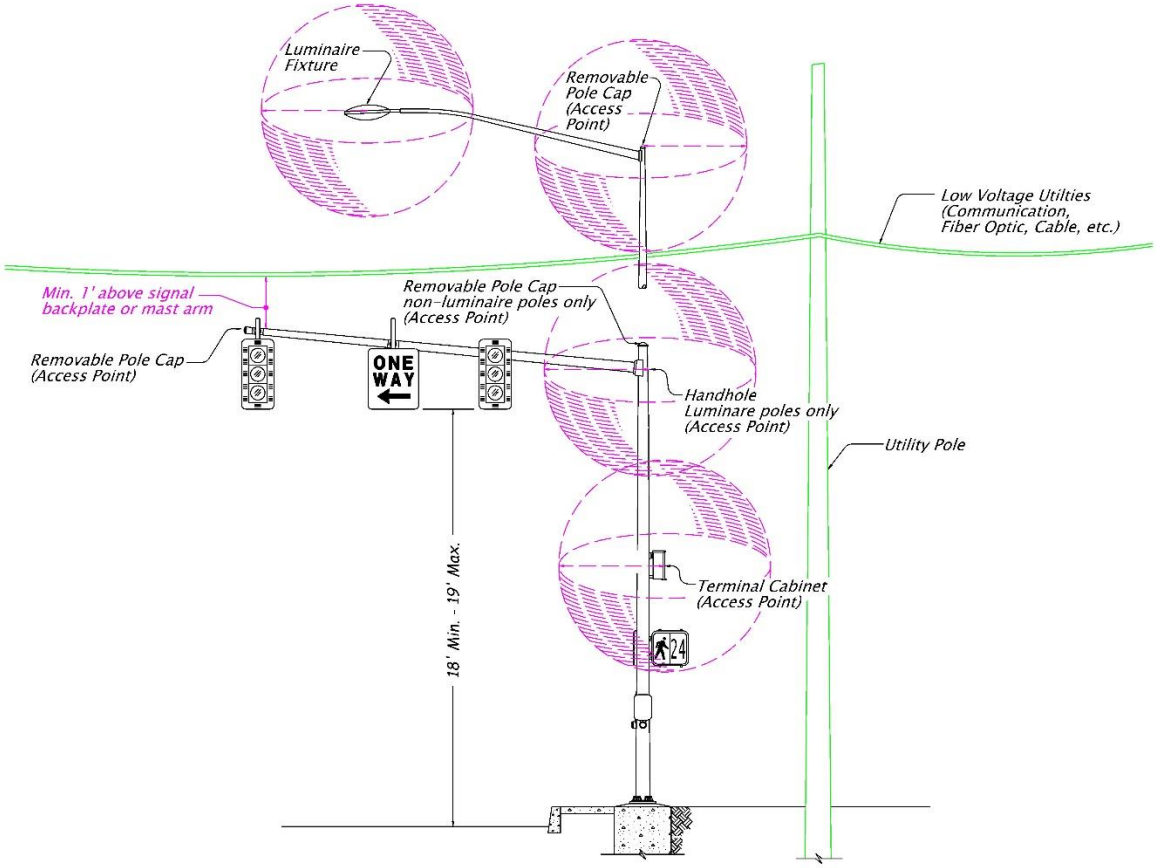
Always check to see if there is the possibility of overhead and underground utility conflicts when locating poles. Conflicts with overhead and underground utilities will

need to be addressed during the design of the signal. A minimum of 10 feet from overhead high voltage lines is required as per OAR 437-002-0047. For low voltage utilities (e.g. communication, fiber optic, cable, etc.), the following minimum clearances should be provided (See Figure 5-79):

- A minimum of 5 feet from access points (e.g. removable pole caps, handholes, and terminal cabinets) and illumination fixtures
- A minimum of 1 foot from above the mast arm and backplates

If there are any known conflicts with utilities, contact the Region Utility Specialist for help. There are three possible solutions depending on the situation; 1.) the signal pole location may need to be adjusted (which may require other auxiliary signal equipment such as pedestrian pedestals), 2.) the utility may need to be relocated, or 3.) a combination of number one and two. Utility conflicts shall be addressed and resolved before the design is complete.

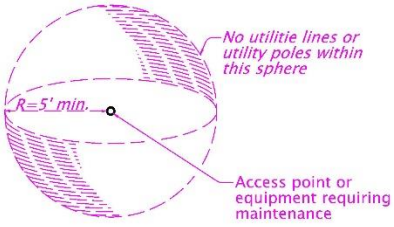
**Figure 5-79 | Low Voltage Utility Clearances**




LOW VOLTAGE UTILITY CLEARANCES

*GENERAL NOTES:*

1. *Clearance of access points such as removable pole caps, handholes, terminal cabinets and equipment such as luminaire fixtures should be as shown to allow for maintenance activities.*




2. *Clearance above signal backplate shall be as shown to allow for unobstructed view of signal head indications and maintenance activites.*
3. *Verify utility provider clearances. Use utility provider clearances if greater than these.*
4. *Clearances shown apply only to low voltage utilities. For high voltage utilities, follow clearance requirements set forth in OAR 437-002-0047*

### 5.5.5 Roadside Placement Requirements

Traffic signal poles shall be located no closer than 5 feet from face of curb to the face of pole or 6 feet from normal edge of pavement when curb is not present. Poles may be located in raised islands if 5 feet clearance can be maintained on all sides of the pole.

### 5.5.6 Mast Arm Poles

Mast arms come in sizes ranging from 15 feet to 55 feet in 5-foot increments. Mast arm poles are normally positioned with the mast arm perpendicular to the center line alignment.

The furthermost piece of equipment on the mast arm (i.e. signal head, sign, or fire preemption detector) shall be located no closer than 6 inches from the tip end of the mast arm. This is measured from the centerline of the mount location (which is typically the centerline of the equipment).

Illumination is typically included on all the mast arm poles at an intersection. The orientation of the illumination (location of the illumination relative to the mast arm) is usually located in-line with the mast arm, but it can be located at any degree on a standard mast arm pole as necessary.

When designing a mast arm for current permissive left turn phasing operation (especially if the lane use for the approach contains a left turn lane), the mast arm should be long enough to allow proper placement of a future signal head for protected only or protected/permitted operation.

Pedestrian signals and pushbuttons should not be mounted to a mast arm pole. See section 5.4 for more information about placement of pedestrian signals and pushbuttons.

### 5.5.7 Strain Poles

Strain poles are only to be used in areas where the use of mast arm poles will not allow for the correct location of signs or signal equipment. Wood strain poles are the standard only in the design of temporary signals.

Possible overhead and underground utility conflicts are more of a factor for strain pole placement since the pole is higher and the foundation is typically deeper than a mast arm pole. See Standard Drawings TM653 and TM661.

Illumination is typically included on all the strain poles at an intersection. The orientation of the illumination (location of the illumination with respect to the north arrow) can be located at any degree on a standard strain pole as necessary.

Pedestrian signals and pushbuttons should not be mounted to a strain pole. See section 5.4 for more information about placement of pedestrian signals and pushbuttons.

### 5.5.8 Pedestals: Vehicle

Vehicle pedestals are used mainly for ramp meter installations, but they also may be necessary at an intersection depending on the geometry and operation (typically used for nearside/supplemental signal heads). Vehicle pedestals shall NOT be used as a substitute for a mast arm or span wire for through movement phases. They also should not be used as a substitute for a mast arm or span wire for the stem of a T-intersection unless there is no other option (such as height limitations due to a bridge). This is because vehicle signals mounted on pedestals are only 12' high (from the ground to the bottom of the signal) which makes them not as visible, especially for vehicles in the back of a platoon, as a standard 18' – 19' overhead mounted signal. If used at the stem of a T-intersection, additional supplemental heads may be required to mitigate the loss of visibility.

### 5.5.9 Pedestals: Pedestrian

Pedestrian pedestals should be used to mount pedestrian signals and pushbuttons. See section 5.4 for more information about pedestrian pedestals.

### 5.5.10 Recessed Terminal Cabinet

A new style terminal cabinet that is integral to the pole design was created in 2013. This terminal cabinet should be used for all new poles, with concurrence from the Region Electrical Crew. Standard Detail DET4405, 4410 and 4650 shows the details for this terminal cabinet.

### 5.5.11 Pushbutton Posts

Pushbutton posts should be used only if the pushbuttons cannot be located on same support as the pedestrian indications. See section 5.4 for more information about placement of pushbuttons.

### 5.5.12 Non-Standard Design: (SM) Poles, Sign Bridge, Monotube, Luminaire Poles, Etc.

A non-standard structure is any structure that does not meet a standard drawing or new structures that do not have a standard drawing associated with the structure. These types of structures typically include poles for dual mast arms or diagonal structures. They are custom designed by a structural engineer during the construction phase of the project. In the case of sign bridges and monotubes, specially designed mounts for the signal equipment may also be required.

Mounting signal equipment (typically pedestrian equipment) to a stand-alone luminaire poles is discouraged because the use of standard pedestal or pushbutton post is usually

feasible. If the use of a standard pedestal or pushbutton post is not feasible, a stand-alone luminaire may be used to mount signal equipment only if the luminaire is operating from the same service as the traffic signal.

Contact the Traffic Structures Engineer and see the ODOT Traffic Structures Design Manual for more information on non-standard design

### 5.5.13 Re-using or altering the loading on existing signal supports

Re-using an existing traffic structure is generally not recommended for a number of reasons:

- The age of the structure may make analysis difficult. It will require a lot of assumptions if the necessary information cannot be found. The assumptions must be conservative, which typically leads to the analysis indicating re-use is not an option.
- The structure may be at or near its lifespan or not in great shape.
- Re-using an older pole requires a custom designed foundation (the standard drawings do not apply). This involves more engineering cost and extended review time. An old standard drawing may be used to as a starting point for analysis and design when creating a custom foundation detail sheet, but it cannot just be referenced and used without modification. This is because the old standard drawings (and specification references within) have not been maintained and therefore most likely contain out-of-date and erroneous information which must be modified and sealed by an engineer.
- For span wire installations – moving just one pole or installing just one new pole will often require adjustments to the other poles, thus necessitating more than one new pole anyway.
- Re-using a signal pole often results in more cost due to more extensive workzone traffic control. For example, moving an existing mast arm to accommodate a wider radius will require either a temporary signal while the existing mast arm is moved to its new location (the existing signal must remain in operation) or 24-7 flagging (if a temporary signal is not used).

For more info on how to analyze existing mast arm poles and strain poles, and additional information on when it may be appropriate to re-use an existing structure, refer to the ODOT Traffic Structures Design Manual.

### 5.5.14 Use of other Agency (non-ODOT) Approved Poles

This practice is typically not allowed. Contact the Traffic Structures Engineer for guidance and approval if use of non-ODOT poles is desired.

**Reusing an existing signal support is often less cost effective than installing a new traffic signal structure!**

## 5.6 Illumination

Providing illumination on all traffic signal mast arm poles and strain poles at an intersection is the default standard. A separate stand-alone luminaire pole may be used if a mast arm or strain pole is not located in a quadrant. If a stand-alone luminaire pole is used at the intersection, it should be powered from the same service as the traffic signal and designed according to standard drawings TM629 and TM630. The ODOT Lighting Policy and Guidelines and Traffic Lighting Design Manual contain additional information for illumination design requirements.

The illumination design should completed or verified by an illumination designer to determine the design specifics listed below. They will need a copy of your CADD signal plan and will provide:

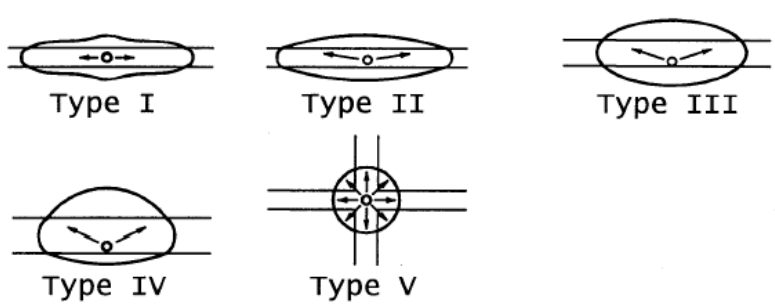
- Length of luminaire arm (as per standard drawing TM629, standard lengths of luminaire arms are 6’, 8’, 10’, 12’, 15’ and 20’)
- Luminaire arm orientation
- Mounting height
- Type and wattage of luminaires
- A copy of the photometric analysis for the project file

The Region Electrical crew shall be contacted to verify the maximum height that can be reached by their equipment and the wattage of the replacement bulbs they normally stock.

Current default standards are:

- 0 degree luminaire arm orientation (in-line with the mast arm)
- 15’ arm length
- 40 feet maximum height
- Light Emitting Diode (LED) fixtures (See Section 5.6.1 for more info). High Pressure Sodium (HPS) fixtures may be used when it is necessary to match the existing illumination system.
- A Type 3 light distribution pattern (See Figure 5-80)

**Figure 5-80 | Illumination Engineering Society (IES) Light Distribution Patterns**



### 5.6.1 Light Emitting Diode (LED) fixtures

LED fixtures shall be approved by the Region Electrical Manager and/or the ODOT Illumination Engineer. They may be used on new projects or on modification projects (that are converting/changing existing fixtures). The new special provision for LED fixtures should be used (special provision 02926).

The general guidance for LED power requirements at standard intersections of two-way, two-lane highways to comply with ODOT illumination standards is as follows:

- 250-275 watt LED (2 locations, far corners on the mainline)
- 130-140 watt LED (4 locations, at each corner of the intersection)

Bigger and more complex intersections should be analyzed using computer lighting software to determine the proper illumination design. Contact the Illumination Engineer.

### 5.6.2 Photo Electric Control Relay

The photo electric control relay is a device used for turning on luminaires based on the ambient lighting conditions. It should be placed on the signal pole that is closest to the Base Mounted Service Cabinet (BMCL). The photo electric control relay should be oriented towards the north sky.

### 5.6.3 Illumination Wiring

The wiring for the illumination that is part of the traffic signal (located on the signal poles) is wired directly from the BMCL to luminaire and photo electric control relay. Illumination wiring shall not be routed through the signal controller cabinet.

- Three No. 12 AWG THWN wires are needed from the BMCL to the photo electric control relay.
- Two No. 10 AWG XHHW wires are needed from the BMCL to each luminaire (each luminaire must have independent wires directly from the BMCL). Daisy chaining the illumination wiring from luminaire to luminaire is no longer allowed. This wiring will be spliced to the TC cable (see bullet below) via an in-line fuse holder at the pole base.
- TC cable is used from the pole base (splice point using an in-line fuse holder) to the luminaire ballast. This wiring is NOT shown on the plans, but is contained in the specification 00970.42.
- The ground/bond wire to the signal/illumination pole is a No. 6 AWG THWN. This wiring is NOT shown on the plans, but is contained in the specification 00960.50(a).

## 5.7 Fire Preemption

Fire preemption is often included in new signal installations, however it should only be included if the area/operators have been approved for use. Typically, if fire preemption is present at an existing intersection, it has already been approved and shall be replaced if the signal is re-built. The ODOT Traffic Signal Operations Engineer maintains a list of approved fire preemption areas/operators. The signal designer should contact the Traffic Signal Operations Engineer to verify the approval is documented. If the project scope does not mention fire preemption, verify that fire preemption is not needed or wanted with Region Traffic. Region Traffic will then work with the local operators in the area and submit a request for operation approval to the STRE if needed.

If fire preemption equipment is planned for the intersection, the detector must be located with a clear line of sight for a minimum distance of 1500 feet. Preferred placement of the detector is on the near side of a mast arm or span wire. Remote detectors, multiple barrel devices or alternate locations will be necessary if the roadway curves prior to entering the intersection.

One specialty cable for the fire preemption system is needed from the device mounted in the field back to the signal controller cabinet. No splices are allowed.

All pre-approved (Green Sheets) fire preemption equipment is capable of providing encryption (to assign ID's to those that use the system). However, ODOT does not currently have any jurisdictions using this feature.

## 5.8 Power Source

Commercial power is used to power all electrical installations (with the exception of some temporary signals). When installing a new traffic signal, the nearest location to draw power from (the power source) should be used. Power can only be tapped off of a transformer. The Figure 5-81 shows a typical example of a transformer.

**Figure 5-81 | Transformer Example**

It is critical to work with the Region Utility Specialist to determine what type of power is available and the location of the power source. The traffic signal service requires commercial power of 120V (or 120V/240V if illumination will be provided on the traffic signal). If the existing power source is unacceptable or needs modifications to work, the Region Utility Specialist will handle these issues.

Sometimes the project will necessitate moving the existing power source location to a new location. If this is the case, the signal plan sheets will need to depict this.

For all new signals, the wiring from the power source should enter into the service cabinet via a conduit (no aerial connections, with the exception of temporary signals). The design and installation of the conduit and wiring from the power source to the service cabinet is per the requirements of the power company. The plan sheets should just show a reference to the conduit and wiring indicating this. The contractor is responsible for installing the conduit and pull line from the service cabinet to the power source, and the power company is responsible for installing and terminating the wiring from the service cabinet to the power source.

## 5.9 Battery Back-Up

A battery back-up system can provide uninterruptable, reliable emergency power to a traffic signal in the event of a power outage or interruption. Some intersections, due to their location, and operational characteristics, may experience congestion or be difficult to drive through in the event of a power outage. Battery back-up may be beneficial in the following situations:

- Isolated location (long travel times for electrical crew to get to the signal)
- Conflicting high-speed approaches
- High volume intersections (ADT >20,000 on the mainline)
- Approaches with limited visibility
- Unusual geometry (e.g. single point urban diamonds)
- More than 4 approach legs
- Six or more travel lanes per road
- Railroad interconnection
- History of frequent power outages

The decision to install battery back-up is made at the District level in conjunction with input from the Region Traffic Engineer.

If battery back-up is deemed necessary, the following standard design practices apply:

- The operating electrical load of the intersection shall be calculated to confirm the applicability of battery back-up equipment meeting the current specifications (see the ODOT Standard Specification for Microcomputer Signal Controller and the approved product listed on the Traffic Signal Material "Green Sheets"). Adjustment for a higher capacity battery back-up system to accommodate larger operating loads will be made on an as needed basis.

## 5.10 Controller Cabinets

### 5.10.1 Location

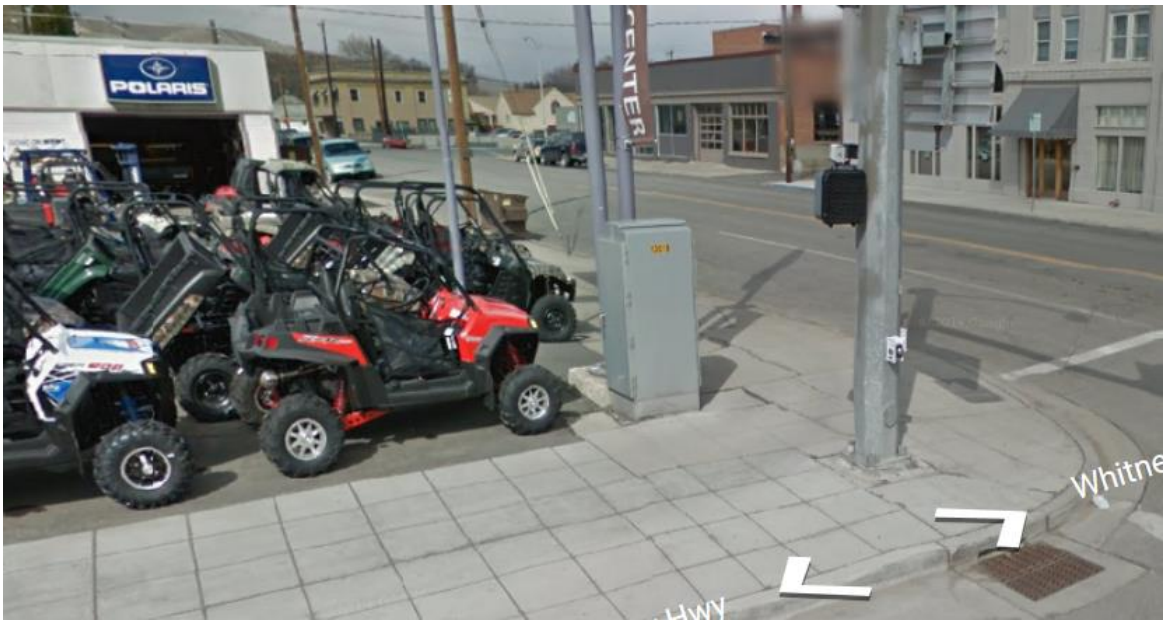
If possible, locate the controller on the right-hand side of a side street approach and try to obtain a power source in that quadrant. There may be limitations that preclude this location such as R/W, power source locations, sidewalk, or businesses located in the quadrant. Always contact the region electrical crew for their preference on the location of the controller cabinet.

The controller cabinet and the service cabinet should always be located in the same quadrant together for ease of maintenance, spaced a minimum of 10 feet apart.

Locate the controller cabinet so that it does not obstruct the view for a side street vehicle turning right-on-red. Standard controller cabinets are constructed such that the controller side cabinet door (front louvered door) swings left. Orient the controller cabinet so that the cabinet doors swing away from traffic. Locate the controller so that when the cabinet is being serviced, the technician can stand facing the louvered door (the front of the cabinet), and see a minimum of two traffic signal phases.

The right-of-way, adjacent properties, and the pedestrian clear circulation path may also have influence on the orientation of the controller cabinet. Figure 5-82 shows an example of controller cabinet that is difficult to open and maintain. Make sure that the cabinet door can fully open and does not encroach on private property when fully open. Also maintain the pedestrian clear circulation path (5’ minimum) when the door is open if possible.

**Figure 5-82 | Controller Cabinet Front Louvered Door Encroaching on Private Property**



### 5.10.2 332S Controller Cabinet

The 332S controller cabinet is a ground mounted cabinet which is the new ODOT standard for any new or temporary traffic signal. It provides more room and options than the old 332 cabinet.

### 5.10.3 332 Controller Cabinet

The 332 controller cabinet is a ground mounted cabinet. It is no longer used in new construction.

### 5.10.4 336 and 336S Controller Cabinet

The 336 and 336S controller cabinets are pole mounted cabinets, smaller than the 332 cabinet. These cabinets are no longer used for permanent or temporary signals.

In the past, these cabinets were commonly used in downtown corridors where the traffic signals operation is simple and pre-timed. However, there are a few reasons why the pole mounted cabinet is no longer used for a permanent or temporary installation:

- They have limited space inside and still take up the same amount of room (width and depth) as a standard 332S cabinet. The only room that is saved is directly underneath the cabinet, which isn't useable.
- They produce challenges for meeting ADA requirements since it creates a protruding object unless it is placed away from a pedestrian walkway.
- We now have a temporary pre-cast foundation that is easy to install and remove for temporary staging.

### 5.10.5 Controller Cabinet Power

The controller cabinet is wired to the service cabinet with two No. 6 AWG XHHW wires (shown on the plan sheets) and a ground wire (NOT shown on the plan sheets).

## 5.11 Service Cabinets

### 5.11.1 Base Mounted Service Cabinet (BMC)

A Base Mounted Service Cabinet (BMC) shown in Standard Drawing TM485 is the standard service type for traffic signal installations. The BMC should be located in the same quadrant as the controller cabinet. This makes the BMC convenient for maintenance personnel working on the signal. Locate the BMC at least 10 feet away from any other equipment (controller or any poles). The BMC shall be located around the corner on the intersecting side street to mitigate mainline exposure and to avoid obstructing the view of right turn traffic.

### 5.11.2 Base Mounted Service Cabinet with illumination (BMCL)

Section 5.11.1 still applies; except a Base Mounted Service Cabinet with illumination contains extra circuit breakers and a contactor to run a separate circuit for illumination that is part of the traffic signal (not strip lighting).

### 5.11.3 Base Mounted Service Cabinet, Flashing Beacons (BMCF, and BMCFL)

Section 5.11.1 still applies; except a base mounted service cabinet for flashing beacons contains contacts for the flashing indications. The BMCFL can accommodate illumination that is part of the flashing beacon. See Chapter 12 for more info on flashing beacons.

### 5.11.4 Pole Mounted Service Cabinet (SC) and Meter Base (MC)

This type of service is only allowed for temporary signals. See Chapter 11 for more information on temporary signals.

### 5.11.5 Remote Post Mounted Service (RPS)

ODOT no longer uses this style of service.

### 5.11.6 Wiring

The service cabinet is wired to the power source according to requirements of the power company. See section 5.8 for more information.

## 5.12 Junction Boxes

Junction boxes provide pull point for circuits coming from the signal controller cabinet to the various pieces of equipment in the field. They also provide a location for loop wire splices. Junction boxes shall be spaced a maximum of 300 feet between junction boxes on a conduit run.

Junction boxes used for the signal wiring should be located toward the approaching traffic end of the corner's radius. This provides dual use for signal wiring and detector loop access. See chapter 6 for detection specific information on junction boxes.

### 5.12.1 Junction Box Type and Size

The junction box type/size is determined by the total conduit diameter that is contained within the junction box and the location of where the junction box is located. However, there is default minimum type/size standard. Table 5-5 shows the default minimum standard and

Table **5-6** shows how to determine the types/sizes of junction if the default minimum is not adequate.

The type of surface that a junction box will be installed in is also an important consideration. This determines whether a concrete apron around the junction box is needed or not. The 'A' in the junction box designation (i.e. JB-2A) denotes a 12-inch wide concrete apron surrounding a precast concrete junction box. The concrete apron provides support to the fragile sides of the box. Type "A" boxes have concrete aprons and are to be used in non-paved areas (i.e. unpaved shoulders or landscaped areas) where maintenance vehicles may be present. **Do not use a precast concrete junction box within a travel lane or any access where it may be exposed to traffic.** Placing a junction box within a travel lane or where it is exposed to traffic should be

avoided at all costs. However, where it absolutely cannot be avoided, an approved cast iron junction box rated for traffic is required (JB-4 through JB-8).

**Table 5-5 | Default Minimum Junction Box Type/Size**

| Type/Size | Location/use |
|---|---|
| JB-3T: Two (Tandem) 30”x17”x12” boxes | The same quadrant as the signal controller: first access point for all signal, detector and interconnect circuits. |
| JB-2: Single 22”x12”x12” box | All quadrants without the signal controller: secondary access point for signal, detector, and/or interconnect circuits |
| JB-1: Single 17”x10”x12” box | All approach legs: detector and/or interconnect circuits |

**Table 5-6 | Sizing for Junction Box Type/Size**

| Type* | Size | Total Conduit Diameters Allowed (Inches) | Remarks | Material |
|---|---|---|---|---|
| JB-1 | 17”x10”x12” | 12 | Non-traffic areas only | Concrete |
| JB-2 | 22”x12”x12” | 18 | Non-traffic areas only | Concrete |
| JB-3 | 30”x17”x12” | 34 | Non-traffic areas only | Concrete |
| JB-4 | 8”x6”x6” | 5 | No loop splices | Cast Iron |
| JB-5 | 12”x10”x6” | 8 | No loop splices | Cast Iron |
| JB-6 | 12”x10”x8” | 8 | Loop spices OK | Cast Iron |
| JB-7 | 16”x12”x6” | 13 | No loop splices | Cast Iron |
| JB-8 | 16”x12”x8” | 13 | Loop splices OK | Cast Iron |

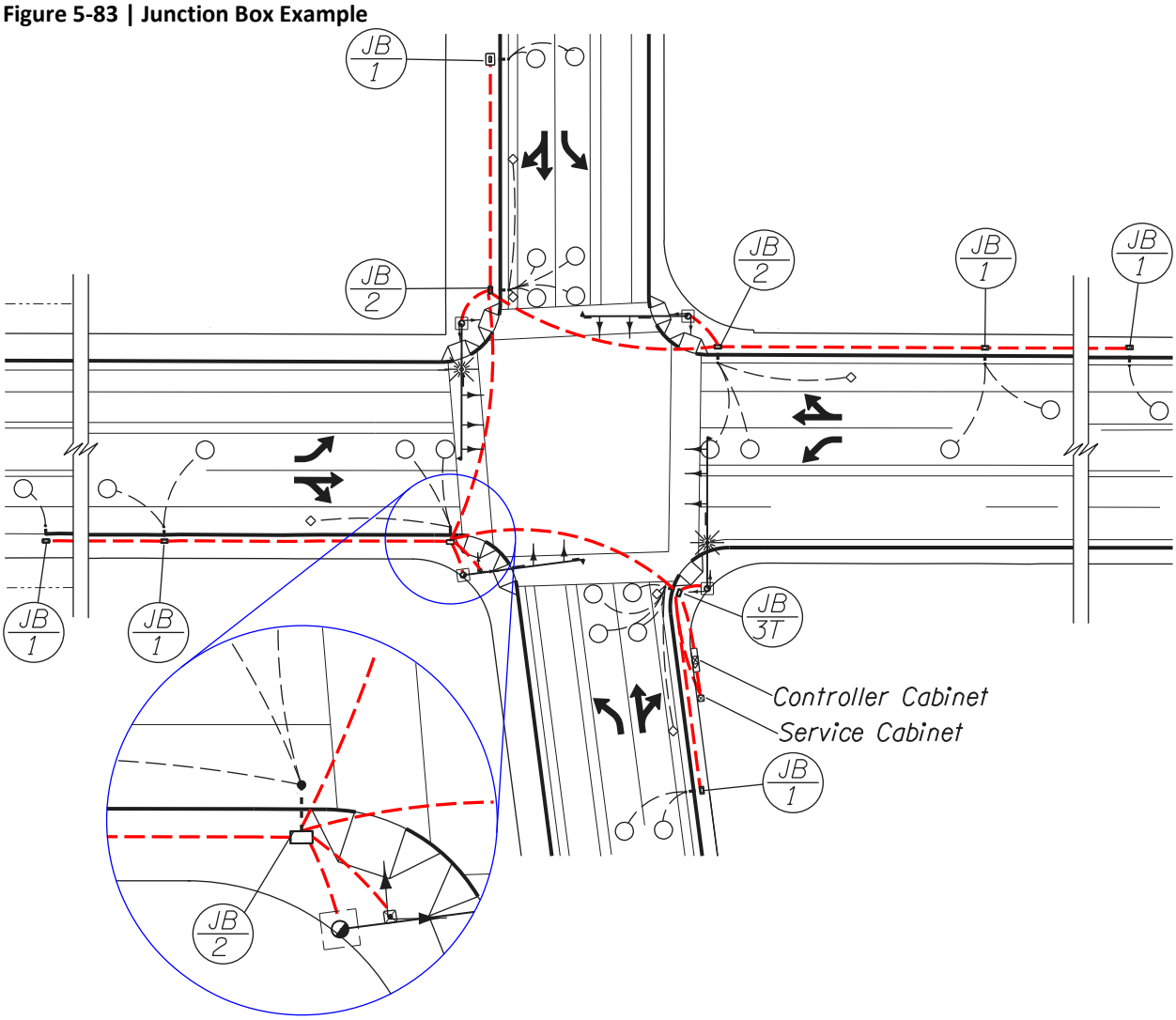
*JB-1 through JB-3 all have the option to be installed with an apron (JB-1A, JB-2A, and JB-3A)

**Do not place junction boxes in the slope or the landing area of an ADA Ramp. Junction boxes shall be placed in or behind sidewalks in a flat area that can be easily accessed by maintenance crews.**

Junction boxes and the guidelines for general use are shown on Standard Drawing TM472. See section 5.14.4 for more information on grounding/bonding requirements.

Figure 5-83 shows a base map that has correct placement of the junction boxes (and conduits) in relation to the signal poles, pedestrian ramps, and detector loops using the minimum default standard types/sizes.

**Figure 5-83 | Junction Box Example**




### 5.12.2 Use of Existing Junction Boxes

Use of existing junction boxes is allowed if all of the following statements are true:

1. the junction box is relatively new, in good condition, and in a good location,
2. the junction box is the appropriate size,
3. the junction box itself will not have to be adjusted due to the adjacent construction work, and
4. the junction box will not have any new conduit installed within.

Junction boxes are a very low cost item and it is more cost effective to remove an old junction box and install a new one if any of the above statements are false. A common construction

change order on preservation projects is additional payment for the contractor to adjust of install new junction boxes as a result of the work done on the roadway shoulder. Change orders should be avoided as they are generally more expensive than having the contractor bid the same work. Therefore, if there is a good chance that an existing junction box will be damaged, need adjustment, or is just a maintenance headache, you should remove it and install a new one. If, during construction, the contractor is able to use the existing junction box they can submit a Cost Reduction Proposal (as per specification 00140.70) that can be considered (which should result in a credit to the contract if the existing boxes can indeed be used).

## 5.13 Conduit

Once the junction box placement is complete, conduits can be planned to connect all equipment to the signal controller cabinet. Standard practice is to cross mainline in only one area (see Figure 5-83). This shall be accomplished with conduits installed by Horizontally Directional Drilling HDD (preferred method) or run in a common trench.

**The illumination circuit and photoelectric cell wiring is contained in a separate conduit for safety reasons. Illumination wiring is never routed through the controller cabinet.**

### 5.13.1 Conduit Size

To determine the proper size of conduit, two criteria need to be considered: ODOT requirements and the wire fill calculation. The larger of the two criteria governs. See Section 5.14 for information on wiring.

ODOT Requirements:

- Conduit crossing mainline or side street shall be 2-inch diameter minimum
- One spare 2-inch conduit from the controller cabinet to the nearest junction box shall be installed for future use, shall contain a poly pull line and be capped at each end
- 1½-inch minimum conduit
- 3-inch maximum conduit
- One spare 2-inch conduit from the signal pole to the nearest junction box shall be installed for future use of alternate detection, shall contain a poly pull line and be capped at each end. This spare conduit shall be omitted when a conduit will be installed for current use of an alternate detection system.

The ODOT minimum design standard for new construction allows a maximum wire fill of 70 percent of the NEC maximum allowed wire fill. This provides ample room for additional wires if needed in the future. For existing signals where new wire is being installed into existing conduit, the NEC maximum allowed wire fill is acceptable to use.

To calculate wire fill, use Table 5-7 through Table 5-9**.**

**Table 5-7 | Wire Area**

| Cable *AWG* | Cable Area ($in^2$) THWN | XHHW | Cable Type | Cable Area ($in^2$) |
|---|---|---|---|---|
| **18** | n/a | n/a | **FPC** | 0.0784 |
| **16** | n/a | n/a | **LF** | 0.0908 |
| **14** | 0.0097 | 0.0139 | **LF 18awg** | 0.0616 |
| **12** | 0.0133 | 0.0181 | **6/P** | 0.3117 |
| **10** | 0.0211 | 0.0243 | **12/P** | 0.4902 |
| **8** | 0.0366 | 0.0437 | **CC 4/14** | 0.1257 |
| **6** | 0.0507 | 0.0590 | **CC 5/14** | 0.1452 |
| **4** | 0.0824 | 0.0814 | **CC 6/14** | 0.1698 |
| **3** | 0.0973 | 0.0962 | **CC 7/14** | 0.1735 |
| **2** | 0.1158 | 0.1146 | **CC 10/14** | 0.2922 |
| **1** | 0.1562 | 0.1399 | | |
| **1/0** | 0.1855 | 0.1825 | | |
| **2/0** | 0.2223 | 0.2190 | | |
| **3/0** | 0.2679 | 0.2642 | | |
| **4/0** | 0.3237 | 0.3197 | | |

**Table 5-8 | Conduit Fill Table (NEC & ODOT Max Fill: RMC Article 344 in NEC Chapter 9, table 4)**

| Conduit size Inch | *Internal Dia inch* | NEC % Max Fill ($in^2$) 1 wire 53% | 2 wire 31% | 3+ wires 40% | ODOT % Max Fill ($in^2$) 1 wire 53% | 2 wire 31% | 3+ wires 40% |
|---|---|---|---|---|---|---|---|
| 1/2 | 0.632 | 0.166 | 0.097 | 0.125 | 0.116 | 0.068 | 0.088 |
| 3/4 | 0.836 | 0.291 | 0.170 | 0.220 | 0.204 | 0.119 | 0.154 |
| 1 | 1.063 | 0.470 | 0.275 | 0.355 | 0.329 | 0.193 | 0.248 |
| 1 1/4 | 1.394 | 0.809 | 0.473 | 0.610 | 0.566 | 0.331 | 0.427 |
| 1 1/2 | 1.624 | 1.098 | 0.642 | 0.829 | 0.768 | 0.449 | 0.580 |
| 2 | 2.083 | 1.806 | 1.056 | 1.363 | 1.264 | 0.739 | 0.954 |
| 2 1/2 | 2.489 | 2.579 | 1.508 | 1.946 | 1.805 | 1.056 | 1.362 |
| 3 | 3.090 | 3.975 | 2.325 | 3.000 | 2.782 | 1.627 | 2.100 |
| 3 1/2 | 3.570 | 5.305 | 3.103 | 4.004 | 3.714 | 2.172 | 2.803 |
| 4 | 4.050 | 6.828 | 3.994 | 5.153 | 4.779 | 2.796 | 3.607 |

**Table 5-9 | Wire Fill Requirements**

| **Wire Fill Requirements** | |
|---|---|
| Existing conduit: | Sum of Cable Area ($in^2$) within conduit **<** NEC % Max Fill ($in^2$) |
| New conduit: | Sum of Cable Area ($in^2$) within conduit **<** ODOT % Max Fill ($in^2$) |

**Figure 5-84 | Conduit Sizing Example 1**

## Conduit Sizing Example No. 1

**Given:** How large of a new conduit is needed if the conduit has to carry the following cables?

1.) Thirteen No. 14 AWG THWN
2.) Two Loop Feeder Cables*
3.) One 6/P (interconnect cable)*
4.) One No. 8 AWG THWN (signal system common)
5.) One No. 6 AWG THWN (Ground/Bond wire. Not shown on) plans, but required by specification)

**Step 1:** Determine Total cable area using Cable Area Chart:

| | | | |
|---|---|---|---|
| 13*(0.0097) = | 0.1261 | 1*(0.0366)= | 0.0366 |
| 2*(0.0908) = | 0.1816 | 1*(0.0507)= | 0.0507 |
| 1*(0.3117) = | 0.3117 | | |

*Note - loop feeder cables and interconnect cable are normally installed in separate conduits from the signal system.

Total Sum = (0.1261+0.1816+0.3117+0.0366+0.0507) = **0.7067**

**Step 2:** Use the ODOT % Max Fill Chart to compare calculated total sum to max. allowable fill (use column for 3+ wires - since the total # of wires in this conduit is 18)

0.7067 > 0.580, therefore, a 1.5" conduit is too small

0.7067 < 0.954 , therefore a 2" conduit is OK**

**check to make sure that a 2" conduit will meet the other ODOT requirements for conduit size

**Figure 5-85 | Conduit Sizing Example 2**

## Conduit Sizing Example No. 2

**Given:** An existing 2" conduit has the following existing cables, can 4 additional Loop Feeder cables be installed?

1.) Thirteen AWG No. 14 THWN
2.) Two Loop Feeder Cables*
3.) One 6/P (interconnect cable)*
4.) One No. 8 AWG THWN (signal system common)
5.) One No. 6 AWG THWN (Ground/Bond wire. Not shown on) plans, but required by specification)

**Step 1:** Determine Total cable area using Cable Area Chart:

| | | | |
|---|---|---|---|
| 13*(0.0097) = | 0.1261 | 1*(0.0366)= | 0.0366 |
| 2*(0.0908) = | 0.1816 | 1*(0.0507)= | 0.0507 |
| 1*(0.3117) = | 0.3117 | | |
| 4*(0.0908) = | 0.3632 } New Cables | | |

*Note - loop feeder cables and interconnect cable are normally installed in separate conduits from the signal system.

Total Sum =(0.1261+0.1816+0.3117+0.3632+0.0366+0.0507+0.3632) =1.0699

**Step 2:** Use the NEC % Max Fill Chart to compare calculated total sum to max. allowable fill (use column for 3+ wires - since the total # of wires in this conduit is 22)

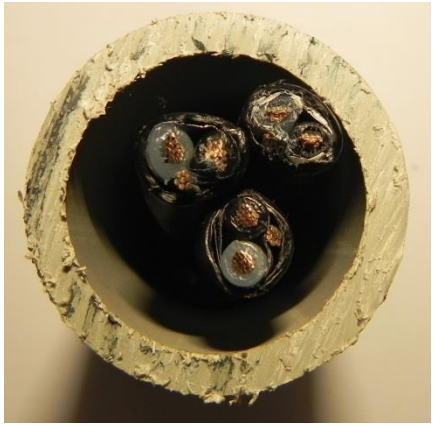
1.0699 < 1.363 , therefore the existing 2" conduit is big enough to allow the new cables**

** note that for a new conduit installation, a 2.5" conduit would be required based on ODOT's Max Fill Chart

Wire fill rates can be visually deceiving if you are not accustomed to working with conduit and wire. The following photos should be helpful in providing some perspective (note: the conduit bushing has not been installed for better photo clarity):

1” conduit w/5 loop feeder cables
Exceeds NEC max fill
Exceeds ODOT max fill

1” conduit w/4 loop feeder cables
Exceeds NEC max fill
Exceeds ODOT max fill



1” conduit w/3 loop feeder cables
Does NOT exceed NEC max fill
Exceeds ODOT max fill

1” conduit w/2 loop feeder cables
Does NOT exceed NEC max fill
Does NOT exceed ODOT max fill

1½” conduit w/control cables
Does NOT exceed NEC max fill
Does exceed ODOT max fill

2” conduit w/control cables
Does NOT exceed NEC max fill
Does NOT exceed ODOT max fill

1½” conduit w/9 loop feeder cables

Does NOT exceed NEC max fill
Does exceed ODOT max fill

1½” conduit w/9 loop feeder cables
+1 video cable
Exceeds NEC max fill
Exceeds ODOT max fill

2½” conduit w/22 loop feeder cables
Exceeds NEC max fill
Exceeds ODOT max fill

3” conduit w/22 loop feeder cables
Does NOT Exceed NEC max fill
Does NOT Exceed ODOT max fill

**For new wire installations in existing conduit, the signal designer MUST check the existing conduit size and wire count in the field to make sure the proposed new wires will not exceed the NEC maximum allowed wire fill. Failure to check this is a fatal flaw.**

### 5.13.2 Conduit Materials

There are several different types of conduit materials that can be used for traffic signal installations. The conduit material is NOT specified on the plan sheets as this information is contained within the standard drawings and section 00960.42 of the Oregon Standard Specifications for Construction. The following information is some basics on conduit materials. Refer to the specifications and standard drawings for detailed info.

- **Rigid Metallic Conduit**
  - Rigid galvanized metallic conduit should be used in all locations where there is the potential for damage, which includes any conduit located above ground (on poles or structures).
  - For conduit located under railroad tracks, there is a requirement to place the conduit holding wires within a rigid metallic conduit “sleeve” as per standard specification 00960.41(e).
- **Rigid Non-Metallic Conduit**
  - Fiberglass (schedule 40) – used for elbows and in foundations as per standard specification 00960.42(f) and 00960.42(d) respectively. Fiberglass can also be used instead of Rigid Metallic Conduit in above ground locations.

- PVC (schedule 40) – typically the type of rigid nonmetallic conduit used in most applications.
- High density polyethylene (HDPE) – typically used when installing conduit by horizontal directional drilling.

### 5.13.3 Expansion Fittings

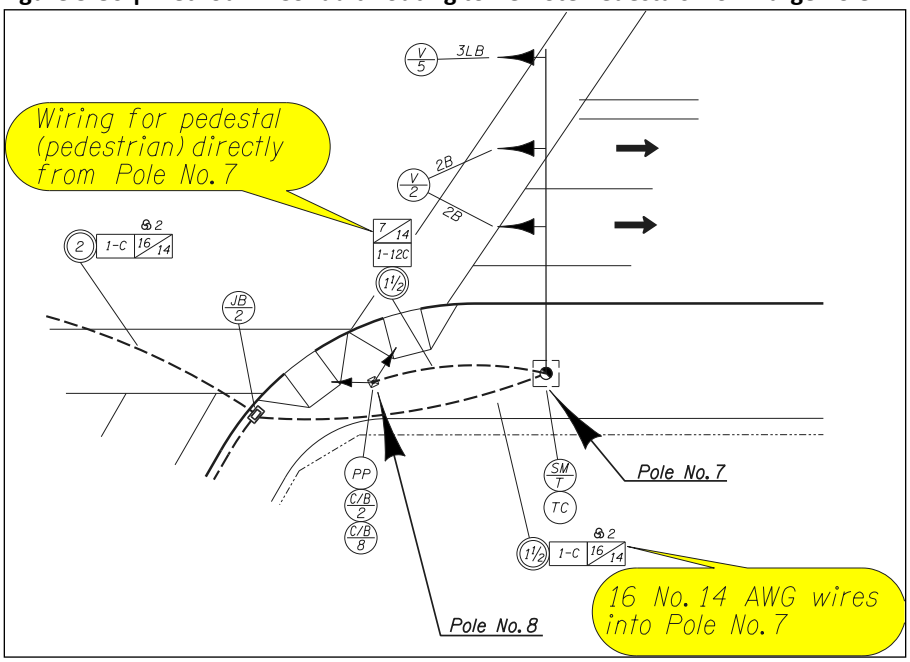
Whenever traffic signal conduit must be placed on or in a structure, conduit expansion fittings are required. The structure will experience expansion/contraction depending on the stresses subjected to it, and so the conduit must also allow for movement too. Therefore, expansion fittings are used on the conduit run at all structure expansion joints as per standard specification 00960.42(k). Because the standard specification states this requirement, it is not necessary to show this detail on the plan sheets.

### 5.13.4 Routing Conduit to Remote Pedestals (Vehicle, Pedestrian and Pushbutton)

Two methods for routing conduit to a remote pedestal when a large pole is located in the same quadrant are described below. Contact the Region Electrical Crew to determine their preference.

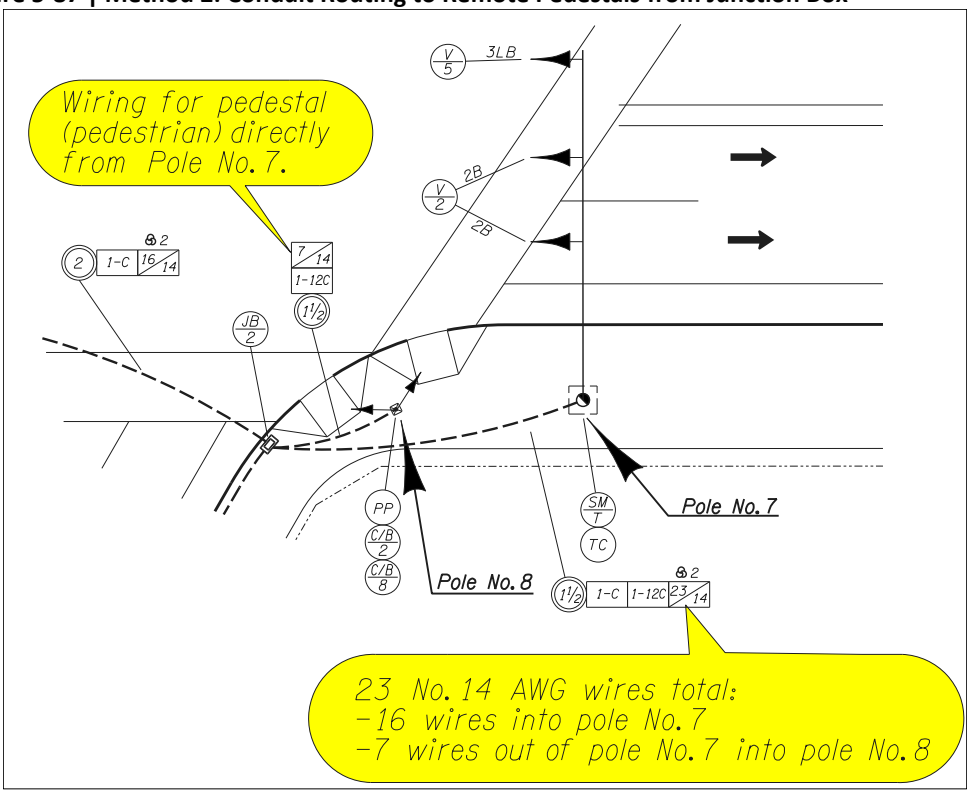
1. Route the conduit from the junction box in the same quadrant to the large pole, then from the large pole to the remote pedestal. The wiring for the remote pedestal will be spliced in the terminal cabinet of the large pole. Routing the conduit and wiring this way allows for easy replacement of the pedestal and wiring to the pedestal in the event of a pedestal knock-down (all pedestals are designed to break-away) due to the splice point in the terminal cabinet. See Figure 5-86.

**Figure 5-86 | Method 1: Conduit Routing to Remote Pedestals from Large Pole**



2. Route the conduit from the junction box in the same quadrant directly to the remote pedestal. The wiring for the remote pedestal will be spliced in the terminal cabinet of the large pole. Routing the conduit and wiring this way still allows for easy replacement of the pedestal and wiring to the pedestal in the event of a pedestal knock-down, but contains one additional access point (the junction box) rather than a direct connection to between the pedestal and large pole. See Figure 5-87.

**Figure 5-87 | Method 2: Conduit Routing to Remote Pedestals from Junction Box**



When a large pole is NOT located in the same quadrant as the remote pedestal (e.g. T-intersection), the conduit should route from a junction box in that quadrant to the remote pedestal, shown in Figure 5-88. Do NOT route conduit directly to the remote pedestal. See Figure 5-89.

**Figure 5-88 | Conduit Routing to Remote Pedestal Not Located in Same Quadrant as Large Pole**

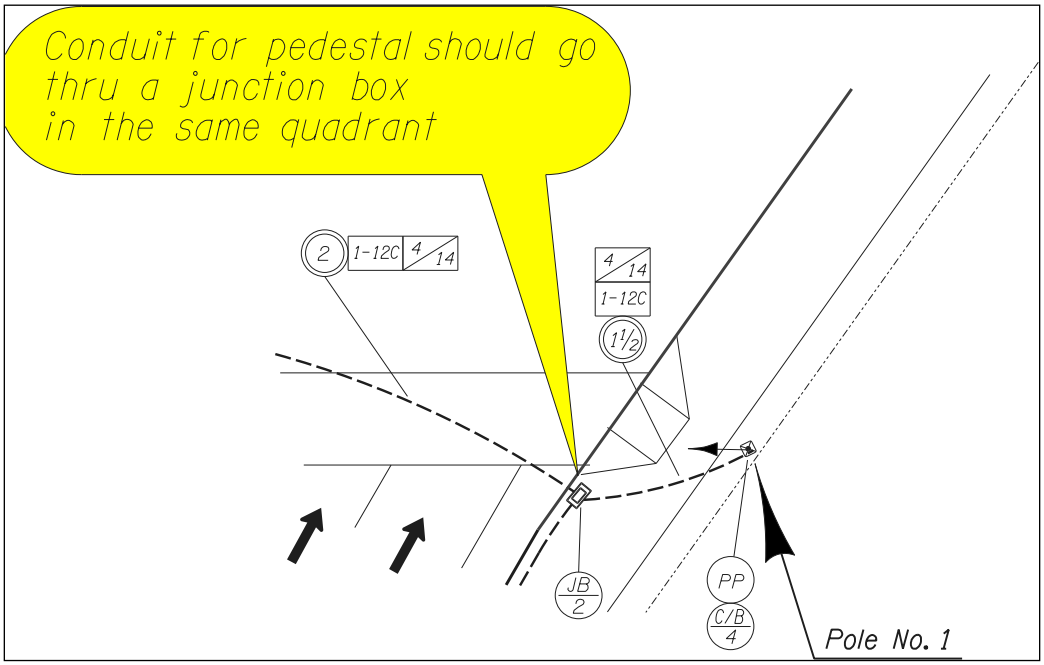
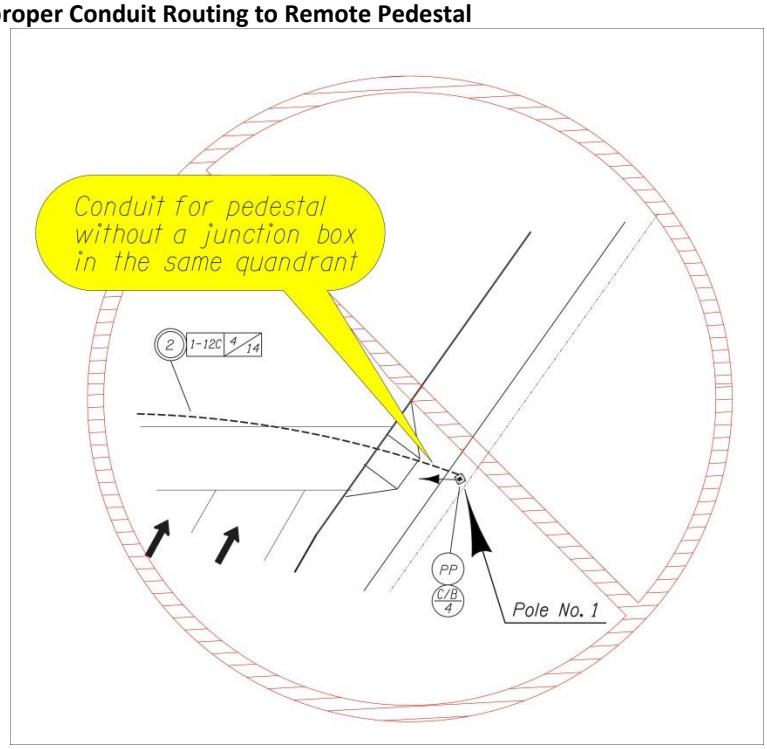



**Figure 5-89 | Improper Conduit Routing to Remote Pedestal**



## 5.14 Wiring

Traffic signals have three distinct systems for wiring based on the voltage used:

- 120V AC for all signal indications (includes both vehicle and pedestrian indications)
- 240V AC for illumination that is part of the traffic signal
- 24V DC for pedestrian pushbuttons and vehicle detection system

**When wiring a traffic signal, NO SPLICING IS ALLOWED! The only exception to this rule is splicing loop wire to loop feeder cable in the junction box.**

### 5.14.1 Wire Types

The following wire types are used for traffic signals:

**Single Conductor Wire**

Single conductor wire is the standard for wiring located within conduits (i.e. from the controller cabinet to the pole's terminal cabinet). See Standard Drawing TM470 for the color code. However, control cables may be used in conduits with concurrence from the ODOT Region Electrical Crew.

**THWN**

THWN stands for:

- T: Thermoplastic insulation
- H: High temperature (usually 75 °C when dry or damp)
- W: Moisture resistant (usually 60 °C when wet)
- N: Nylon jacket

This wire consists of a stranded copper conductor with thermoplastic installation and nylon jacket. This type of wire is the standard for providing electricity to:

- signal heads
- pedestrian signal heads
- pushbuttons
- system commons
- photo control electronic relay
- flashing beacons

**XHHW**

XHHW stands for:

- X: Cross-linked synthetic polymer insulation
- HH: Higher temperature (usually 90 °C when dry or damp)
- W: Moisture resistant (usually 60 °C when wet)

This wire consists of a stranded copper conductor with cross-linked synthetic polymer insulation. This type of wire is the standard for providing electricity to:

- loop wires
- illumination
- power from BMCL to signal controller cabinet

**Control Cable (multi-conductor cable)**

Control cables are multi-conductor cable with assorted stranded copper wires of a particular gauge (No. 14 AWG, No. 12 AWG, etc.). The standard material (wire and insulation) are defined by IMSA (International Municipal Signal Association). They are the standard for aerial installations, such as a temporary signal. Control cables may be used within conduits (rather than single conductor wires) with concurrence from the Region Electrical Crew. See Standard Drawing TM470 for color code.

ODOT's standard is to use control cable from the terminal cabinet to each of the signal heads, in both mast arm and span wire installations. The control cables are shown and labeled on all span wire plan sheets between strain poles. The cables within a mast arm are not shown on the plans, but are instead detailed in the specifications. See Standard Drawing TM470 for wiring guidance on single conductor and control cable color codes.

**Interconnect Cable**

Interconnect cable consists of a shielded cable containing 6+ twisted pairs of No. 19 AWG wires. This cable is used solely for the purposes of communication between traffic signals. 12+ twisted pair of No. 19 AWG wires may also be used if additional wires are needed. See Chapter 7 for more information on interconnect design.

### 5.14.2 Wire Gauge

The American Wire Gauge (AWG) is a standardized wire gauge system for the diameters of round electrically conducting wire. The cross-sectional area of each gauge is an important factor for determining its current carrying capacity. Increasing gauge numbers give decreasing wire diameters.

The standard wire gauges used by ODOT for traffic signal installations are shown below:

- No. 6 AWG is used for:
  - power from the BMCL to the signal controller
  - Ground/bond wire
- No. 8 AWG is used for the traffic signal system neutral
- No. 10 AWG is used for illumination
- No. 12 AWG is used for:
  - Pedestrian signal system neutral (for use with pedestrian pedestals only)
  - Traffic signal system neutral (for use with vehicle pedestals only)
  - Power from BMCL to the photo control electronic relay
  - PTR signs

- No. 14 AWG is used for powering:
  - Signal heads (vehicle/bike)
  - Pedestrian signal heads
  - Pushbuttons
  - Pushbutton system common
  - Flashing beacons

### 5.14.3 Voltage Drop

In certain circumstances, such as a temporary one-lane, two-way traffic signal where the distance between the signal controller and the signal equipment is excessive, a larger gauge wire (than the ODOT standard) may be needed to power the equipment due to the voltage drop that occurs over the distance of the wire. Voltage drop should not exceed three percent. However, with the use of LED signal heads (which do not require as many watts as an incandescent signal head) the need to use larger gauge wire is now rarely a necessity, even with temporary one-lane, two-way traffic signals.

### 5.14.4 Bonding/Grounding Requirements

All ground rods, metal conduit, metal poles, grounding wire, metallic junction boxes, metallic junction box covers, and cabinets shall be mechanically and electrically secure to form a continuous, effectively grounded and bonded system. Typically, a No. 6 AWG stranded copper wire is used for grounding/bonding.

The ODOT Standard Drawings, Section 00960.50 of the Oregon Standard Specifications for Construction, and National Electric Code contain all the requirements for bonding and grounding. Because of this, the signal plan sheets typically do NOT show or detail any grounding/bonding requirements. It is recommend that the signal designer consult these sources or contact the ODOT Region Electrical Crew for additional information on grounding/bonding.

### 5.14.5 Common/Neutral (Shared) Wire

A neutral/common wire is needed for each signal system to complete the circuit. There are three separate wiring systems used in traffic signals:

1. 120V AC for signal indications – Includes both pedestrian & vehicle indications
2. 24V DC for pedestrian pushbuttons
3. 240V AC for illumination on signal poles (two hot 120V wires, No. 10 AWG XHHW wire, therefore no common/neutral required)

One common/neutral wire is required from the signal controller cabinet to each pole that has signal indications attached to it, regardless of the number of signal indications or phases. One common/neutral wire is required from the signal controller cabinet to each pole that has a pedestrian pushbutton attached to it, regardless of the number of pushbuttons. For example, a vehicle pedestal with a signal indication, two pedestrian

indications, and two pushbuttons will require a total of two common/neutral wires; one for the signal indications (120V AC) and one for the pushbuttons (24V DC).

When using single conductor, the size of the common/neutral wire used for signal indications varies depending on the size of the pole that it will be going into:

- For large signal poles (those over 4” in diameter, i.e. mast arm poles and strain poles) with signal indications, one No. 8 AWG THWN wire is required.

- For small signal poles (those 4” in diameter, i.e. pedestals) with signal indications, one No. 12 AWG THWN wire is required.

When using control cable, the common/neutral is inclusive, therefore the size of the common/neutral is based on the AWG of the control cable (typically No. 14).

The size of the common wire used for pedestrian pushbuttons does not vary with pole size:

- For pedestrian pushbutton, one No. 14 AWG THWN wire is required.

The common/neutral wire from the signal cabinet is terminated at the terminal cabinet located on the signal pole (this is the common/neutral wire that is shown and detailed on the signal plan sheet). From there, additional common/neutral wires are used as necessary from the terminal cabinet on the signal pole to each signal indication (this wiring is NOT shown or detailed on the signal plan sheet). For small poles that do not have a terminal cabinet, such as vehicle and pedestrian pedestals, the common/neutral wire is terminated in a terminal block within the signal indication.

### 5.14.6 Wiring Signal Heads (From Head to Terminal Cabinet)

Each signal indication in a signal head requires a “Hot” wire and a “common/neutral” wire in order to complete the circuit. Refer to Figure 5-91 when reading the bulleted text below for a description of the wiring diagram that is used in Figure 5-91 through Figure 5-98 for each signal head type:

- The Type 2 signal head shows the hot wiring for each indication (red, yellow, green) entering the signal indication from right side and the common/neutral wiring entering from the left side. This wiring is contained within the signal head itself and NOT shown or detailed on the plan sheets.

- The wiring from the terminal block within the signal head connects to the terminal cabinet located on the signal pole. This wiring is accomplished with a 7 conductor control cable; one for each signal head regardless of type (See Standard Drawing TM470, See Figure 5-90). It is located within the mast arm

or along the span wire. Note that use of a 7 conductor control cable results in one to three spare wires depending on the type of signal head that is used. This wiring is NOT shown or detailed on the plan sheets for mast arm installations, as the specifications and standard drawing TM470 detail this information, but it is shown and detailed on the plan sheets for span wire installations.

- From the terminal cabinet on the signal pole, individual conductor wire (default standard) or control cable (if requested by the Region Electrical Crew) is routed back to the signal controller cabinet (in conduit, for both mast arm and span wire installations) to power each signal phase. See 5.14.8 for more info. This wiring is shown and detailed in the plan sheets. Note that the No. 8 AWG common/neutral wire used in each example for the individual conductors assumes that the signal head is attached to a large pole (over 4” in diameter). If the signal head was attached to a small pole, such as a vehicle pedestal, then a No. 12 AWG common/neutral wire would be used instead.

**Figure 5-90 | Standard Drawing TM470 Signal Head Wiring**

| | | | SIGNAL HEAD TYPES | | | |
|---|---|---|---|---|---|---|
| 7 CONDUCTOR CONTROL CABLE | | | 6L or 3LBF | 5 or 7 | 1R, 1Y 2, 3L, 3LCF, 3R 4 or 9 | 10 |
| CONDUCTOR NUMBER | BASE COLOR | FIRST TRACER | | | | |
| 1 | WHITE | — | NEUTRAL | NEUTRAL | NEUTRAL | NEUTRAL |
| 2 | BLACK | — | YELLOW | YELLOW | YELLOW | YELLOW |
| 3 | RED | — | RED | RED | RED | RED 1 |
| 4 | ORANGE | — | FLASHING YELLOW | TURN YELLOW | SPARE | RED 2 |
| 5 | GREEN | — | GREEN | GREEN | GREEN | GREEN |
| 6 | BLUE | — | SPARE | TURN GREEN | SPARE | SPARE |
| 7 | WHITE | BLACK | SPARE | SPARE | SPARE | SPARE |

Figure 5-91 shows the wiring required for a type 2, 3L, 3R, or 3LCF signal head. These signal head types contain one phase and three functions (Red, Yellow, and Green). The 3LCF signal head yellow indication performs two functions (flashing arrow and solid arrow) via software programming. One "hot" wire for each function and one common/neutral wire is required.

**Figure 5-91 | Wiring for Type 2, 3L, 3R, and 3LCF Signal Heads**

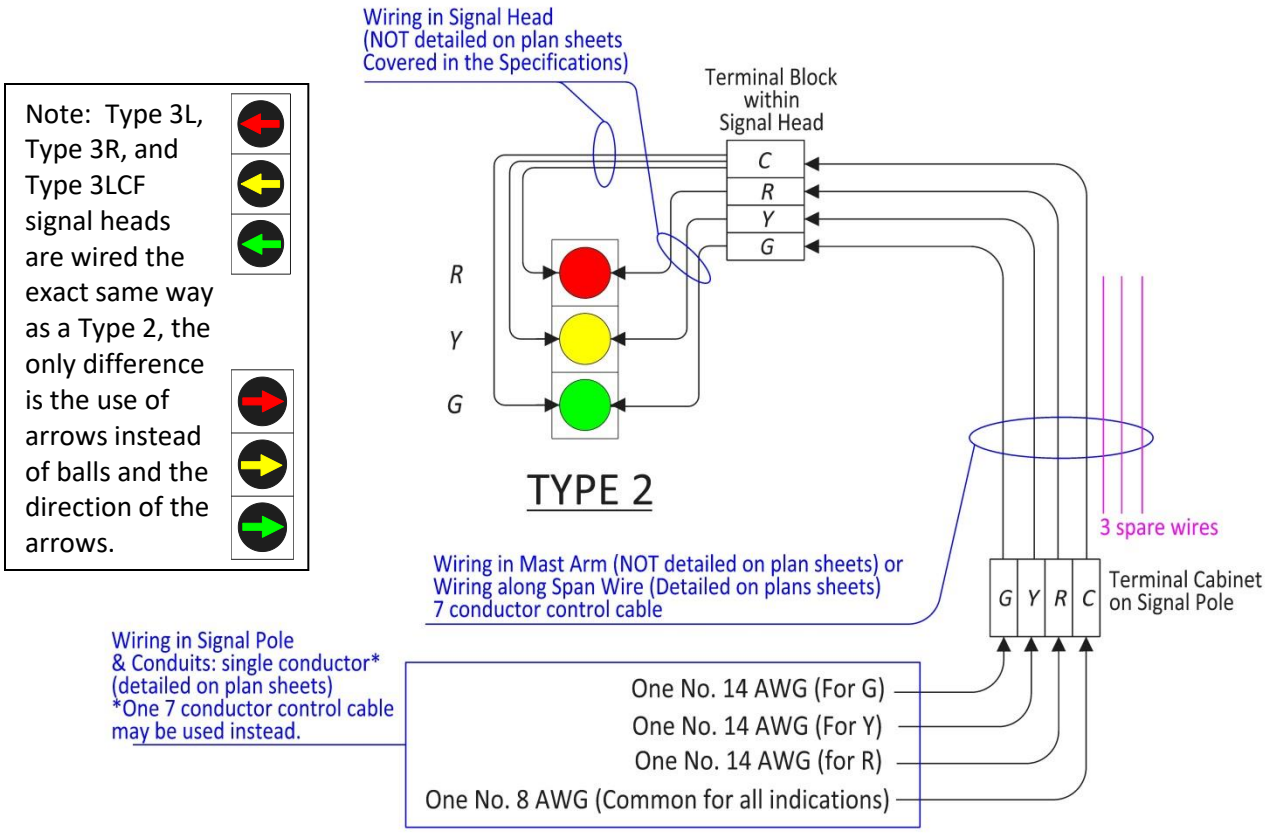


Figure 5-92 shows the wiring required for a Type 3LBF signal head. This signal head type contains one phase and four functions (Red, Yellow, Flashing Yellow and Green). All of the solid arrow indications are wired to the protected left turn phase (typically 1, 3, 5, or 7) and the flashing yellow arrow is wired to an unused pedestrian yellow phase (typically ped phase 2, 4, 6, or 8) which via software is linked to the opposing through movement. This results in a total of four No. 14 AWG wires (plus a common/neutral) to power this type of signal head.

**Figure 5-92 | Wiring for Type 3LBF Signal Head**

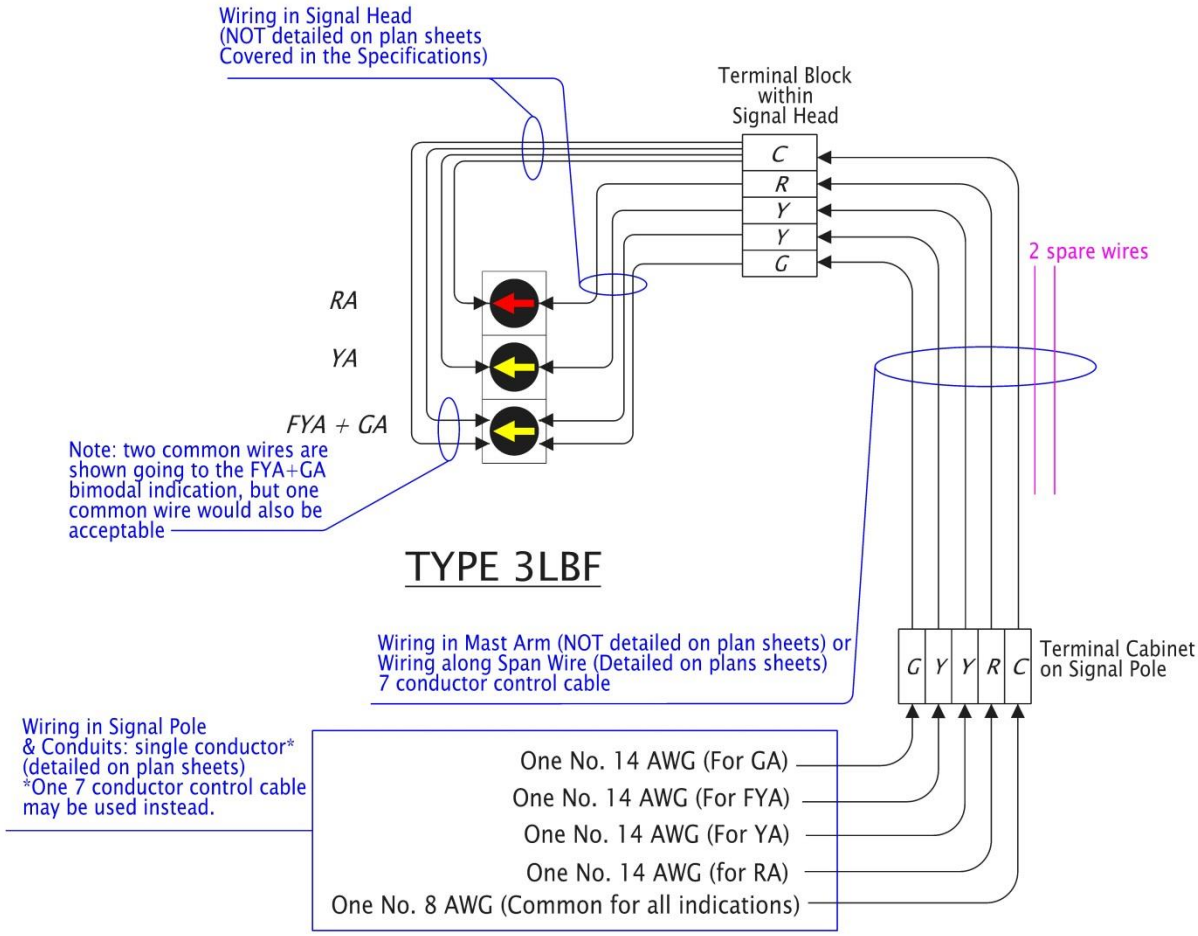


Figure 5-93 shows the wiring required for a type 4 or type 9 signal head. These signal head types contain one phase and three functions (Red, Yellow, and Green). The two green indications (one ball and one arrow) always operate together on the same phase. Because of this, the wiring shown and detailed on the plan sheets looks no different than for a type 2 signal head. The additional wires needed to power each green indication occur within the signal head, which is not shown or detailed on the plan sheets.

**Figure 5-93 | Wiring for Type 4 & 9 Signal Heads**

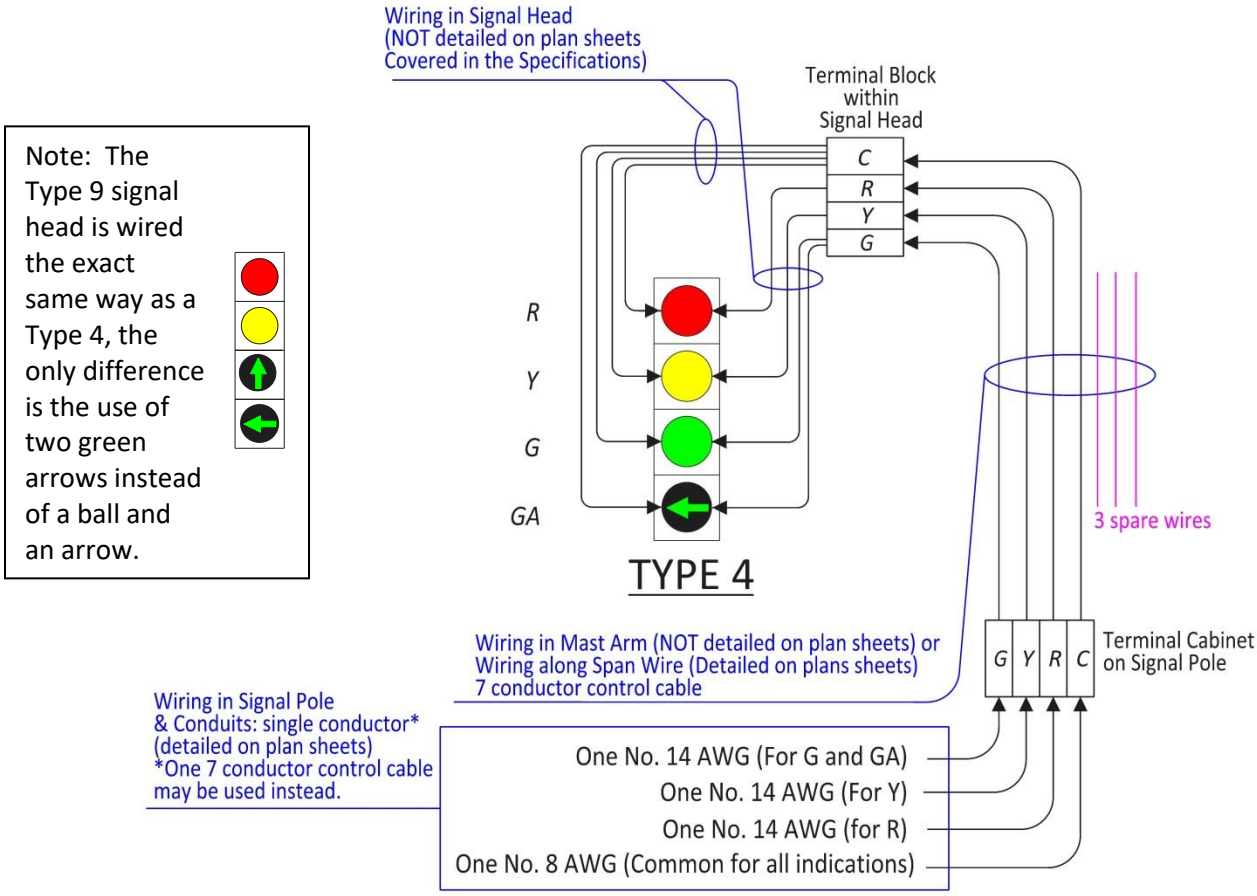


Figure 5-94 shows the wiring required for a Type 5 signal head. This signal head type contains two separate phases (the arrow indications are for the protected right turn phase and the ball indications are for the through phase/permissive right turn) and five functions total (Red, Yellow, and Green for one phase. Yellow and Green for the second phase). All of the ball indications are wired to the through movement phase (typically 2, 4, 6, or 8) and the two arrow indications are wired to the complimentary protected left turn phase (typically 1, 3, 5, or 7). This results in a total of five No. 14 AWG wires (plus a common/neutral) to power these types of signal heads.

**Figure 5-94 | Wiring for Type 5 Signal Heads**

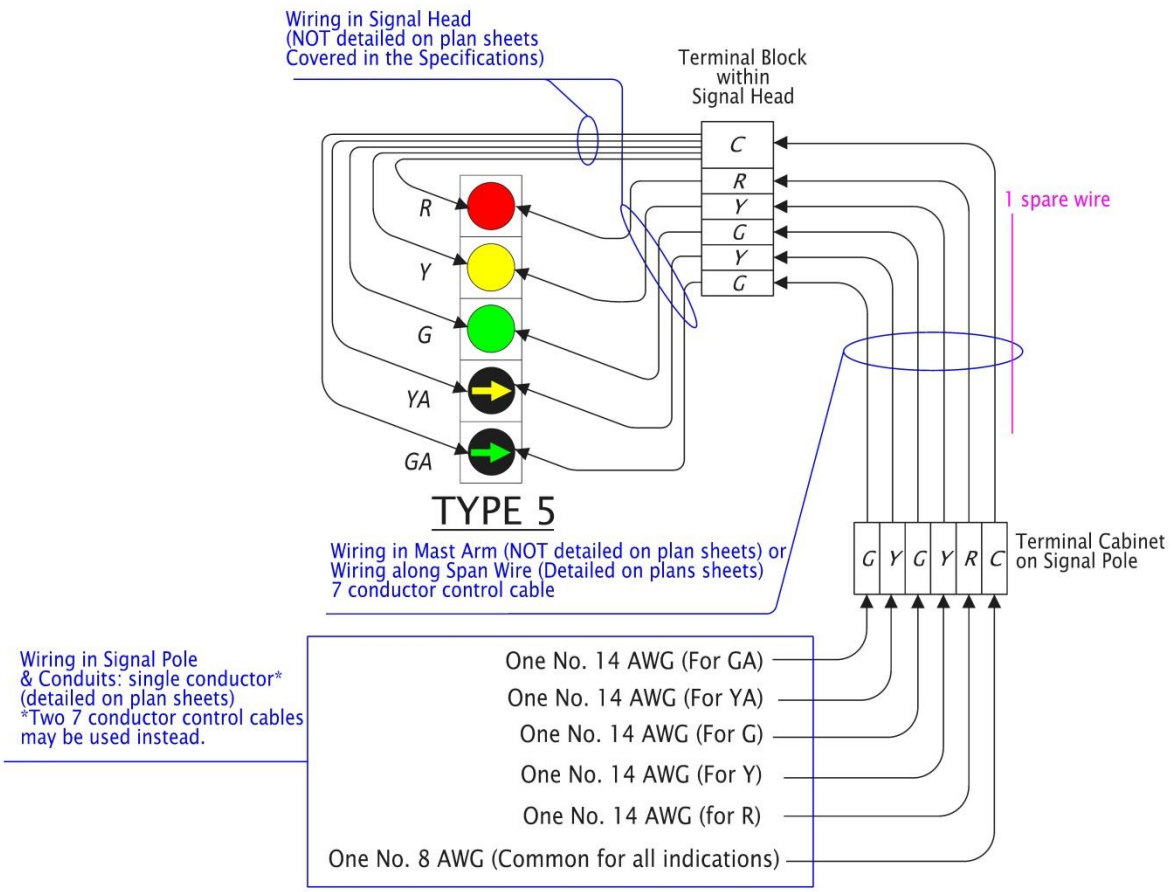


Figure 5-95 shows the wiring required for a Type 6L signal head. This signal head type contains one phase (the left turn) and four functions (Red, Yellow, Flashing Yellow, and Green). All of the solid arrow indications are wired to the protected left turn phase (typically 1, 3, 5, or 7) and the flashing yellow arrow is wired to an unused pedestrian yellow phase (typically ped phase 2, 4, 6, or 8) which via software is linked to the opposing through movement. This results in a total of four No. 14 AWG wires (plus a common/neutral) to power this type of signal head.

**Figure 5-95 | Wiring for Type 6L Signal Head**

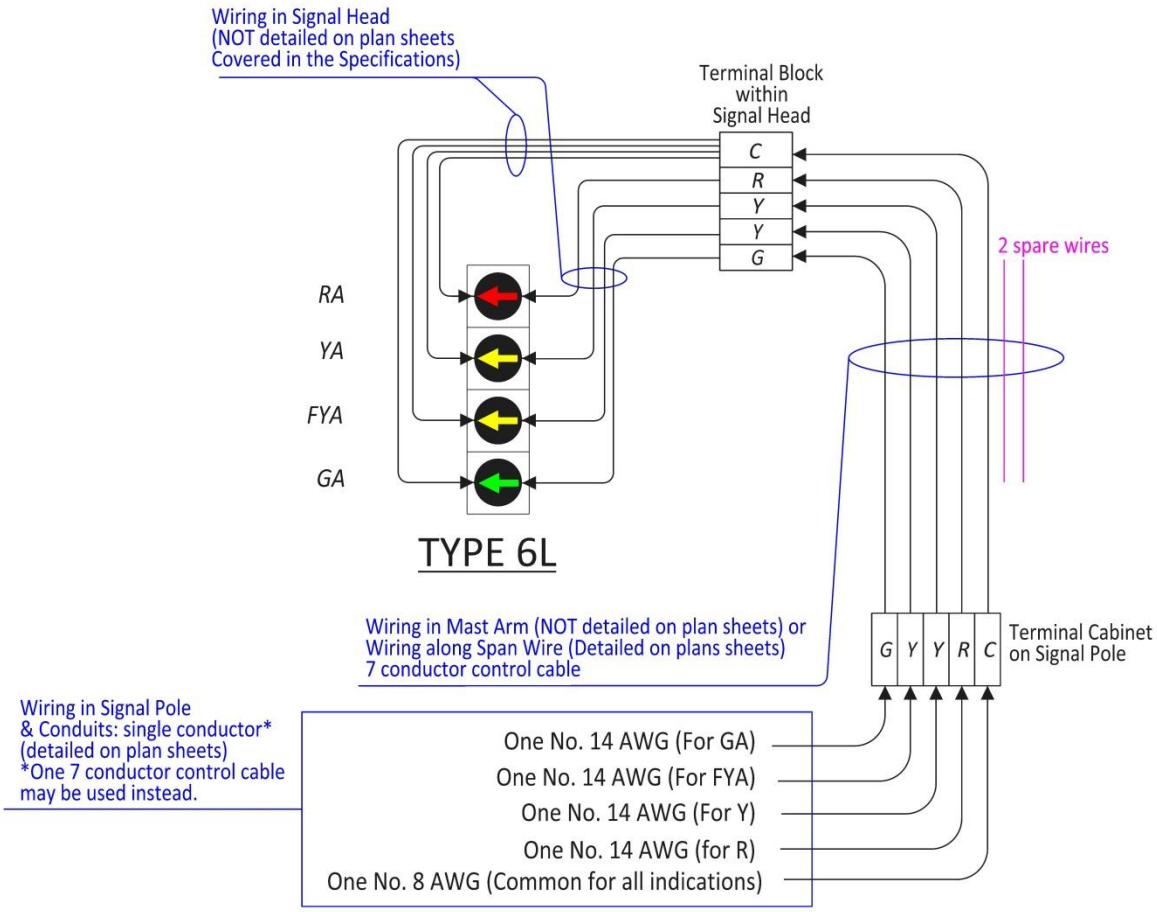


Figure 5-96 shows the wiring requirements for a type 7 signal head. This signal head type contains two separate phases and a total of four functions (Red, yellow, Green for one phase. Green for the second phase). Unlike the type 4 signal head, the green arrow and green ball operate on the different phases. All of the ball indications are wired to the through movement phase (typically 2, 4, 6, or 8) and the green arrow indication is wired to the adjacent protected left turn phase (typically 1, 3, 5, or 7). This enables the green arrow to only be displayed during railroad preemption and remain dark during normal phase rotation. This results in a total of four No. 14 AWG wires (plus one common/neutral) to power this type of signal head.

**Figure 5-96 | Wiring for Type 7 Signal Head**

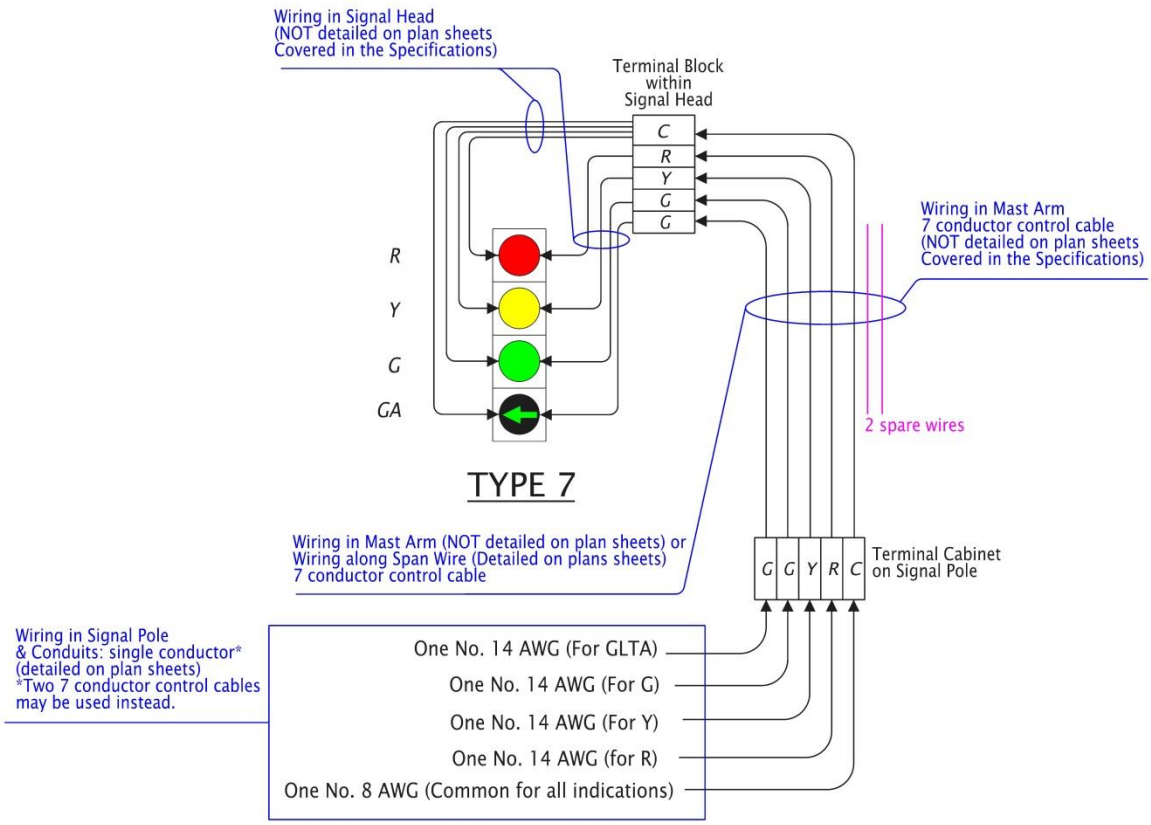


Figure 5-97 show the wiring requirements for a type 8 signal head. This signal head type contains one phase and two functions (red and green), resulting in a total of two No. 14 AWG wires (plus one common/neutral) to power it. This signal head type is always mounted on a vehicle pedestal as per standard drawing TM497.

**Figure 5-97 | Wiring for Type 8 Signal Head**

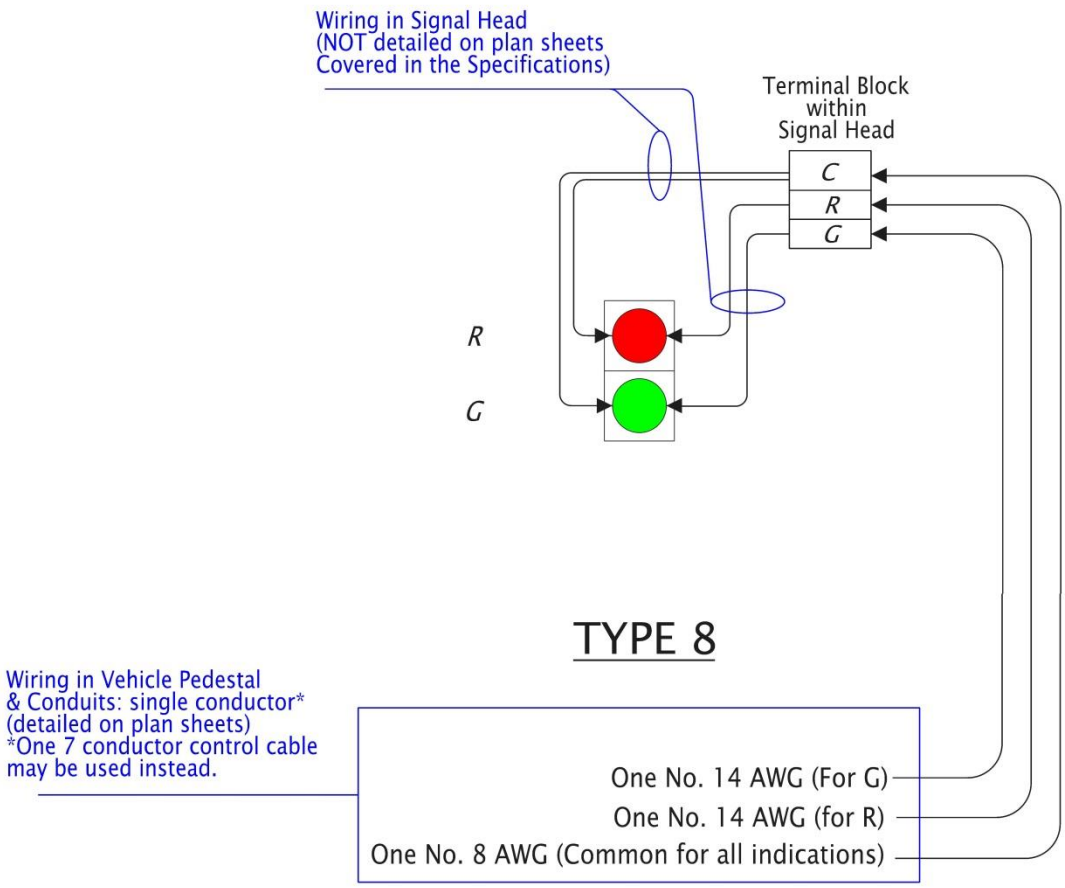
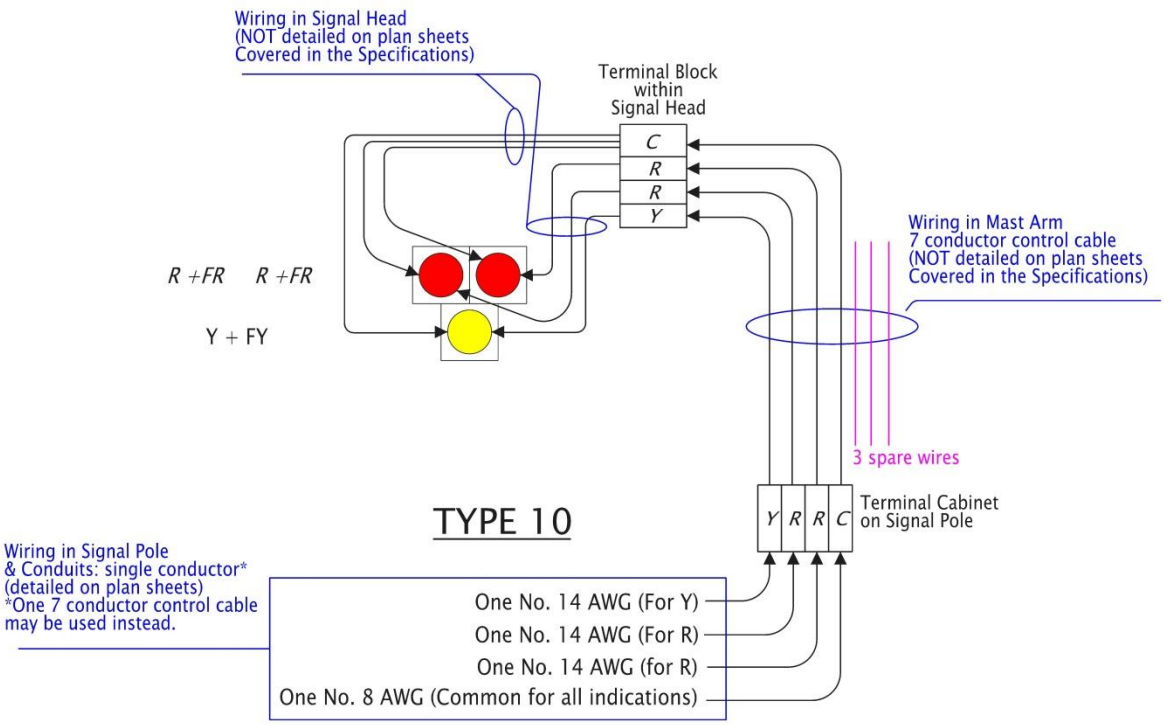


Figure 5-98 shows the wiring requirements for a type 10 signal head. This signal head type contains one phase and two functions (Red and Yellow). However, the red function is comprised of two indications that must operate in a “wig-wag” pattern (one off, one on and visa-versa) and therefore requires a separate wire for each indication. This results in a total of three No. 14 AWG wires (plus one common/neutral) to power this type of signal head.

**Figure 5-98 | Wiring for Type 10 Signal Head**

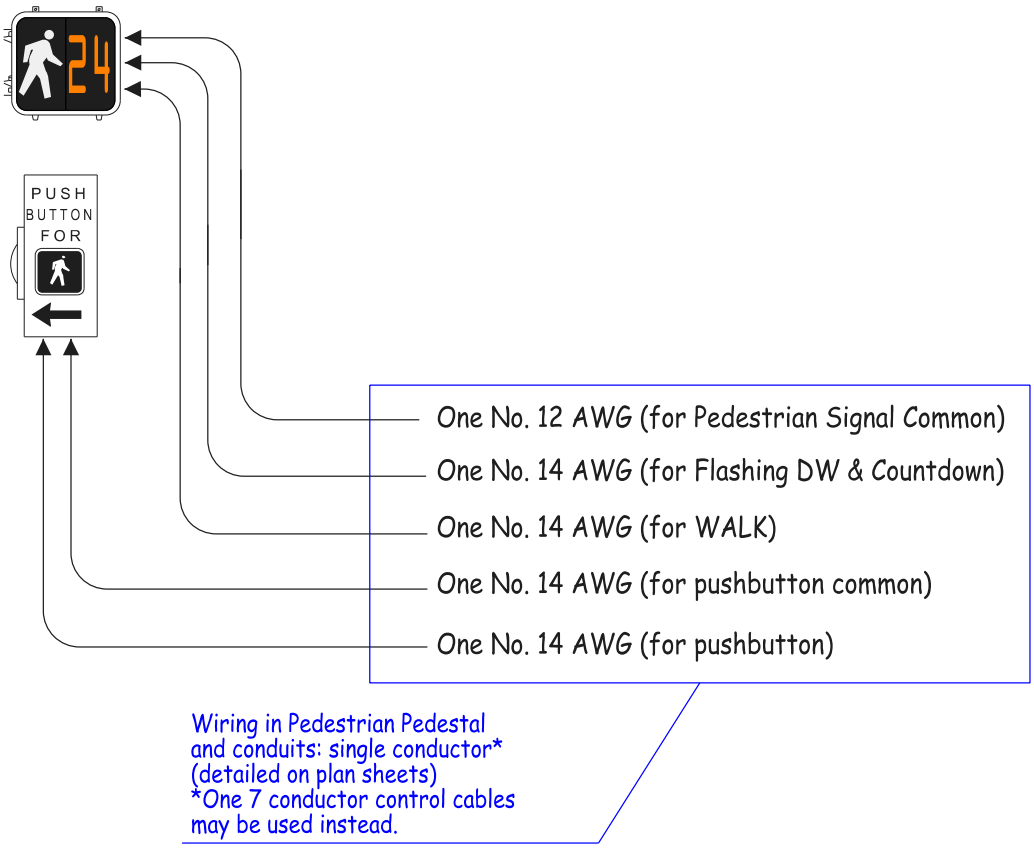


### 5.14.7 Wiring Pedestrian Indications and Pushbuttons

Pedestrian indications include WALK and FLASHING DON'T WALK, which require two No. 14 AWG wires. The standard countdown style pedestrian head does not require any additional wiring. Depending on the size of the pole that the pedestrian head is mounted on, the common/neutral wire for the pedestrian indications will either be a No. 12 AWG (for poles 4" in diameter, i.e. pedestals) or a No. 8 AWG (for poles larger than 4", i.e. mast arm or strain pole). Figure 5-99 assumes the indications are mounted on a pedestrian pedestal.

The only function of the pedestrian pushbutton is to provide one input to the traffic signal controller to indicate a pedestrian call. Therefore, only two No. 14 AWG wires are needed to make the pushbutton function; one wire for the pushbutton and one wire for the common to complete the circuit. The pushbutton common is terminated independent of the signal indications because the pedestrian pushbuttons operate on a different voltage (24V) than the signal indications (120V, pedestrian & vehicle).

**Figure 5-99 | Pedestrian Indication and Pushbutton Wiring**

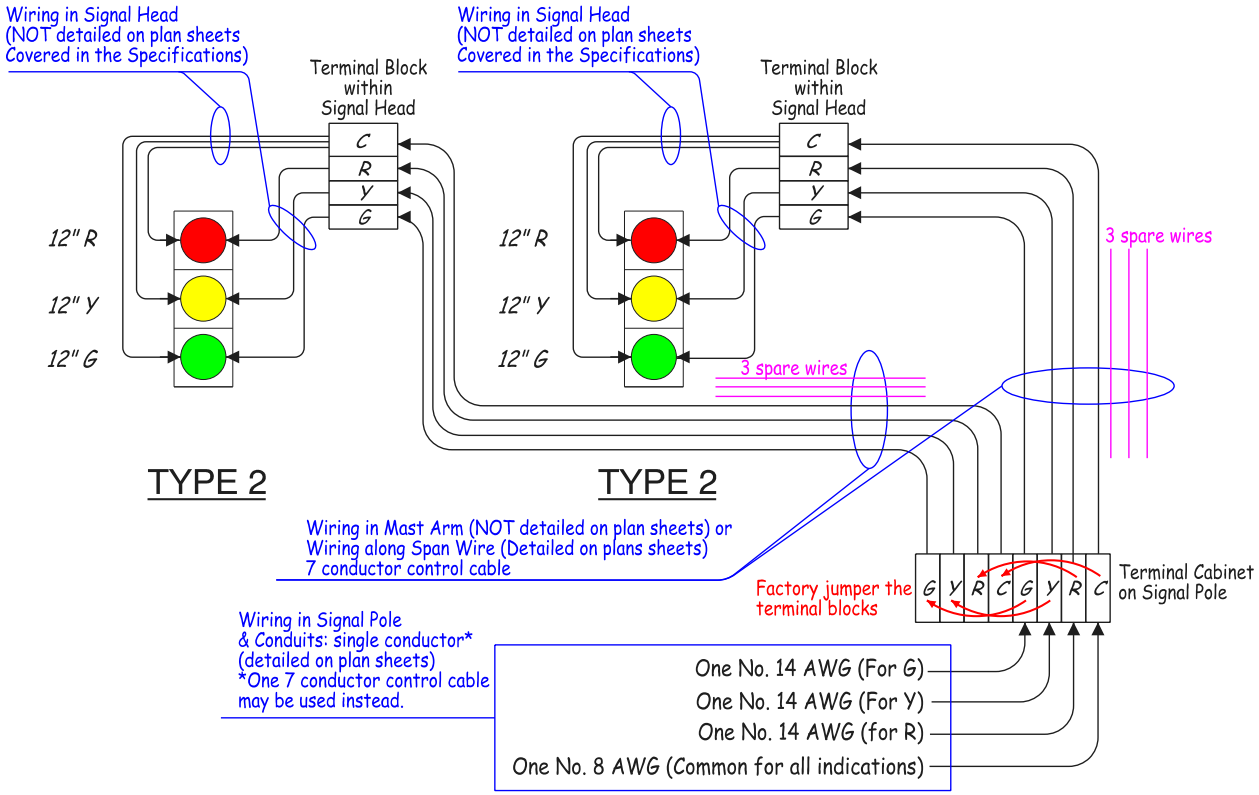


### 5.14.8 Wiring Signal Phases (from Terminal Cabinet to Controller)

The previous section detailed how each signal head needs to be wired, while this section focuses on how each signal phase is wired (wiring from the terminal cabinet on the signal pole to the controller). This section is applicable to both mast arm and span wire installations as both installations shall use conduit routed to each pole from the controller.

Typically multiple signal heads (located on the same pole) are needed for one phase. Figure 5-100 shows one of the most common applications, two signal heads for one through movement phase (Typically phases 2, 4, 6, or 8). Note that only three No. 14 AWG wires (plus a common/neutral) are needed from the signal controller cabinet to the terminal cabinet on signal pole and "factory jumpers" are used on the terminal block within the terminal cabinet on the signal pole to provide power to the additional signal head. If a third signal head was added to the same phase, the same three No. 14 AWG wires and one No. 8 AWG common/neutral would be used from the signal controller cabinet to the terminal block on the signal pole, but an additional set of jumpers in the terminal cabinet on the signal would be used to power the third signal head. This principle of using jumpers in the terminal cabinet on the signal pole applies to any number of signal heads that are intended to operate on the same phase (on the same pole).

**Figure 5-100 | Wiring Multiple Signal Heads for the Same Phase on the Same Pole**



Using individual conductors is the default standard for wiring phases from the controller to terminal cabinet (in conduits) for both span wire and mast arm installations. See Figure 5-102 for an example. However, at the request of the Region Electrical Crew, control cables may be used according to standard drawing TM470. See Figure 5-101. One 7 conductor control cable is required per phase (vehicle and pedestrian) from the controller to the pole terminal cabinet. See Figure 5-103 for an example.

**Span wire installations shall use conduit to each pole. Aerial wiring on the messenger cable is only allowed for wiring from the terminal cabinet to each signal head and for temporary signal installations.**

**Figure 5-101 | Standard Drawing TM470 Signal Phase Wiring**

| | | | PEDESTRIAN PHASES | VEHICLE PHASES |
|---|---|---|---|---|
| 7 CONDUCTOR CONTROL CABLE | | | 1 PEDESTRIAN PHASE | 1 VEHICLE PHASE |
| CONDUCTOR NUMBER | BASE COLOR | FIRST TRACER | | |
| 1 | WHITE | — | NEUTRAL | NEUTRAL |
| 2 | BLACK | — | WALK | YELLOW |
| 3 | RED | — | DONT WALK | RED |
| 4 | ORANGE | — | P.B. COMMON | SPARE |
| 5 | GREEN | — | PUSHBUTTON | GREEN |
| 6 | BLUE | — | SPARE | SPARE |
| 7 | WHITE | BLACK | SPARE | SPARE |

**Figure 5-102 | Wiring Phases with Individual Conductors**

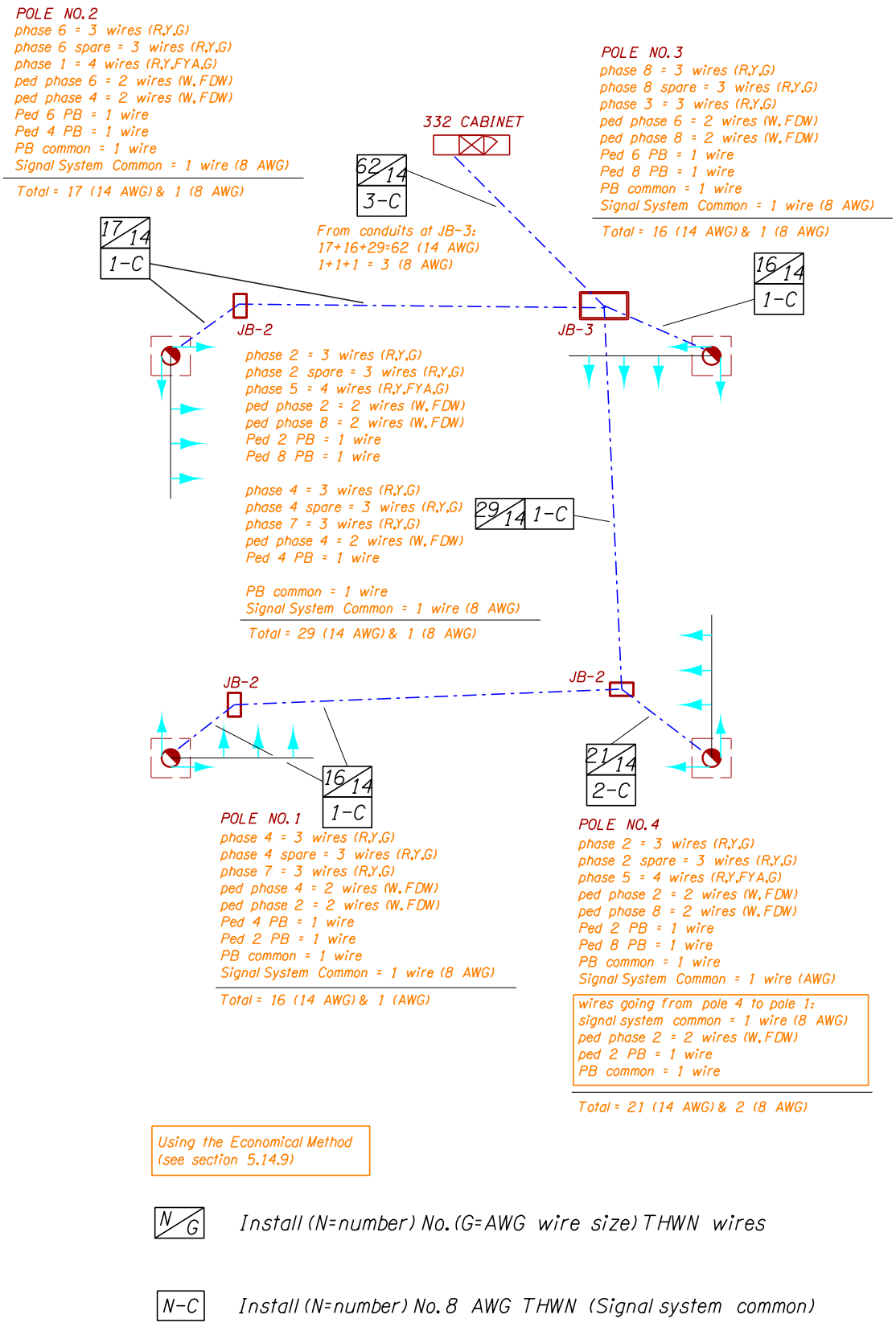
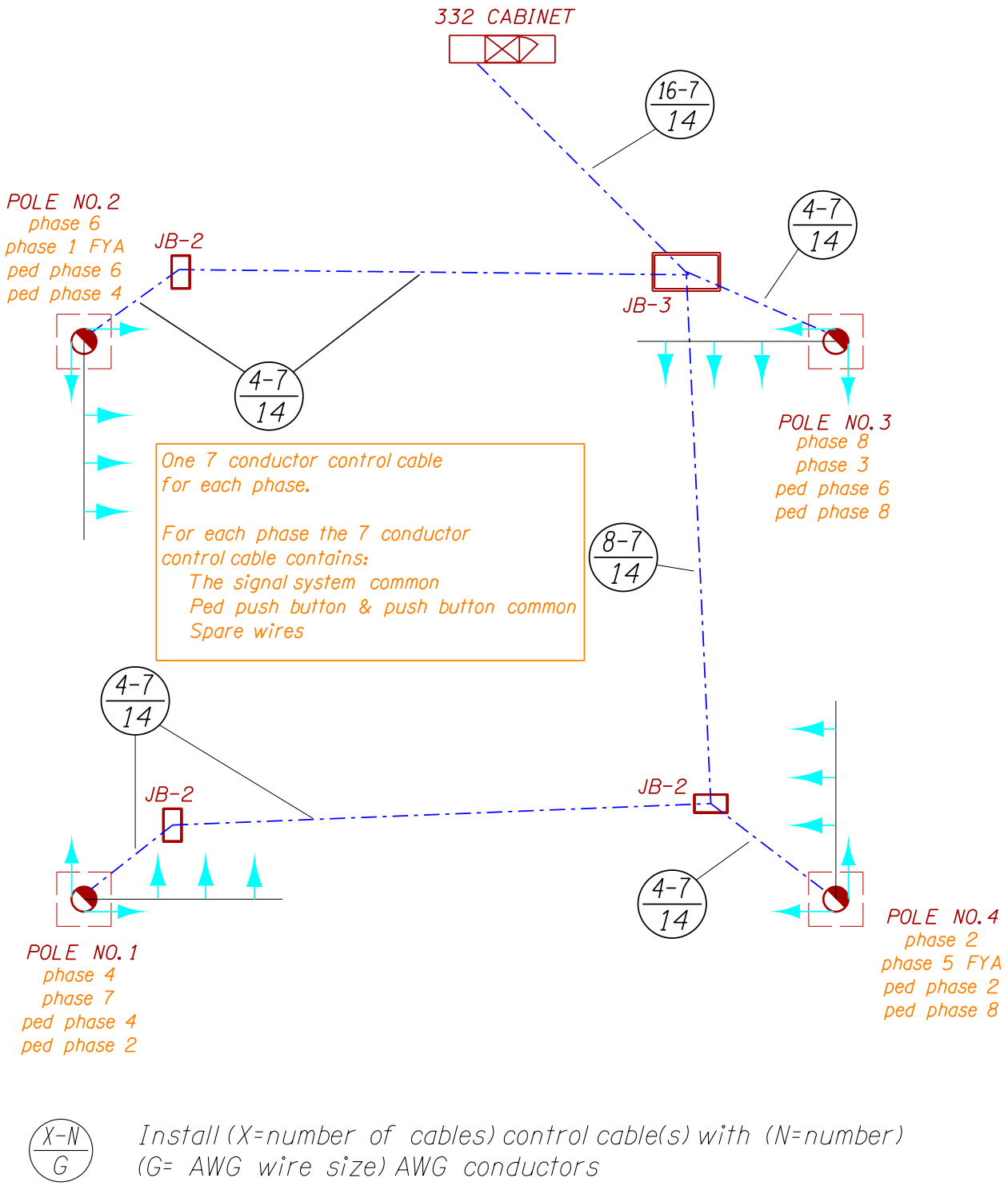


**Figure 5-103 | Wiring Phases with Control Cables**



### 5.14.9 Verifying Wire Fill at the Terminal Cabinet Entrance and Mast Arm Connection

There are two critical locations on the mast arm pole that limit the amount of control cables that can be used within the pole:

- the terminal cabinet entrance
- the mast arm connection

If the mast arm has an external terminal cabinet and is using control cables from the terminal cabinet to the signal controller cabinet, both critical locations should to be verified. See Figure 5-104. If the mast arm has a recessed terminal cabinet or if individual conductors are used from the terminal cabinet to the signal controller cabinet, only the mast arm connection should be verified. See Figure 5-105.

- External Terminal Cabinet Entrance: The terminal cabinet entrance dimension is through a 2 ½ inch diameter factory installed hub. This can accommodate a maximum of 16, 7-conductor control cables with No. 14 AWG conductors, using a 60% max fill rate as per the NEC for conduit and tubing nipples that do not exceed 24 inches in length. The external terminal cabinet entrance will contain control cables going into the terminal cabinet (from the signal controller cabinet) and control cables going out of the terminal cabinet (to the equipment mounted on the pole and mast arm).

- Mast arm Connection: The mast arm connection dimension is a 2 inch diameter pipe sleeve. This can accommodate a maximum of 11, 7-conductor control cables with No. 14 AWG conductors, using a 60% max fill rate as per the NEC for conduit and tubing nipples that do not exceed 24 inches in length. The mast arm connection will contain all control cables from the terminal cabinet to the equipment located on the mast arm.

**Figure 5-104 | Verify Wire Fill at Terminal Cabinet and Mast Arm Connection (control cables with external terminal cabinet)**

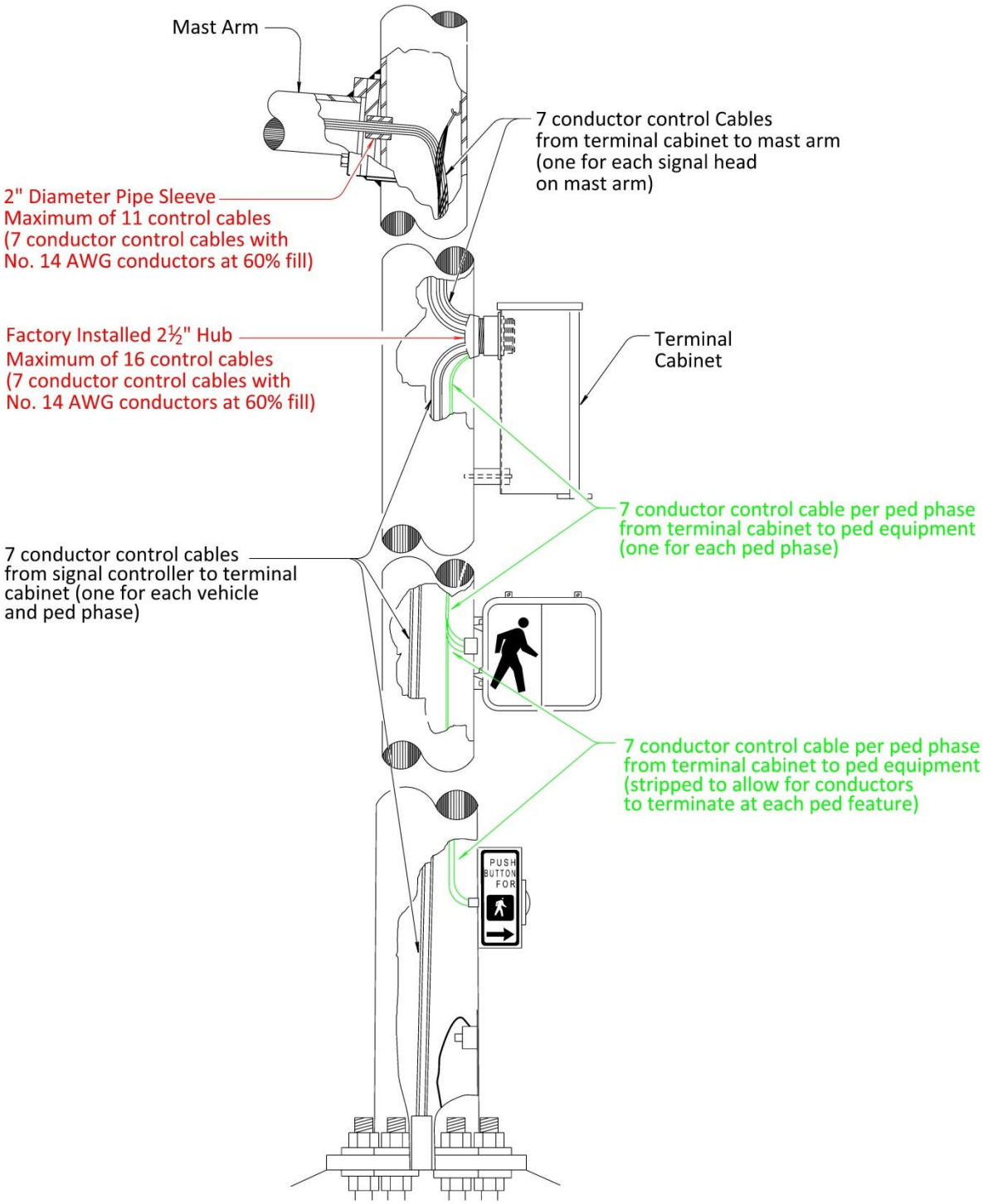
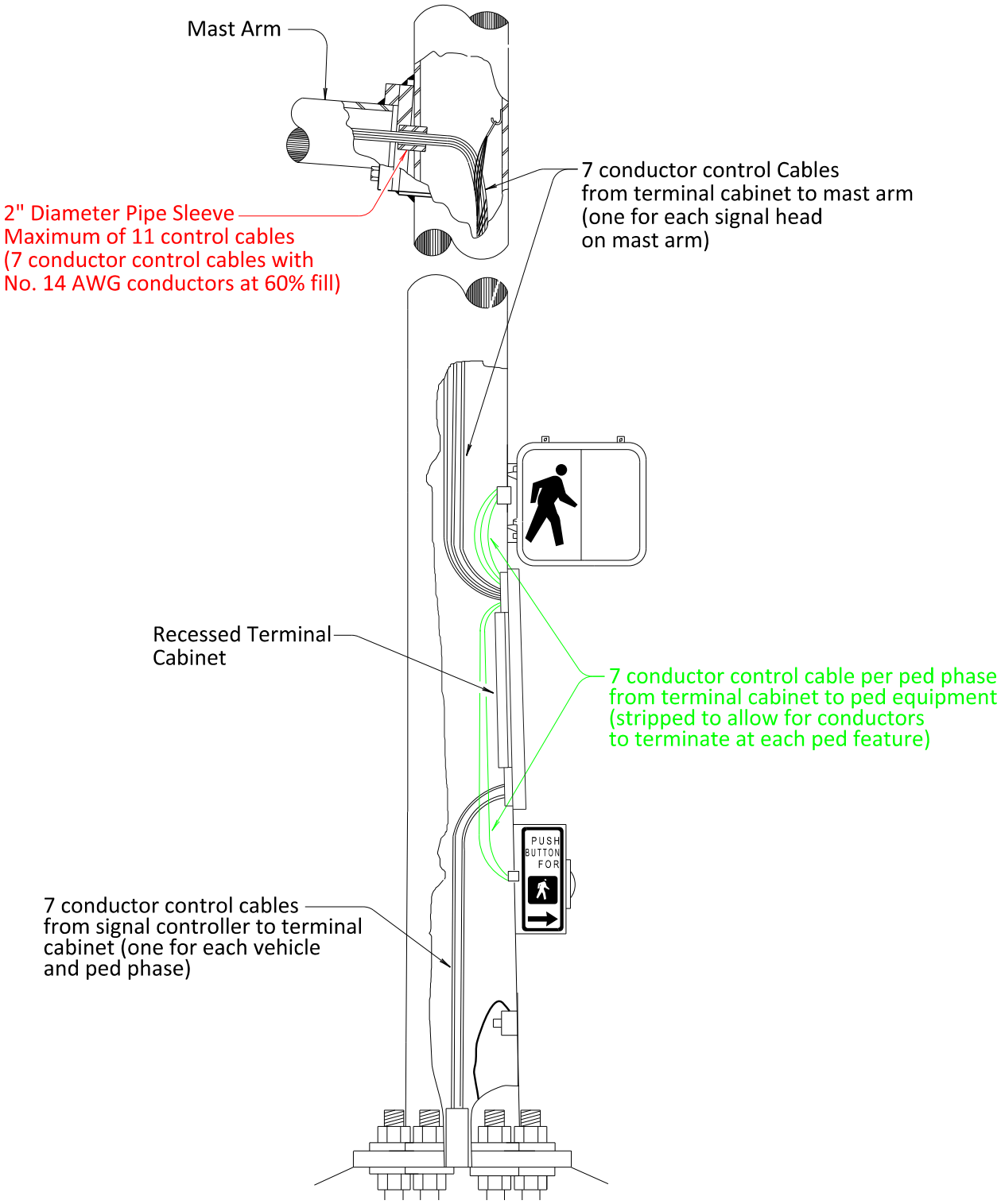


**Figure 5-105 | Verify Wire Fill at Mast Arm Connection (recessed terminal cabinet)**



### 5.14.10 Wire Economy – Individual Conductors

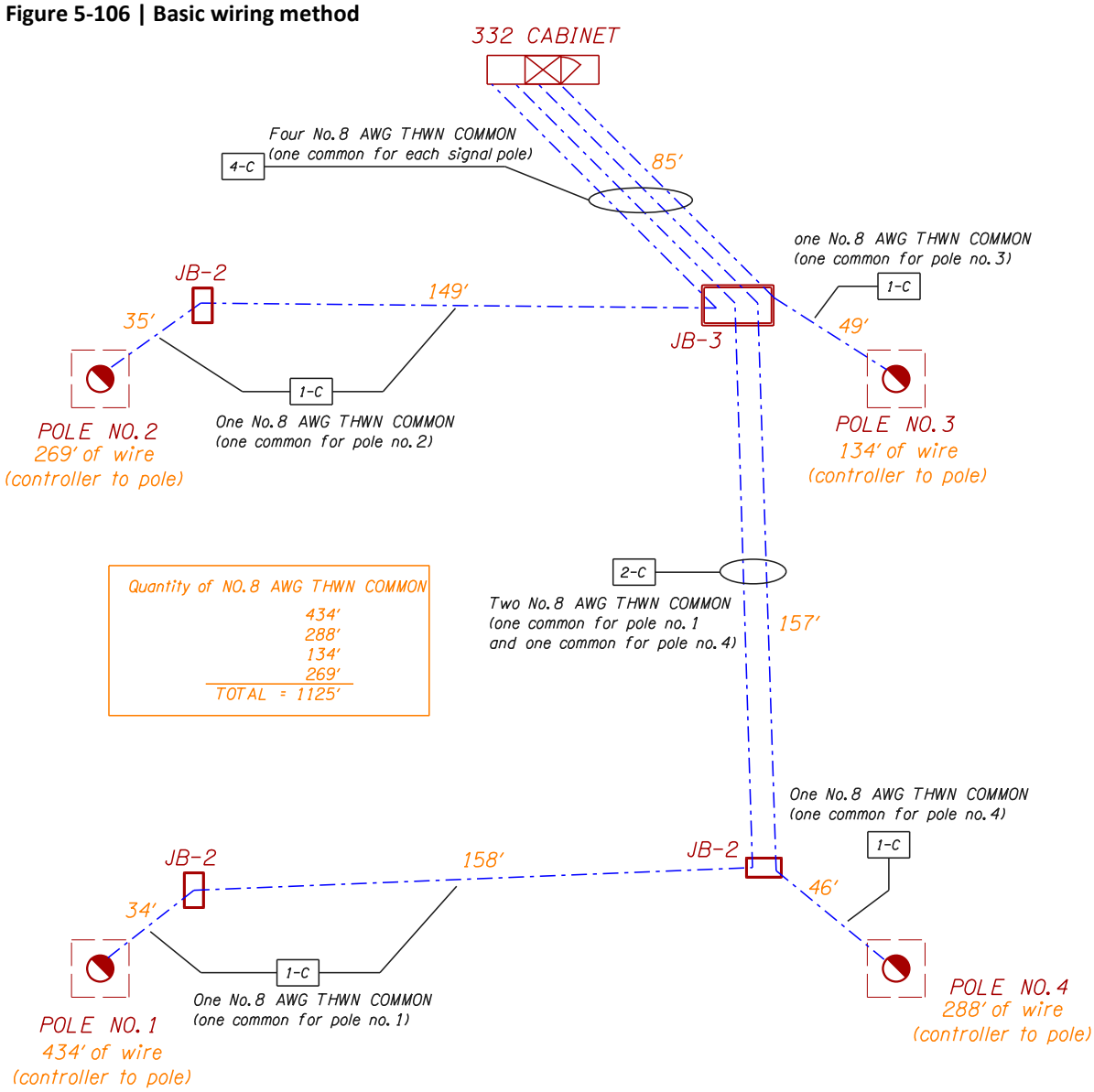
Traffic signals can be wired a number of different ways and function correctly. However, in an effort to be more economical, there is a preferred method of routing wiring.

Figure 5-106 shows the basic method for wiring the common/neutral and Figure 5-107 shows the economical method for wiring the common/neutral. While these figures only show wiring for the commons, the same principle can be applied to any traffic signal wiring that share a common system/phase (e.g. No. 14 AWG THWN that is used for the signal phases). A typical scenario for using the economical method is for pedestrian indications of the same phase, as each pedestrian phase will have two indications located on different poles. There may also be opportunities to use the economical method for pedestrian pushbuttons, pushbutton common, and overlap phases (opportunity for indications that are part of the same system/phase but located on different poles).

To understand the preferred economical method, it is necessary to understand the basic method first. The basic method is a direct connection for each wire from the origin (signal controller cabinet) to the destination (the terminal cabinet on the pole). Figure 5-106 shows the basic method for the signal system common wires. This results in 4 common wires from the signal cabinet to the first junction box (JB-3), with each wire then routing directly to the appropriate signal pole, resulting in a total of 1125’ of wire needed.

**This section is NOT applicable to control cables or Illumination Wiring!**

**Figure 5-106 | Basic wiring method**

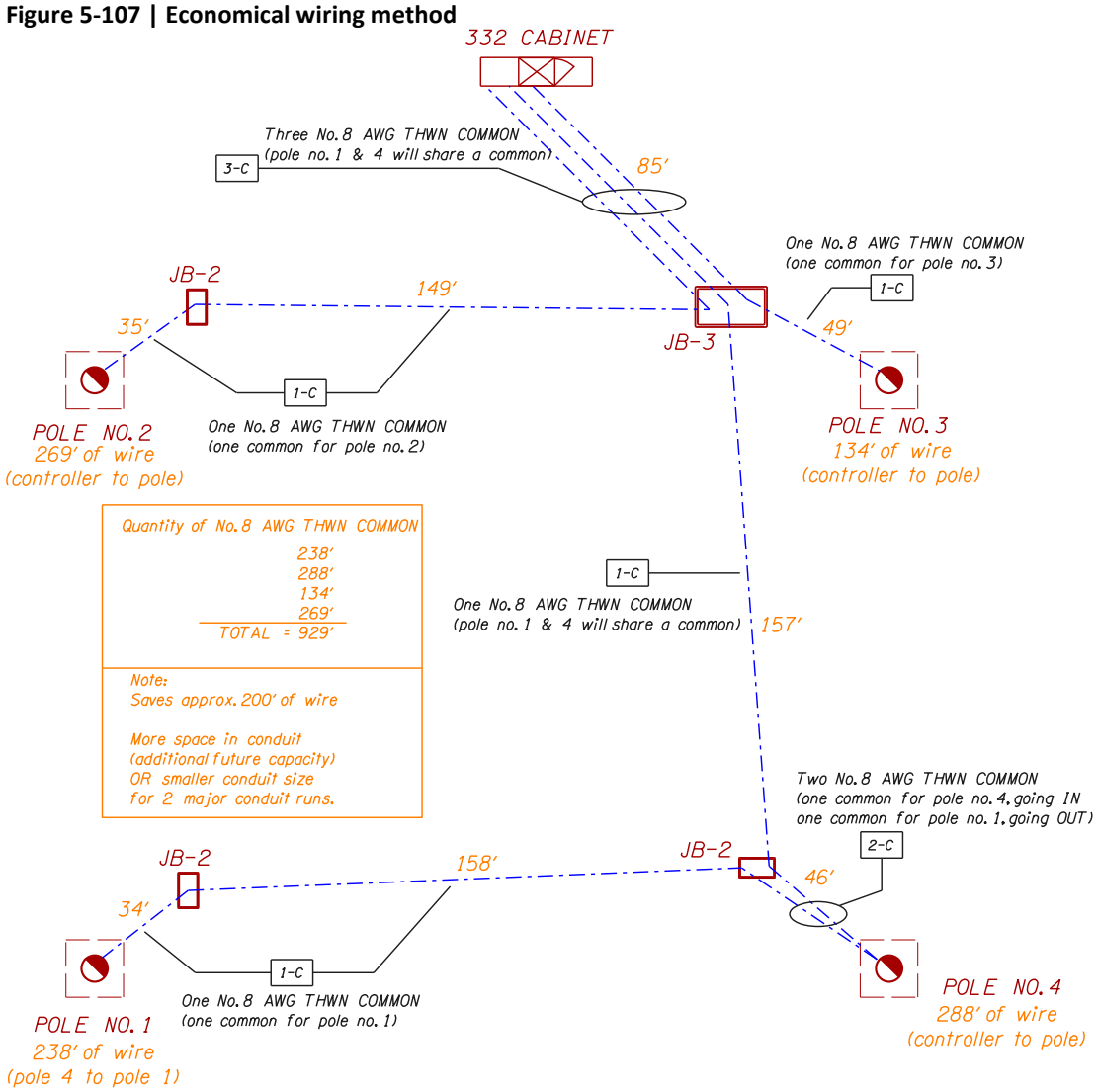



The economical method, by contrast, makes efficient use of the terminal cabinets. Figure 5-107 shows the economical method for wiring the common/neutral. The economical method takes advantage of the terminal cabinet located on Pole No. 4, supplying the common/neutral wire to Pole No. 1 from the terminal cabinet on Pole 4. This is possible because the common/neutral wire from Pole No. 4 goes back to the origin and the all the common/neutral wires are part of the same system, so pole no. 1 doesn't have to have a separate common/neutral wire going back to the origin. This saves approximately 200' of total wire when compared with the basic method, as the common/neutral wire as pole no. 1 doesn't go all the way back to the signal cabinet, but instead terminates at pole no. 4. It also creates additional space in the conduit (future capacity) or might allow the use of a smaller conduit for two of the major conduit runs

(from the signal controller cabinet to the JB-3 and from the JB-3 to the JB-2 next to pole no. 4).

Note that in the economical method, the goal is not to achieve 100% wire efficiency, such that the total wire quantity is as low as it can possibly be, but rather to only take advantage of the large gains in efficiency. For example, in Figure 5-107, there is additional wire efficiency that can be gained by routing just one common/neutral wire from the controller cabinet to pole no. 3, and using the terminal cabinet on pole no. 3 to supply the common/neutral wire to pole no. 2 and pole no. 4. If that was done, it would result in a total of 857' of wire, which is only 72' less wire and doesn't result in any net gain for conduit space (instead of the conduit run from the signal cabinet to the JB-3 having 3 common/neutral wires, the conduit run from the JB-3 to pole no. 3 would have 3 common/neutral wires). This is an example of diminishing returns; not a lot of benefit for the added complexity.

**Figure 5-107 | Economical wiring method**



### 5.14.11 Span Wire Installations: Wiring Signal Heads

The same basic principles discussed in section 5.14.6 for wiring signal heads on a mast arm apply to span wire installations. The one main difference between wiring signal heads on mast arms verses span wires:

- The control cable used to wire the signal head from the terminal cabinet on the pole to the signal head (this is the same for both span wires and mast arms) is NOT detailed on the signal plan sheet for mast arm installations, while it IS detailed on the signal plan sheet for span wire installations. The standard specifications and standard drawing TM470 completely cover installation for mast arms, which is why it is not detailed for a mast arm installation.

On a span wire, the signal heads should be wired from the pole where a mast arm would be attached if a mast arm was used. There is an exception to this preference that applies to temporary signals with multiple construction stages (See Chapter 11). Figure 5-108 illustrates the preferred method and Figure 5-109 illustrates the non-preferred method.

**Figure 5-108 | Preferred Method for Wiring Signal Heads on a Span Wire**

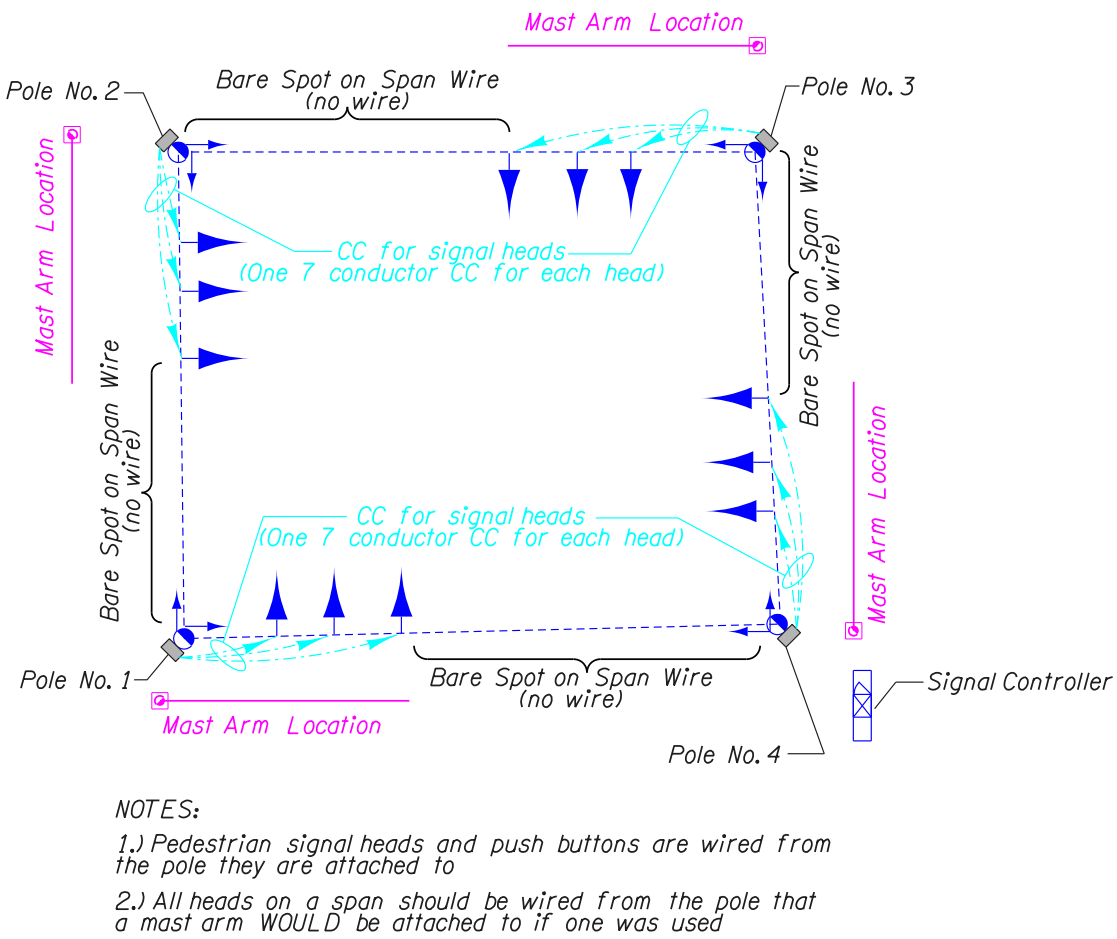
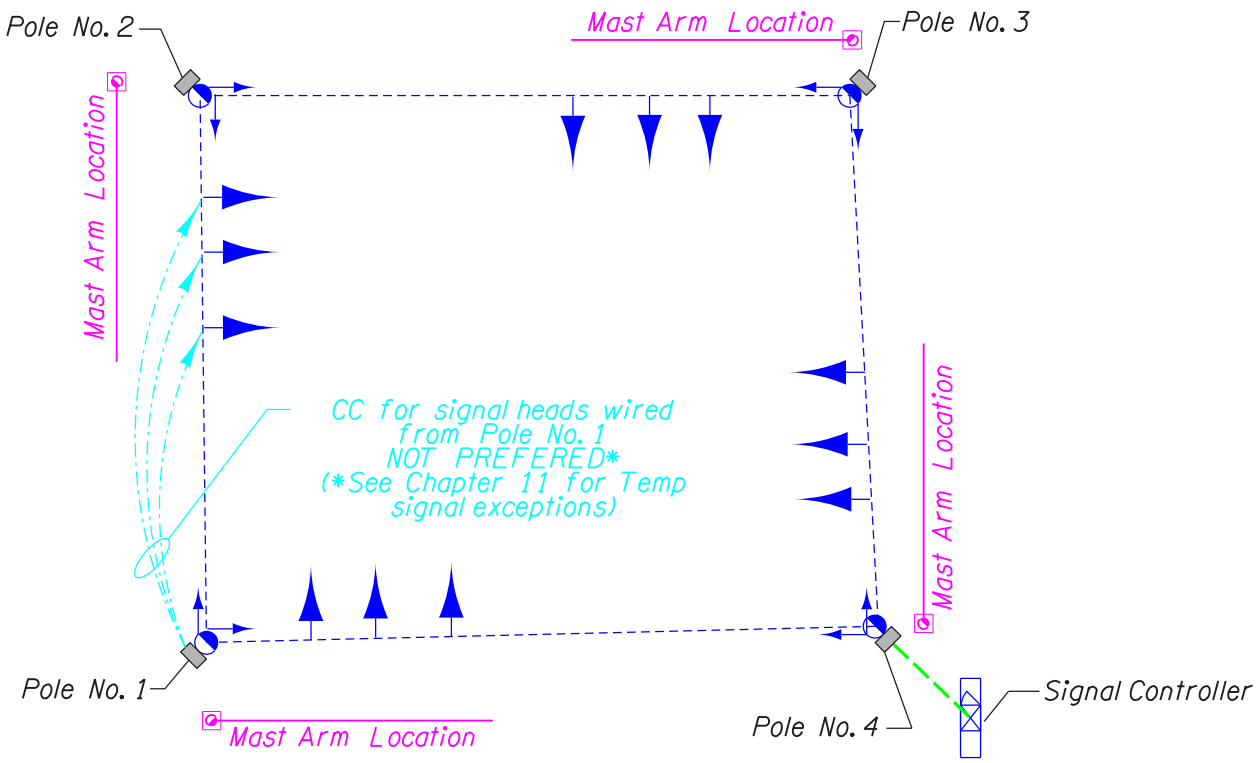


**Figure 5-109 | NON-PREFERRED method for Wiring Signal Heads on a Span Wire**




### 5.14.12 Wiring Part Time Restriction (PTR) signs

The only function of the Part Time Restriction (PTR) sign is on or off. Therefore, only two THWN No. 12 AWG wires are required for it to function; one "hot"wire for the PTR sign and one wire for the common/neutral to complete the circuit. If using a control cable, a No. 12 AWG two conductor control cable is used. Using a No. 12 AWG wire helps easily identify the PTR wiring at a glance in the field.

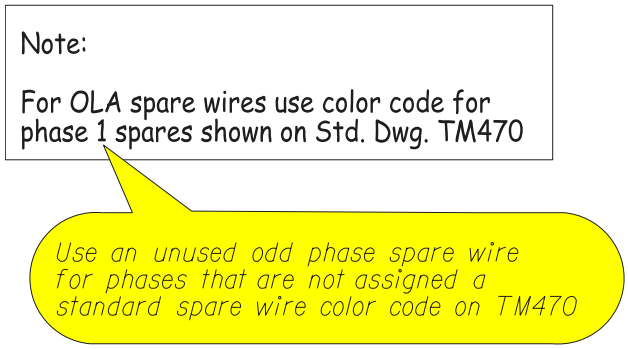
### 5.14.13 Spares Wires

ODOT standard is to include 3 spare wires for each thru phase (ø2, ø4, ø6, and ø8) when using individual conductors. These spare wires are for future use. These wires shall be color coded as shown in the table on Standard Drawing TM470 and shall not be spliced at any point from the controller cabinet to the terminal cabinet on each pole.

Three spare wires should be installed to a mast arm pole terminal cabinet if a thru phase is not located on a mast arm. For example, a dual right turn often requires a separate mast arm pole for the right turn overlap phase. In this case, 3 spare wires for the overlap phase should be provided. When providing spare wires for overlap phases, be

aware that spare wires for overlap phases have not been assigned a standard color code in Std. Dwg. TM470 and will need to be defined on the plan sheet with a custom note. Define the color code for these spare wires as an unused, odd phase spare wire (such as phase 1, 3, 5, or 7 spare). See Figure 5-110.

**Figure 5-110 | Spare Wire Custom Note**




The spare wires for are already built-into the control cable (although, not as many spares as used for a mast arm installation).

## 5.15 Background/Reference Information

This section contains more in-depth information to aid in understanding guidance presented in this chapter.

### 5.15.1 Wiring History

This section has been provided for information and documentation purposes only.

Control cable with a variety of conductors (i.e. four, five, six, ten, twelve, and fifteen conductor control cables) have been used in the past for certain signal heads and certain combinations of phases to be more efficient (result in less cost and less spare wires). The decision to use 7 conductor control cables for all signal wiring was made for the following reasons:

- the cost savings between a four, five and six conductor control cables (for signal heads) verses a seven conductor control is not significant (less than a dollar/foot difference)
- the additional spare wires are beneficial (for future signal head changes such as a Type 3L to a Type 6L the additional wire is already in place)
- Consistency
- Ease of construction (only need to buy and use one type of control cable for all signal heads)
- Large quantity unit pricing (instead of needing several different sizes of control cable for the various types of signal heads, seven conductor control cable can be purchased in a larger quantity for all signal heads)

### 5.15.2 Type 3LCF Signal Heads for Flashing Yellow Arrow

On August 12th 2014 FHWA issued Interim Approval for the optional use of three section flashing yellow arrow signal faces (IA-17): https://mutcd.fhwa.dot.gov/resources/interim_approval/ia17/ia17.pdf

On December 11th 2014 ODOT received approval from FHWA to install three section center flashing arrows as part of IA-17:
https://www.oregon.gov/ODOT/Engineering/Documents_TrafficStandards/FHWA-IA-17_Oregon-Use.pdf

The following list contains the reasons why three section center flashing arrows were pursued as the ODOT standard:

1. Physical characteristic of the 3 section center flashing arrow signal head
    a. Structural loading between 3 section protected only and 3 section center flash are the same.
        i. This is not the case when using a four section FYA signal head which is 14 inches taller.
    b. Vertical clearance between 3 section protected only and 3 section center flash are the same.

        i. This is not the case when using a four section FYA signal head which is 14 inches taller.
    c. Maintenance is allowed to standardize parts since the three section head can be used for protected only, P/P, and permissive only operation.
        i. This is not the case when using the four section head.
    d. Maintenance is allowed to standardize LED modules. They only need six LED modules to allow any operation: Red/Yellow/Green balls and Red/Yellow/Green arrows.
        i. This is not the case when using bimodal green/yellow arrow LED modules.
            1. Note: The bimodal green/yellow arrow LED modules are not supported by the ITE specification for LED modules.
    e. Outputs from the controller cabinet remain the same to run protected only or center flash P/P: Three wires.
        i. This is not the case when using the four section head: Requires four wires.
        ii. This is not the case when using the bimodal LED module: Requires four wires.
    f. Three section center flash is an easy conversion from 3 section protected only. Requires cabinet modifications only.
        i. This is not the case when using the four section head: Requires a head change out and adding one wire from the cabinet
        ii. This is not the case when using the three section bimodal green/yellow LED module: Requires the change out of one LED module and adding one wire from the cabinet.
2. Safety and Operational characteristic of the 3 section center flashing arrow signal head
    a. Research completed on the 3 section center flash as noted in IA-17: http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=2763
    b. Quote from IA-17 "The research results demonstrated that a three-section FYA signal face in which the middle yellow arrow signal indication is used to display both the steady change interval and the flashing yellow permissive interval provides a safe and effective operation for road users"

3. Currently there are three options for flashing yellow arrow head types: Three section center flash, three section bottom bimodal green/yellow, and four section. All three are acceptable options and are considered equals for operations and safety. But when considering physical characteristics and ease of maintenance for the 1,500 traffic signals and numerous personnel that work on them on the State Highways the three section center flash is the best option.

### 5.15.3 Sign History

Below shows a list of signs that are no longer used. It is by no means all inclusive, but is included in this manual for historical purposes.

**Figure 5-111 | Signs No Longer Used**

| SIGNS NO LONGER USED | |
|---|---|
| OR10-10L 30"x36" | "LEFT TURN SIGNAL" sign |
| OR10-10R 30"x36" | "RIGHT TURN SIGNAL" sign |
| OR17-1 30"x36" | "LEFT TURN YIELD TO ONCOMING TRAFFIC" sign replaced by R10-12 |
| OR22-14 30"x36" | "RIGHT TURN YIELD TO PEDS ON GREEN ball symbol" sign replaced by OR10-15 |