

Annual Revisions to the SUDAS Design Manual

2020 Edition

If you want to update your printed manual, please print this packet and follow the instructions below. The current edition of the manual, with the latest revisions fully incorporated, can be found on our website - www.iowasudas.org.

Please remove the old sheets and place the revised sheets in your manual. Some pages are completely new and do not replace an existing sheet. Also, some pages do not contain revisions, but are included due to changes on the other side of the sheet or a change in the page number. **PLEASE READ CAREFULLY - PAY ATTENTION TO THE SECTION NUMBER!** Included shading to help distinguish between chapters. Questions can be directed to Beth Richards, SUDAS Program Coordinator, at 515-294-2869 or brich@iastate.edu.

Chapter	Section	pg #	Summary of Revision(s)
Manual introductory info			Updated the Contributors and Acknowledgments page and the general table of contents. <i>Note - if you want to replace the small business card for the spine of your manual, you can print a copy from our website.</i>
1	Table of Contents	ii	Updated to reflect changes made in Chapter 1.
	1D-1, I through K	13-66	Revised "Items to be Specified" list based on SUDAS Specifications revisions. Updated "Incidental or Included Items" list. Updated "Bid Items" list.
3	Table 3D-1.01	1	Revised due to the combining of AWWA C900 and C905.
	Table 3D-1.03	2	Updated based on spec changes.
4	4C-1	1-4	Deleted references to a figure that no longer exists.
	5C-1	3-9	Set the preferred and acceptable clear zone on low speed urban roadways without consideration for the roadway classification; deleted Table 5C-1.05 and updated references as a result.
5	5G-1, A	1-2	Revised to reflect Iowa DOT's new maximum of 12' longitudinal and 17' transverse joint spacing.
	5G-2	ALL	Revised to reflect Iowa DOT's new maximum of 12' longitudinal and 17' transverse joint spacing.
	5G-3	1-4; 13-16	Revised to reflect Iowa DOT's new maximum of 12' longitudinal and 17' transverse joint spacing.
	5G-4	ALL	Revised to reflect Iowa DOT's new maximum of 12' longitudinal and 17' transverse joint spacing.
	5J-1, C, 1, b	7-8	Modified binder grade to ensure adequate crack resistance properties.
	5L-4	ALL	Clarified that the flare should be 3 to 5 feet for residential and agricultural driveways. Other error corrections.
7	7E-24, B, 4, b	3-4	Changed topsoil requirement to 8 inches to match the specifications.
11	Table of Contents	i	Updated to reflect changes made in Chapter 11.
	11A-1	ALL	Updated section to reflect use of LED street lighting.
	11B-1	ALL	Updated section to reflect use of LED street lighting.
	11C-1	ALL	Updated section to reflect use of LED street lighting.
13*	Table of Contents	ALL	Updated to reflect changes made in Chapter 13.
	ENTIRE CHAPTER	ALL	Changed chapter title to Traffic Control and added new sections for work zone traffic control.
	* revised chapter title to Traffic Control		

Contributors and Acknowledgments

In 2019, SUDAS staff held many meetings to accomplish the various revisions reflected in the 2020 versions of the SUDAS manuals. These revisions would not have been possible without the efforts of the SUDAS technical committee members. The SUDAS program's success is also due to the dedication of the district committees and Board of Directors. Keeping the SUDAS manuals current is an ongoing, cooperative effort, involving hundreds of people who volunteer their time and expertise. It is not possible to acknowledge each of these volunteers individually, but we appreciate them all.

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I. Items to be Specified on Plans or in Contract Documents (Continued)**Section 4010 - Sanitary Sewers**

4010, 1.08, E	Specify the distance beyond the right-of-way line that the sanitary sewer service stub is to extend, if other than 10 feet.
4010, 1.08, H, 3	For removal of sanitary sewer, specify if capping is required.
4010, 2.01, A, 1	For solid wall PVC pipe, 8 inch to 15 inch, specify if SDR 35 may be used.
4010, 2.01, C, 2, a	For corrugated PVC, 8 inch to 10 inch, specify if a minimum pipe stiffness of 46 psi may be used.
4010, 2.02, A	Specify when joint restraints for ductile iron pipe force mains are required.
4010, 2.02, B	Specify when restrained joints are required for PVC force mains.
4010, 2.02, E, 2	Specify the color of plastic post used for tracer wire station.
4010, 3.02, B, 7	Specify the location for installation of wye or tee service fitting.
4010, 3.05, B, 2	Specify the location for any installation of a tracer wire station in addition to each end of the force main.
4010, 3.06, A	Specify the locations for installation of sanitary sewer service stub.
4010, 3.06, C	Specify the distance beyond the right-of-way line that the sanitary sewer service stub is to extend, if other than 10 feet.
4010, 3.06, C, 3	Specify the depth of sanitary sewer service stub at its termination, if other than 10 to 12 feet.
4010, 3.06, C, 5	Specify method of marking the end of the sanitary sewer service line.
4010, 3.08, B, 2	Specify when to fill an abandoned sanitary sewer with flowable mortar, foamed cellular concrete, or CLSM.
4010, 3.10	Specify where to provide sanitary sewer cleanouts.

Section 4020 - Storm Sewers

4020, 1.08, D, 3	Specify if capping is required for removal of storm sewer.
4020, 2.01, A, 3	Specify when to use a rubber O-ring or profile gasket in lieu of a tongue and groove joint wrapped with engineering fabric.
4020, 2.01, B, 3	Specify when to use a rubber O-ring or profile gasket in lieu of a tongue and groove joint wrapped with engineering fabric.

I. Items to be Specified on Plans or in Contract Documents (Continued)

4020, 2.01, C, 3	Specify when to use a rubber O-ring or profile gasket in lieu of a tongue and groove joint wrapped with engineering fabric.
4020, 2.01, G, 1, d	Specify gage of corrugated metal pipe, if other than Iowa DOT Standard Road Plan DR-104.
4020, 2.01, I, 2	Specify gage of coated corrugated metal pipe, if other than Iowa DOT Standard Road Plan DR-104.
4020, 3.04, A	Specify any special linear trench drain installation requirements.
4020, 3.05, B, 2	Specify the use of a rubber O-ring or profile gasket.
4020, 3.06	Specify where to install pipe aprons, apron footings, and apron guards.
4020, 3.09, B, 2	Specify when to fill a line to be abandoned with flowable mortar, foamed cellular concrete, or CLSM.

Section 4030 - Pipe Culverts

4030, 2.01, C, 5	Specify gage of the structural plate culverts, if other than Iowa DOT Standard Road Plan DR-104.
4030, 3.02, A	Specify the locations to install pipe aprons.
4030, 3.02, B	Specify the locations to install apron footings.
4030, 3.02, E	Specify the locations to install apron guards.
Figure 4030.225	Specify when to extend the bottom cross bar through the apron.

Section 4040 - Subdrains and Footing Drains

4040, 1.08, A, 3	Specify the use of engineering fabric.
4040, 1.08, E	Specify the distance beyond the right-of-way that the storm sewer service stub is to extend, if other than 10 feet.
4040, 3.01, A, 1	Excavate trench and provide pipe bedding and backfill as shown on the figures. Install engineering fabric if specified in the contract documents.
4040, 3.02, B	Specify the use of engineering fabric.
4040, 3.03, A	Specify the locations to install footing drain service stubs.
4040, 3.03, C	Specify the distance beyond the right-of-way that the footing drain service stub is to extend, if other than 10 feet.
Figure 4040.231	For Type 1 subdrains, specify Case A, B, or C. For Type 2 subdrains, specify Case D or E and the pipe diameter. When using Case A or Case D, specify the distance from back of curb. For both types, specify when engineering fabric is to be used.
Figure 4040.232	Specify the type of subdrain cleanout to be used.

I. Items to be Specified on Plans or in Contract Documents (Continued)

Figure 4040.233

Specify when to use a CMP outlet.

Section 4050 - Pipe Rehabilitation

4050, 1.07, B

Specify if water will not be provided for cleaning and installation of cured-in-place pipe by the Jurisdiction at no cost.

4050, 1.08

Specify if bypass pumping is not included in the measurement and payment of other bid items. *Applies to C, 1, c; D, 3; E, 1, c; E, 2, c; F, 1, c; F, 2, c; F, 3, c; and F, 4, c.* {Note - 1.08, G is the bid item for bypass pumping}.

4050, 1.08, A, 1, c

Specify if unit price will include disposal and associated costs for all debris removed from sewer.

4050, 1.08, E, 2, a

Specify the length of service pipe to line.

4050, 2.01, C, 2

Specify if the CIPP structural requirements are not fully deteriorated conditions.

4050, 2.01, Table 4050.01

Specify the ovality reduction factor and height of soil above pipe.

4050, 2.02, B

Specify the CIPP point repair liner length.

4050, 2.02, C

Specify if the ovality is a value other than 2%.

4050, 2.03, A, 1

Specify the distance the tube should extend from the sewer main into the service.

4050, 2.03, B, 2

Specify the service liner length.

4050, 2.03, E, 1

Specify if the cured-in-place service liner should be designed following different assumptions than those described in Table 4050.02.

4050, 2.03, Table 4050.02

Specify the depth of cover for each service repair location.

4050, 2.04, C

Specify when to provide a root deterrent chemical to control root regrowth.

4050, 2.07, B

Specify the materials to use for pipe replacement.

4050, 3.01, A, 6

Specify if the Contractor is to pay for disposal fees.

4050, 3.05, B, 1

Specify the length of the CIPP service repair.

4050, 3.06, B, 2

Specify if the length of the service line grouting plug should be a length other than 18 inches.

4050, 3.07, C, 1

Specify the materials to use for the replacement pipe.

I. Items to be Specified on Plans or in Contract Documents (Continued)

Section 4060 - Cleaning, Inspection, and Testing of Sewers

- | | |
|------------------|---|
| 4060, 2.01, B, 3 | Specify the type of recording media that will be used to record the inspection. |
| 4060, 3.03, A, 1 | Specify whenever video inspection of storm sewers is <u>not</u> desired. |

Section 5010 - Pipe and Fittings

- | | |
|---------------------|---|
| 5010, 1.08, C | Specify whether measurement of fittings will be made by count or by weight. |
| 5010, 2.01, A, 1, b | Specify the minimum wall thickness for PVC pipe sizes over 24 inches. |
| 5010, 2.01, A, 2 | Specify joint type for PVC pipe if other than push-on. |
| 5010, 2.01, B, 1, b | Specify the minimum wall thickness for DIP sizes over 24 inches. |
| 5010, 2.01, B, 4 | Specify joint type for DIP if other than push-on. |
| 5010, 2.04, C | Specify when thrust blocks will be used for pipe sizes greater than 16 inches in diameter. |
| 5010, 2.07, B | Specify the materials to use for water service pipe and appurtenances. |
| 5010, 3.01, A, 3 | Specify the lines and grades to install pipe with fittings. |
| 5010, 3.01, A, 8 | For pipes larger than 16 inches, specify when concrete thrust blocks are required in addition to restrained joints. |
| 5010, 3.06, E | Specify the locations to install ground rods if other than adjacent to connections to existing piping. |
| 5010, 3.07, B | Specify where to construct utility line supports. |
| 5010, 3.08 | Specify when the change of piping material is to be on the inside of the structure wall. |
| Figure 5010.101 | Specify when to use the alternate method of thrust blocks at dead ends. |

Section 5020 - Valves, Fire Hydrants, and Appurtenances

- | | |
|------------------|---|
| 5020, 1.08, I, 3 | Specify if the fire hydrant assembly is to be delivered to the Contracting Authority. |
| 5020, 1.08, J, 3 | Specify if the valve is to be delivered to the Contracting Authority. |
| 5020, 1.08, K, 3 | Specify if the valve box is to be delivered to the Contracting Authority. |
| 5020, 2.01, A, 2 | Specify whenever the opening direction for valves is clockwise. |

I. Items to be Specified on Plans or in Contract Documents (Continued)

5020, 2.01, D, 7	Specify the locations to use tapping valve assemblies.
5020, 2.02, B	Specify allowable manufacturer(s) of fire hydrant assemblies.
5020, 2.02, C, 5	Specify whenever the opening direction for fire hydrant assemblies is clockwise.
5020, 2.02, C, 6	For fire hydrant assemblies, specify the operating nut, pumper nozzle, nozzle threads, and main valve nominal opening sizes.
5020, 2.03, A	Specify the type of flushing device (blowoff) to be used.
5020, 2.03, B, 2	Specify the allowable manufacturer(s) for valve boxes.
5020, 3.02	Specify where to install and how to construct flushing device (blowoff).
5020, 3.04, D	Specify if exterior of a new fire hydrant barrel section will be painted a color other than matching the existing fire hydrant.

Section 6010 - Structures for Sanitary and Storm Sewers

6010, 2.05, B, 2, b	Specify the use of engineering fabric.
6010, 2.06, B	Specify when to use a concentric cone on sanitary sewer manholes.
6010, 2.11, B, 1	Specify if sanitary sewer manhole exterior is to be coated.
6010, 2.11, B, 2	Specify whenever sanitary sewer manhole lining is required.
6010, 2.13, A	Specify if steps are to be provided in manholes or intakes.
6010, 3.01, D	Specify if intake lids are NOT to be set to match the longitudinal slope of the adjacent street.
6010, 3.01, J	Specify the type of casting to use for manholes and intakes, except for intakes that have a specific casting type identified on the figures. Specify if casting frame is to be attached to the structure with bolts.
6010, 3.02, B, 2	Specify if reinforcing steel is to lap other than 36 diameters.
6010, 3.04, A, 1	Specify when to install casting extension rings.
6010, 3.04, B, 3	Specify when existing casting may be reinstalled for minor adjustment of existing manhole or intake.
6010, 3.04, C, 4	Specify when existing casting may be reinstalled for major adjustment of existing manhole or intake.
6010, 3.05, C, 1, a	Specify whenever a knockout opening is allowed in lieu of a cored opening.

I. Items to be Specified on Plans or in Contract Documents (Continued)

6010, 3.05, C, 1, b	Specify if sanitary sewer service is NOT required to be maintained at all times when connecting a sanitary sewer to existing manhole or intake.
6010, 3.05, C, 3	Specify whenever a knockout opening is allowed in lieu of a cored opening.
6010, 3.06, A	Specify if removal of manhole or intake is other than to a minimum of 10 feet below top of subgrade in paved areas or 10 feet below finished grade in other areas.
6010, 3.06, B, 3	Specify when to fill abandoned pipe line with flowable mortar or controlled low strength material.
Figure 6010.501	Specify when Type Q grate is to be used in lieu of Type R.
Figure 6010.502	Specify when Type Q grate is to be used in lieu of Type R.
Figure 6010.603	Specify when Type Q grate is to be used in lieu of Type R.

Section 6020 - Rehabilitation of Existing Manholes

6020, 2.02, A	Specify the thickness of the in-situ manhole replacement wall.
6020, 2.02, C	Specify whenever the Contractor is required to provide a PVC or PE plastic liner for in-situ manhole replacement.
6020, 3.01, C	Specify when the use of a urethane chimney seal is allowed.
6020, 3.02, B, 3	Specify whenever a plastic liner is to be installed in an in-situ manhole replacement.

Section 6030 - Cleaning, Inspection, and Testing of Structures

6030, 3.04, A, 1	Specify when exfiltration testing is required for sanitary sewer manholes in lieu of vacuum testing.
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Section 7010 - Portland Cement Concrete Pavement

7010, 2.01, E	Specify the use of an intermediate aggregate for concrete.
7010, 2.01, L, 2	Specify the type of performed expansion jointing filler or sealer to use if NOT using a resilient filler.
7010, 2.02, A, 1	Specify the type of Class C or Class M mix to use.
7010, 2.02, C, 2	Specify the type and amount of supplementary cementitious material in the mix.
7010, 3.01, C, 1, c	Specify the use of stringless paving.

I. Items to be Specified on Plans or in Contract Documents (Continued)

7010, 3.02, H, 5, a	Specify when a textured finished surface other than an artificial turf or burlap drag is desired (i.e. surface tining).
7010, 3.02, H, 5, b	Specify when surface tining is required. <i>Note - longitudinal tining is listed as the default.</i>
7010, 3.02, I, 1, a	Specify when the use of a linseed oil solution is required.
7010, 3.02, J, 1, a	Specify the type and locations for construction of joints.
7010, 3.02, J, 2, i	Specify when to use wet sawing for dust control.
7010, 3.02, J, 3, a	Specify the location of longitudinal and transverse construction joints.
7010, 3.02, J, 4, a	Specify the location of expansion joints.
7010, 3.07, C, 2, a	Specify when the use of a profilograph for pavement smoothness is required.
Figure 7010.101, sheet 4	Specify when to use Detail D-1, D-2, or D-3.

Section 7011 - Portland Cement Concrete Overlays

7011, 2.01, L, 1	Specify the mass per unit area.
7011, 3.02, E, 3, a	Specify the high spots in the existing asphalt surface to be milled.

Section 7020 - Hot Mix Asphalt Pavement

7020, 1.08, A & B	Specify if measurement of HMA pavement is by ton or square yard.
7020, 1.08, C & D	Specify if measurement of HMA base widening is by ton or square yard.
7020, 3.05, B, 1	Specify when the use of profilograph for pavement smoothness is required.
7020, Table 7020.05	Specify if the field laboratory air voids target value is other than 4%.

Section 7021 - Hot Mix Asphalt Overlays

7021, 2.04, A	Specify the asphalt binder grade.
7021, 3.01, A	Specify the milling depth, cross-section, or profile.

Section 7030 - Sidewalks, Shared Use Paths, and Driveways

7030, 1.08, H, 2	Specify whether granular surfacing for driveways will be computed in square yards or tons.
7030, 1.08, I, 1	Specify whenever the Contractor will be responsible for concrete compression or HMA density testing.
7030, 2.03, A	Specify color and surface texture of clay brick pavers, or select from samples submitted by the Contractor.

I. Items to be Specified on Plans or in Contract Documents (Continued)

7030, 2.03, B	If concrete pavers are to be used, specify the material requirements.
7030, 2.04, B	Specify the use of a pre-mixed high performance cold mix in lieu of an HMA setting bed.
7030, 2.06	Specify the use of colored cement for brick/paver joint filler.
7030, 3.01, A-C	Specify removal limits of sidewalks, shared use paths, driveways, bricks, and curbs.
7030, 3.01, E	Specify the locations to grind or saw existing curbs to install sidewalks, shared use paths, and driveways.
7030, 3.04, D	Specify when curing is required.
7030, 3.04, F, 2, a, 1)	Specify the spacing for transverse joints in shared use paths, if other than equal to the width of the shared use paths.
7030, 3.06, A, 2	Specify the cross-section and patterns to use for brick sidewalks with a concrete base.
7030, 3.11, A	Specify when testing will be the Contractor's responsibility.
Figure 7030.101	Specify the radius for commercial and industrial driveways. Specify when a 'B' joint is to be provided at the back of curb. Specify the driveway width. Specify when a 5 foot sidewalk is to be constructed through the driveway.
Figure 7030.102	Specify the radius for commercial and industrial driveways. Specify the driveway width. Specify when a 5 foot sidewalk is to be constructed through the driveway.
Figure 7030.104	Specify parking grading slope and property slope if different than 4:1.
Figure 7030.201	If a special grade is required for parking slopes, specify the grade. Specify the width of the sidewalk.
Figure 7030.202	Specify one of the curb details for Class A sidewalk.
Figure 7030.203	Specify the brick sidewalk pattern. Specify the jointing of the concrete base.
Figure 7030.205	Specify the use of a BT-3, KT-2, or expansion joint.

Section 7040 - Pavement Rehabilitation

7040, 2.01, A, 1	Specify if patches are <u>not</u> constructed as standard patches.
7040, 2.01, A, 2	Specify the use of calcium chloride in high early strength patching.

I. Items to be Specified on Plans or in Contract Documents (Continued)

7040, 2.01, B	Specify if an HMA mixture other than a minimum Low Traffic (LT) mixture is desired.
7040, 2.01, C, 5	Specify the use of soil sterilant for crack and joint filler material.
7040, 2.01, G	Specify if a subbase material other than modified subbase is desired.
7040, 2.01, K	Specify the length and diameter of epoxy coated dowel bars.
7040, 3.01, C	Specify the dimensions of full depth and partial depth patches.
7040, 3.01, F	Specify seeding or sodding the area outside the pavement.
7040, 3.02, A, 1	Specify when a second saw cut is required.
7040, 3.02, C, 6	Specify the locations of joints.
7040, 3.03, B, 2	Specify when to tool the joint.
7040, 3.04, J	Specify when pavement smoothness testing is required.
7040, 3.05, B	Specify the depth to mill the pavement area.
7040, 3.05, D	Specify if materials removed are <u>not</u> the property of the Contractor.
7040, 3.06, B, 3	Specify when to clean wet sawn joints.
7040, 3.06, C, 2	Specify the level to heat, handle, and apply joint filler material.
7040, 3.07, A, 3	Specify when to apply soil sterilant.
7040, 3.07, B, 2	For cracks wider than 1 inch, specify when to utilize additional methods to clean cracks of old crack filler.
7040, 3.07, C, 2	For cracks 1/4 inch to 1 inch in width, specify when to utilize additional methods to clean cracks of old crack filler.
Figure 7040.102	Specify the use of a 'CD' joint.
Figure 7040.105	Specify the use of filter fabric. Specify the type of subbase.

Section 7050 - Asphalt Stabilization

7050, 1.02	Specify the crown of the pavement.
7050, 2.01, B	Specify the type of aggregate required.
7050, 3.03, A	Specify the depth of existing roadway surface to reclaim, if other than 4 inches.
7050, 3.07	Specify the type of surface treatment to apply.

I. Items to be Specified on Plans or in Contract Documents (Continued)**Section 7060 - Bituminous Seal Coat**

7060, 1.08 A & B	Specify measurement of bituminous seal coat is in area or units.
7060, 2.01, A	Specify the cover aggregate size.
7060, 2.01, B	Specify bituminous material if different than CRS-2P.
7060, 3.02, A, 1	Specify when to patch and joint fill hard surfaced streets.
7060, 3.04, B	Specify the application rate for spreading binder bitumen, if other than shown in the table.
7060, 3.04, D	Specify the application rate for spreading cover aggregate, if other than shown in the table.
7060, 3.06, B, 2	Specify the rate for spreading binder bitumen for two course seal coats.
7060, 3.06, B, 3	Specify the size of aggregate and the rate for spreading cover aggregate for two course seal coats.
7060, 3.07	Specify if sweeping of rural pavements is <u>not</u> necessary.

Section 7070 - Emulsified Asphalt Slurry Seal

7070, 1.02, B	Specify the application of fine or coarse slurry mixtures.
7070, 2.01, B	Specify when to use crushed aggregates.
7070, 2.02, A	Specify the amount of asphalt emulsion to blend with the aggregate.
7070, 3.01, B, 1, b	Specify the width of slurry mixture application.
7070, 3.02, A	Specify when to complete pavement patches and joint or crack filling for surface preparation.
7070, 3.02, C	Specify if water flushing for surface preparation is <u>not</u> allowed.
7070, 3.03, C	Specify the rate of applying the slurry seal, if other than 10 to 18 pounds per square yard for fine aggregate and 15 to 22 pounds per square yard for coarse aggregate.
7070, 3.03, F	Specify when to apply a burlap drag.
7070, 3.05, E	Specify if strip slurry treatment is to be placed in two separate operations.

I. Items to be Specified on Plans or in Contract Documents (Continued)**Section 7080 - Permeable Interlocking Pavers**

7080, 2.02, A	Specify either slotted or perforated underdrain pipes.
7080, 2.02, B	Specify the size of collector pipe if other than 6 inch diameter is desired.
7080, 2.03, C	Specify the size of lateral pipe if other than 4 inch diameter is desired.
7080, 3.02, A	Specify the elevation and grade for the excavation area.
7080, 3.02, B	Specify the use and location of underdrains.
7080, 3.03, A	Specify the use of engineering fabric over completed subgrade.
7080, 3.04, A, 5	Specify cleanout locations.
7080, 3.04, A, 7	Specify the use of underdrain cleanout pipes and observation wells.
7080, 3.04, B, 1	Specify underdrain lateral pipe locations.
7080, 3.05, A	Specify the thickness of storage aggregate.
7080, 3.05, C	Specify the storage aggregate elevation.
7080, 3.09	Specify the installation pattern of the pavers.

Section 7090 - Cold-in-Place Pavement Recycling

7090, 2.02	Specify the required strength of the recycled pavement section.
7090, 3.01, B, 1	Specify the width and depth to mill the existing pavement material.
7090, 3.01, B, 2	Specify the use of an asphalt foaming system.
7090, 3.08, C	Specify if the compacted recycled roadway does not have to be within 6 inches of the established centerline.

Section 7091 - Full Depth Reclamation

7091, 2.02	Specify the required strength of the reclaimed pavement section as specified in the contract documents.
7091, 3.01, B, 1	Specify the width and depth to reclaim.
7091, 3.01, B, 2	Specify the use of an asphalt foaming system.
7091, 3.05, A	Specify if multiple passes are required.
7091, 3.09, C	Specify if the compacted, reclaimed roadway does not have to be within 6 inches of the established centerline.
7091, 3.11	Specify when to complete microcracking.
7091, 3.12	Specify the use of an HMA interlayer.

I. Items to be Specified on Plans or in Contract Documents (Continued)**Section 8010 - Traffic Signals**

8010, 1.08, B, 3	Specify if pedestrian equipment is required with temporary traffic signal.
8010, 2.01, A, 1, c	Specify if a message besides "TRAFFIC SIGNAL" will be required on the handhole cover.
8010, 2.01, B, 3, a, 2)	Specify solvent welded, socket type fittings for use other than PVC conduit and fittings.
8010, 2.01, C, 6, a	Specify the mode type, size, and number of fibers for fiber optic cable required.
8010, 2.01, C, 6, p	Specify the type of fiber distribution panel if a panel other than one capable of terminating a minimum of 24 fibers is desired.
8010, 2.01, C, 6, t	Specify the use of fusion splice continuous fiber runs or branch circuit connections in splice enclosures.
8010, 2.02, B, 2, c	Specify the voice message to be used for accessible pedestrian signal push button stations.
8010, 2.02, D, 9	Specify the type of mounting for microwave vehicle detectors.
8010, 2.03, A	Specify the use of traffic monitoring systems.
8010, 2.03, B	Specify the use of fiber optic hub cabinet.
8010, 2.03, C, 2, b	Specify the location to mount the antenna for a wireless interconnect network, if other than near the top of the signal pole nearest the controller cabinet.
8010, 2.04, A, 2, b	Specify dimensions and type of aluminum cabinet riser to be used.
8010, 2.04, A, 2, g	Specify accommodations of phasing and expansibility of cabinet back panel positions.
8010, 2.04, C	Specify the use of emergency vehicle preemption system.
8010, 2.05, A, 1, a	Specify the color of vehicle traffic signal head assembly housing.
8010, 2.05, B, 1, a	Specify the color of pedestrian traffic signal head assembly housing.
8010, 2.05, C, 1, a	Specify the mast arm length and vertical pole height.
8010, 2.05, C, 1, f	Specify where to use a combination street lighting/signal pole. Specify if the luminaire arm is to be mounted somewhere other than the same vertical plane as the signal arm.

I. Items to be Specified on Plans or in Contract Documents (Continued)

8010, 2.05, D, 1, a	Specify the vertical pole height of the traffic signal pedestal pole.
8010, 2.05, F, 3	Specify the street name sign dimensions, letter height and font, and sheeting.
8010, 3.01, B, 3, c	Specify if boring pits are allowed to be closer than 2 feet to the back of curb.
8010, 3.01, C, 9, c	Specify if the conduit cables could be pulled through intermediate junction boxes, handholes, pull boxes, pole bases, or any conduit opening.
8010, 3.01, C, 9, g	Specify how much cable slack to provide in each handhole, junction box, and cabinet.
8010, 3.01, C, 9, h	Specify installation of fiber optic accessories.
8010, 3.01, D, 1	Specify the foundation excavation size, shape, and depth.
8010, 3.02, C	Specify the installation of video detection camera system.
8010, 3.03, A	Specify the installation of traffic monitoring system.
8010, 3.03, B	Specify the installation of fiber optic hub cabinet.
8010, 3.04, A, 1	Specify the installation of controller cabinet and auxiliary equipment.
8010, 3.04, B	Specify the installation of controller.
8010, 3.04, C	Specify the installation of UPS battery backup system.
8010, 3.04, D	Specify the installation of emergency vehicle preemption system.
8010, 3.06	Specify construction of temporary traffic signal.
Figure 8010.104	Specify the length of rectangular detector loop.
Figure 8010.105	Specify the number of signals, signs, and spacing.

Section 8020 - Pavement Markings

8020, 3.02, A, 3, c	Specify lane widths.
8020, 3.02, B, 2	Specify if pavement surface will not be cleaned with a rotary broom or street sweeper.
8020, 3.02, D	Specify if pavement is to be grooved prior to placing marking tape.
8020, 3.02, G, 2	Specify when to place pavement markings in a groove cut into the pavement surface.

I. Items to be Specified on Plans or in Contract Documents (Continued)**Section 8030 - Temporary Traffic Control**

8030, 1.08, A, 3	Specify when to include portable dynamic message signs, temporary barrier rail, temporary flood lighting, and pilot cars in the traffic control lump sum bid item.
8030, 2.04, B	Specify if something other than precast concrete units are to be used for temporary barrier rail.
8030, 3.01, C	Specify the locations to place temporary barrier rail.
Figure 8030.117	Specify the use of auxiliary lighting or audible information devices.
Figure 8030.118	Specify the use of a crash cushion to separate the temporary sidewalk from vehicular traffic.
Figure 8030.119	Specify the use of auxiliary lighting or audible information devices.

Section 9010 - Seeding

9010, 2.01, B	Specify PLS, which shall <u>not</u> be less than the accumulated total.
9010, 2.02	Specify seed mixture in the contract documents.
9010, 2.03, A, 2	Specify if fertilizer is <u>not</u> to be applied for temporary conventional seeding.
9010, 3.01, A	Specify when aerial application of seed and fertilizer is desired.
9010, 3.01, M	Specify the use of a no-till attachment if desired.
9010, 3.04, E, 4, a	Specify if winter dormant seeding is required.
9010, 3.10, B	Specify when a warranty for seeding is required.

Section 9020 - Sodding

9020, 2.04	Specify when contractor is <u>not</u> to provide water and watering equipment.
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Section 9030 - Plant Material and Planting

9030, 1.03, E	Specify when the contractor is to submit a schedule of unit prices for each size and variety of tree, shrub, and ground cover plant.
9030, 2.01, A, 4	Specify whenever plants in rows do <u>not</u> need to be matched in form or size.
9030, 2.01, E, 1	Specify where to use bare root plants.
9030, 3.05	Specify when tree drainage wells are needed.
9030, 3.08, A	Specify when tree wrapping is required.

I. Items to be Specified on Plans or in Contract Documents (Continued)

9030, 3.12, B Specify when a warranty for plants is required.

Figure 9030.102 Specify when tree wrapping is required.

Section 9040 - Erosion and Sediment Control

9040, 1.08, A, 1 Specify if the Contractor will be responsible for the SWPPP preparation.

9040, 1.08, A, 2 Specify if the Contractor will be responsible for the SWPPP management.

9040, 1.08, B Specify thickness for compost blankets.

9040, 1.08, E, 1 Specify the width of temporary RECP.

9040, 1.08, I Specify if level spreaders are not to be removed.

9040, 1.08, L, 1, c Specify the use of anti-seep collars.

9040, 1.08, O Specify measurement for stabilized construction entrance in square yards or tons.

9040, 2.02, B Specify the use of filter berms or compost blankets.

9040, 2.03 Specify the use of filter material in areas other than filter socks and filter berms.

9040, 2.06, A Specify diameter for open weave, degradable netting if other than 9 inches is required.

9040, 2.07, A, 2 Specify if using RECP for permeable check dam.

9040, 2.08, A Specify length of pressure-treated timber for level spreaders.

9040, 2.11, A Specify class of concrete if not Class C.

9040, 2.11, B Specify riser diameter for sediment basin outlet structures.

9040, 2.11, C, 1 Specify the number, diameter, and elevation of the holes in the riser of the dewatering device in sediment basin outlet structures.

9040, 2.11, D Specify barrel diameter of the sediment basin outlet structures.

9040, 2.11, E Specify riser diameter for anti-vortex device.

9040, 3.02, D Specify if weekly erosion and sediment control site inspections are not required as a part of SWPPP management.

9040, 3.05, B Specify depth of compost blankets.

9040, 3.06, A Specify when the filter berm is not to be installed along the contour.

I. Items to be Specified on Plans or in Contract Documents (Continued)

9040, 3.06, C	Specify when a vegetated berm is required.
9040, 3.07, A, 1	Specify the size and length of filter sock.
9040, 3.07, A, 3	Specify when the filter sock is <u>not</u> to be installed along the contour.
9040, 3.07, B	Specify when to remove the filter sock.
9040, 3.08, A, 2	Specify if placement of seed and fertilizer is to be accomplished before installation of temporary rolled erosion control products.
9040, 3.08, A, 3	Specify if placement of seed and fertilizer is to be accomplished on the anchor trench.
9040, 3.08, B, 1	Specify if placement of seed and fertilizer is to be accomplished before installation of temporary rolled erosion control products.
9040, 3.09, B	Specify when to remove the wattle.
9040, 3.10, A, 2	Specify when to provide an RECP under the check dam.
9040, 3.10, D	Specify when to remove check dams.
9040, 3.12, C	Specify the excavated depth behind the level spreader.
9040, 3.12, E	Specify the minimum depth of depression before accumulated sediment is removed.
9040, 3.15, B, 1	Specify the number, diameter, and configuration of holes in the riser section of sediment basin outlet structures.
9040, 3.17	Specify the size and elevations of sediment traps.
9040, 3.18, A, 1	Specify when the silt fence material is <u>not</u> to be installed along the contour.
9040, 3.19, E	Specify when to install subgrade stabilization fabric prior to placing crushed stone.
9040, 3.19, F	Specify the thickness and dimensions of crushed stone for stabilized construction entrance.
Figure 9040.101	Specify if compost blankets are vegetated or unvegetated.
Figure 9040.102	Specify size of berm if slope is steeper than 3:1. Specify berm placement locations in uncompacted windrow perpendicular to the slope. Specify filter sock diameter.
Figure 9040.105	Specify diameter of wattle. Specify space between wattles.
Figure 9040.107	Specify height between engineering fabric and crest on the rock check dam.

I. Items to be Specified on Plans or in Contract Documents (Continued)

Figure 9040.108	Specify total height of diversion.
Figure 9040.109	Specify excavated depression depth.
Figure 9040.110	Specify the rock thickness (T), width (W), and length (L) for rip rap apron for pipe outlet onto flat ground.
Figure 9040.111	Specify the rock thickness (T), width (W), and length (L) for rip rap apron for pipe outlet into channel.
Figure 9040.112	Specify diameter of pipe for temporary pipe slope drain. Specify A, B, and C anchoring options.
Figure 9040.113	Specify barrel length and diameter for sediment basin without emergency spillway. Specify when anti-seep collars are required.
Figure 9040.114	Specify barrel length and diameter for sediment basin with emergency spillway. Specify when anti-seep collars are required.
Figure 9040.115	Specify elevations and dimensions for sediment basin dewatering device. Specify perforation configurations. Specify diameter of discharge pipe barrel.
Figure 9040.116	Specify riser diameter for anti-vortex device.
Figure 9040.117	Specify when anti-seep collars are required.
Figure 9040.118	Specify width of sediment trap.
Figure 9040.119	Specify spacing of post installation for silt fence.

Section 9050 - Gabions and Revet Mattresses

9050, 1.08, A, 3	Specify PVC coating for gabions.
9050, 1.08, B, 3	Specify PVC coating for revet mattresses.
9050, 2.01	Specify when double twisted wire baskets are <u>not</u> required.
9050, 2.02	Specify when to use welded wire baskets.
9050, 2.05	Specify when to use anchor stakes. Specify the length of anchor stakes.
9050, 3.01, A	Specify when to cut and reshape the area behind a proposed gabion wall to allow for placement of the wall.
9050, 3.01, E	Specify the placement, compaction, and dimensions of granular subbase materials.
9050, 3.04, A	Specify special details of gabion wall installation including height, slope of wall, gabion setback, special backfill materials, and tieback requirements.

I. Items to be Specified on Plans or in Contract Documents (Continued)**Section 9060 - Chain Link Fence**

9060, 1.08, A, 3	Specify PVC coating for chain link fence.
9060, 1.08, B, 3	Specify the use of barbed wire for gates.
9060, 1.08, C, 3	Specify the type of barbed wire supporting arm.
9060, 2.01, D, 2	Specify the PVC coating color.
9060, 2.02, A, 2	Specify the nominal diameter of fence height for post use, if other than shown in the table.
9060, 2.05, A	Specify the type of arm configuration for barbed wire supporting arms.
9060, 2.07, A	Specify the type, height, and width of gates.
9060, 3.01, A	Specify fence location and height.
9060, 3.01, B, 2, a	Specify post holes dimensions.
9060, 3.01, B, 2, e	Specify the required brace-post assembly.
9060, 3.01, G	Specify when to use barbed wire.
9060, 3.01, G, 1	Specify the installation of barbed wire, if other than 3 parallel wires on each barbed wire supporting arm on the outside of the area being secured.
9060, 3.01, H	Specify the installation requirements for gates.
9060, 3.01, I, 1	Specify the installation of electrical grounds.
9060, 3.02	Specify when all fences, including posts and footings, are <u>not</u> to be removed from within work areas.
9060, 3.03, A	Specify the height of temporary fence.
Figure 9060.101	Specify the fence fabric width. Specify when to install fence on the roadway side of the right-of-way.
Figure 9060.103	Specify the length of the sidewalk.

Section 9070 - Landscape Retaining Walls

9070, 2.01, B	Specify the depth of limestone slabs, if other than 8 inches.
9070, 3.01, B	Specify the excavation line and grade.

I. Items to be Specified on Plans or in Contract Documents (Continued)**Section 9071 - Segmental Block Retaining Walls**

9071, 3.01, B	Specify the excavation line and grade.
9071, 3.02, B	Specify leveling pad materials.
9071, 3.02, C	Specify the elevation and orientation.
9071, 3.02, D, 1	Specify the use of subdrains.

Section 9072 - Combined Concrete Sidewalk and Retaining Wall

9072, 2.01, A, 3	Specify the type of expansion joint, if resilient filler is <u>not</u> desired.
9072, 3.01, B	Specify the excavation line and grade.
9072, 3.04	Specify the formation of rustications.

Section 9080 - Concrete Steps, Handrails, and Safety Rail

9080, 2.04, B	Specify when to galvanize handrail and safety rail.
9080, 2.04, C	Specify when to apply powder coat to steel, galvanized steel, or aluminum handrail and safety rail.
9080, 3.02, A, 1	Specify the length of rail.
Figure 9080.103	Specify the field painting of safety rail.

Section 10,010 - Demolition

10,010, 1.07, A	Specify when the use of explosives is allowed.
10,010, 3.08, D	Specify when the removal and disposal of all brush, shrubs, trees, logs, downed timber, and other yard waste on the site is <u>not</u> desired.
10,010, 3.08, E	Specify when the removal of all retaining walls is <u>not</u> desired.
10,010, 3.11	Specify what materials are required to be recycled from the demolition site.

Section 11,010 - Construction Survey

11,010, 1.02	Specify any additional items to be included in construction survey work.
11,010, 3.02, D	Specify if property limits are to be marked.
11,010, 3.04	Specify which land corners, property corners, permanent reference markers, and benchmarks are to be replaced.

I. Items to be Specified on Plans or in Contract Documents (Continued)**Section 11,040 - Temporary Sidewalk Access**

11,040, 3.02, A	Specify locations to construct temporary granular sidewalks.
11,040, 3.03, B	Specify locations to locate temporary longitudinal channelizing devices.
Figure 11,040.102	Specify when to install orange construction safety fence between the top of the bottom rail and the bottom of the top rail.

J. Incidental or Included Items

Items that are necessary to properly complete construction, including work and materials, and are not pay items. The following is a list of items in the SUDAS Standard Specifications that are considered incidental to other work unless specified as a pay item on the plans or in the contract documents. Please note - this list is not all-inclusive.

Section 2010 - Earthwork, Subgrade, and Subbase

2010, 1.08, A, 3	<u>Clearing and Grubbing (by units)</u> Placement of backfill in area where roots have been removed, and removal and disposal of all materials.
2010, 1.08, B, 3	<u>Clearing and Grubbing (by area)</u> Removal and disposal of all materials and placement of backfill in area where roots have been removed.
2010, 1.08, D, 2, c	<u>Topsoil, Compost-amended</u> Furnishing and incorporating compost.
2010, 1.08, E, 3	<u>Excavation, Class 10, Class 12, or Class 13</u> <ol style="list-style-type: none">Site preparation for, and the construction of, embankment, fills, shoulder backfill, and backfill behind curbs.Overhaul.Finishing the soil surface, including roadways, shoulders, behind curbs, side ditches, slopes, and borrow pits.Repair or replacement of any fences that have been unnecessarily damaged or removed.
2010, 1.08, F, 3	<u>Below Grade Excavation (Core Out)</u> Equipment, tools, labor, disposal of unsuitable materials, dewatering, drying, furnishing, and placement of foundation materials as required by the Engineer, compaction and finishing of the excavated area, and all incidental work as may be required.
2010, 1.08, G, 3	<u>Subgrade Preparation</u> Excavating, manipulating, replacing, compacting, and trimming to the proper grade.
2010, 1.08, H, 3	<u>Subgrade Treatment</u> Furnishing, placing, and incorporating the subgrade treatment material (cement, asphalt, fly ash, lime, geogrid, or geotextiles).
2010, 1.08, I, 3	<u>Subbase</u> Furnishing, placing, compacting, and trimming to the proper grade.
2010, 1.08, J, 1, c	<u>Removal of Structures</u> Removal and disposal of structures.
2010, 1.08, J, 2, a, 3)	<u>Removal of Known Box Culverts</u> Removal and disposal of known box culverts.

J. Incidental or Included Items (Continued)

- 2010, 1.08, J, 2, c, 3) Removal of Known Pipe Culverts
Removal and disposal of known pipe culverts.
- 2010, 1.08, J, 3, a, 3) Removal of Known Pipes and Conduits
Removal, disposal, and plugging, if specified, of pipes and conduits.

Section 3010 - Trench Excavation and Backfill

- 3010, 1.08, A General
1. Standard trench excavation.
2. Removal and disposal of unsuitable backfill material encountered during standard trench excavation.
3. Removal of abandoned private utilities encountered during trench excavation.
4. Furnishing and placing granular bedding material.
5. Placing and compacting backfill material.
6. Dewatering including, but not limited to, all equipment such as generators, pumps, rock for sump pits, discharge piping, and any extra excavation needed to facilitate dewatering according to stormwater regulations, as applicable.
7. Sheet piling, shoring, and bracing.
8. Adjusting the moisture content of excavated backfill material to the range specified for placement and compaction.
- 3010, 1.08, C, 3 Trench Foundation
Removal and disposal of over-excavated material required to stabilize trench foundation; and furnishing, hauling, and placing stabilization material.
- 3010, 1.08, D, 3 Replacement of Unsuitable Backfill Material
Furnishing, hauling, and placing backfill material.
- 3010, 1.08, E, 3 Special Pipe Embedment or Encasement
Furnishing and placing all required special pipe embedment or encasement materials.

Section 3020 - Trenchless Construction

- 3020, 1.08 All items of work contained in this section are incidental to the underground utility pipe being installed and will not be paid for separately.

Section 4010 - Sanitary Sewers

- 4010, 1.08, A, 1, c Sanitary Sewer Gravity Main, Trenched
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; wyes and other fittings; pipe joints; pipe connections; testing; and inspection.

J. Incidental or Included Items (Continued)

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|---------------------|--|
| 4010, 1.08, A, 2, c | <u>Sanitary Sewer Gravity Main, Trenchless</u>
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; pipe connections; testing; and inspection. |
| 4010, 1.08, B, 1, c | <u>Sanitary Sewer Gravity Main with Casing Pipe, Trenched</u>
Furnishing and installing both carrier pipe and casing pipe, trench excavation, dewatering, furnishing bedding material, placing bedding and backfill material, furnishing and installing annular space fill material, casing spacers, pipe connections, testing, and inspection. |
| 4010, 1.08, B, 2, c | <u>Sanitary Sewer Gravity Main with Casing Pipe, Trenchless</u>
Furnishing and installing both carrier pipe and casing pipe; trenchless installation materials and equipment; pit excavation; dewatering; and placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; pipe connections; testing; and inspection. |
| 4010, 1.08, C, 1, c | <u>Sanitary Sewer Force Main, Trenched</u>
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill; wyes and other fittings; pipe joints; testing; and inspection. |
| 4010, 1.08, C, 2, c | <u>Sanitary Sewer Force Main, Trenchless</u>
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; pipe connections; testing; and inspection. |
| 4010, 1.08, D, 1, c | <u>Sanitary Sewer Force Main with Casing Pipe, Trenched</u>
Furnishing and installing both carrier pipe and casing pipe; trench excavation; dewatering; furnishing, placing, and compacting bedding and backfill material; furnishing and installing annular space fill material; casing spacers; pipe connections; testing; and inspection. |
| 4010, 1.08, D, 2, c | <u>Sanitary Sewer Force Main with Casing Pipe, Trenchless</u>
Furnishing and installing both carrier pipe and casing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; pipe connections; testing; and inspection. |
| 4010, 1.08, E, 3 | <u>Sanitary Sewer Service Stub</u>
Trench excavation; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; tap; fittings; testing; and inspection. |
| 4010, 1.08, F, 3 | <u>Sanitary Sewer Service Relocation</u>
Removal of existing pipe, trench excavation, furnishing new pipe and bedding material, placing and compacting bedding and backfill material, connection back to existing service, compaction, testing, and inspection. |

J. Incidental or Included Items (Continued)

- 4010, 1.08, G, 3 Sewage Air Release Valve and Pit
Excavation; furnishing, placing, and compacting bedding and backfill material; and testing.
- 4010, 1.08, H, 3 Removal of Sanitary Sewer
Removal, disposal, and capping (if specified) of pipe; and furnishing, placing, and compacting backfill material.
- 4010, 1.08, I, 3 Sanitary Sewer Cleanout
Plug at the end of the main, fittings, riser pipe, cap with screw plug, casting, and concrete casting encasement.
- 4010, 1.08, K, 3 Sanitary Sewer Abandonment, Plug
Trench excavation (if necessary), cutting pipe (if required), furnishing and placing plug materials, and placing and compacting backfill material.
- 4010, 1.08, L, 3 Sanitary Sewer Abandonment, Fill and Plug
Trench excavation (if necessary), cutting pipe (if required), furnishing and placing pipe fill material, furnishing and placing plug materials, and placing and compacting backfill material.

Section 4020 - Storm Sewers

- 4020, 1.08, A, 1, c Storm Sewer, Trenched
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; joint wrapping; wyes and other fittings; pipe joints; pipe connections; testing; and inspection.
- 4020, 1.08, A, 2, c Storm Sewer, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; pipe connections; testing; and inspection.
- 4020, 1.08, B, 1, c Storm Sewer with Casing Pipe, Trenched
Furnishing and installing both carrier pipe and casing pipe; trench excavation; dewatering; furnishing, placing, and compacting bedding and backfill material; furnishing and installing annular space fill material; casing spacers; pipe connections; testing; and inspection.
- 4020, 1.08, B, 2, c Storm Sewer with Casing Pipe, Trenchless
Furnishing and installing both carrier pipe and casing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; pipe connections; testing; and inspection.

J. Incidental or Included Items (Continued)

- 4020, 1.08, C, 3 Linear Trench Drain
Furnishing and installing the linear trench drain including all appurtenances; furnishing and placement of PCC transition; furnishing, excavation, and backfill of discharge pipe; connection to manhole or intake, if required; installation of apron, if required.
- 4020, 1.08, D, 3 Removal of Storm Sewer
Removal, disposal, and capping (if specified) of pipe; and furnishing, placing, and compacting backfill material.
- 4020, 1.08, F, 3 Storm Sewer Abandonment, Plug
Trench excavation (if necessary), cutting pipe (if required), furnishing and placing plug materials, and placing and compacting backfill material.
- 4020, 1.08, G, 3 Storm Sewer Abandonment, Fill and Plug
Trench excavation (if necessary), cutting pipe (if required), furnishing and placing pipe fill material, furnishing and placing plug materials, and placing and compacting backfill material.

Section 4030 - Pipe Culverts

- 4030, 1.08, A, 1, c Pipe Culvert, Trenched
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; connectors; testing; and inspection.
- 4030, 1.08, A, 2, c Pipe Culvert, Trenchless
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation, dewatering, and placing and compacting backfill material; pipe connections; testing; and inspection.
- 4030, 1.08, B, 3 Pipe Apron
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; connectors; and other appurtenances.
- 4030, 1.08, C, 3 Footings for Concrete Pipe Aprons
Excavation; dewatering; reinforcing steel; concrete; furnishing and installing apron; furnishing, placing and compacting bedding and backfill material.

Section 4040 - Subdrains and Footing Drain Collectors

- 4040, 1.08, A, 3 Subdrain
Trench excavation, furnishing and placing bedding and backfill material, engineering fabric (when specified), connectors, and elbows and tees. The length of elbows and tees of the pipes installed will be included in the length of pipe measured.

J. Incidental or Included Items (Continued)

- 4040, 1.08, B, 3 Footing Drain Collector
Trench excavation, pipe, wyes, tap, fittings, and furnishing and placing bedding and backfill material.
- 4040, 1.08, D, 3 Subdrain or Footing Drain Outlets and Connections
Pipe, non-shrink grout, coupling bands, and rodent guards for pipes 6 inches or smaller.
- 4040, 1.08, E, 3 Storm Sewer Service Stub
Trench excavation, furnishing bedding material, placing bedding and backfill material, tap, fittings, and plugs.

Section 4050 - Pipe Rehabilitation

- 4050, 1.08, A, 1, c Pre-Rehabilitation Cleaning and Inspection
Pre-cleaning CCTV inspection, light sewer cleaning, debris removal and transport, post cleaning CCTV inspection for Engineer review, and identification and logging of active service taps. If specified in the contract documents, unit price also includes disposal and associated costs for all debris removed from sewer.
- 4050, 1.08, A, 2, c Additional Sewer Cleaning
Heavy sewer cleaning; root cutting; deposit cutting; and removing, transporting, disposing, paying associated costs for all debris removed from sewer, and post cleaning CCTV inspection for Engineer review.
- 4050, 1.08, B, 3 Remove Protruding Service Connections
Removal of protruding service connections and debris removal.
- 4050, 1.08, C, 1, c CIPP Main Lining
Furnishing and installing the liner and appurtenances, CCTV inspection immediately prior to lining, bypass pumping unless otherwise specified, sliding foil, post-lining CCTV inspection, and all costs associated with the public information and notification program.
- 4050, 1.08, C, 2, c Building Sanitary Sewer Service Reinstatement
Reinstating sanitary sewer service connections, removal of debris, and coordination with service owners.
- 4050, 1.08, C, 3, c CIPP End Seal
End seal and installation.
- 4050, 1.08, D, 3 CIPP Point Repair
Furnishing and placing point repair liner, bypass pumping unless otherwise specified, sewer cleaning, removal of obstructions, debris removal, pipe preparation, and pre and post repair CCTV inspection.
- 4050, 1.08, E, 1, c CIPP Service Pipe, Connection
Furnishing and placing service connection liner, bypass pumping unless otherwise specified, documentation, and all costs associated with the public information and notification program.

J. Incidental or Included Items (Continued)

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| 4050, 1.08, E, 2, c | <u>CIPP Service Repair, Partial Pipe</u>
Furnishing and installing service repair liner, bypass pumping unless otherwise specified, documentation, and all costs associated with the public information and notification program. |
| 4050, 1.08, F, 1, c | <u>Pressure Testing of Mainline Sewer Joints</u>
Bypass pumping unless otherwise specified, control testing, and documentation. |
| 4050, 1.08, F, 2, c | <u>Injection Grouting of Mainline Sewer Joints</u>
Bypass pumping unless otherwise specified, material testing, pressure testing after grouting, re-grouting of failed joints, and documentation. Unit price does not include the quantity of chemical grout used. |
| 4050, 1.08, F, 3, c | <u>Pressure Testing of Service Connections</u>
Bypass pumping unless otherwise specified, and documentation. |
| 4050, 1.08, F, 4, c | <u>Injection Grouting of Service Connections</u>
Bypass pumping unless otherwise specified, material testing, pressure testing after grouting, and documentation. Unit price does not include the quantity of chemical grout used. |
| 4050, 1.08, F, 5, c | <u>Chemical Grout</u>
Grout additives; root inhibitor; and supplying, mixing, and measurement of chemical grout. |
| 4050, 1.08, G, 3 | <u>Bypass Pumping</u>
Development and submittal of the bypassing plan, all staffing, equipment, and appurtenances necessary to accomplish the approved bypassing plan, including reserve equipment. |
| 4050, 1.08, H, 1, c | <u>Spot Repairs (by Pipe Replacement)</u>
Uncovering and removing existing pipe and furnishing and placing bedding and backfill material for replacement pipe. |
| 4050, 1.08, H, 2, c | <u>Spot Repairs (by Linear Foot)</u>
Furnishing and installing replacement pipe and connections. |

4060 - Cleaning, Inspection, and Testing of Sewers

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| 4060, 1.08 | Cleaning, inspecting, and testing sanitary sewers, storm sewers, pipe culverts, and rehabilitated pipes (including video inspection) are incidental to other project costs and will not be paid for separately. |
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Section 5010 - Pipe and Fittings

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| 5010, 1.08, A, 1, c | <u>Water Main, Trenched</u>
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; tracer system; testing; disinfection; and polyethylene wrap for ductile iron pipe and for fittings. |
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J. Incidental or Included Items (Continued)

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| 5010, 1.08, A, 2, c | <u>Water Main, Trenchless</u>
Furnishing and installing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; tracer system; testing; and disinfection. |
| 5010, 1.08, B, 1, c | <u>Water Main with Casing Pipe, Trenched</u>
Furnishing and installing both carrier pipe and casing pipe; trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; casing spacers; furnishing and installing annular space fill material; tracer system; testing; and disinfection. |
| 5010, 1.08, B, 2, c | <u>Water Main with Casing Pipe, Trenchless</u>
Furnishing and installing both carrier pipe and casing pipe; trenchless installation materials and equipment; pit excavation; dewatering; placing and compacting backfill material; casing spacers; furnishing and installing annular space fill material; tracer system; testing; and disinfection. |
| 5010, 1.08, C, 1, c | <u>Fitting (by count)</u>
Restrained joints and thrust blocks. |
| 5010, 1.08, C, 2, c | <u>Fitting (by weight)</u>
Restrained joints and thrust blocks. |
| 5010, 1.08, D, 3 | <u>Water Service Stub (by each)</u>
Water service corporation; service pipe; curb stop; stop box; trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; and installation of tracer wire system for non-metallic service pipe. |
| 5010, 1.08, E, 1, c | <u>Water Service Stub (by length), Water Service Pipe</u>
Trench excavation; dewatering; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; and installation of tracer wire system for non-metallic service pipe. |

Section 5020 - Valves, Fire Hydrants, and Appurtenances

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| 5020, 1.08, A, 3 | <u>Valve (Butterfly or Gate)</u>
All components attached to the valve or required for its complete installation, including underground or above ground operator, square valve operating nut, valve box and cover, valve box extension, and valve stem extension. |
| 5020, 1.08, B, 3 | <u>Tapping Valve Assembly</u>
Tapping sleeve, tapping valve, the tap, valve box and cover, valve box extension, and valve stem extension. |

J. Incidental or Included Items (Continued)

- 5020, 1.08, C, 3 Fire Hydrant Assembly
The fire hydrant, barrel extensions sufficient to achieve proper bury depth of anchoring pipe and height of fire hydrant above finished grade, and components to connect the fire hydrant to the water main, including anchoring pipe, fittings, thrust blocks, pea gravel or porous backfill material, and fire hydrant gate valve and appurtenances, except tapping valve assembly if used.
- 5020, 1.08, E Measurement and payment for minor adjustment of an existing valve box by raising or lowering the adjustable valve box is incidental.
- 5020, 1.08, G, 3 Valve Box Replacement
Removal of existing valve box; excavation; furnishing and installing new valve box; backfill; compaction; and all other necessary appurtenances.
- 5020, 1.08, H, 3 Fire Hydrant Adjustment
Removal and reinstallation of the existing fire hydrant; furnishing and installing the extension barrel section and stem; and all other necessary appurtenances.
- 5020, 1.08, I, 3 Fire Hydrant Assembly Removal
Excavation, removal of the fire hydrant, hydrant valve, thrust block, delivery of the fire hydrant assembly to the Contracting Authority (if specified), capping of the pipe, backfill, compaction, and surface restoration to match the surrounding area.
- 5020, 1.08, J, 3 Valve Removal
Excavation, removal of each valve, replacing the removed valve with pipe and connections if required or capping the former valve connection, delivery of the valve to the Contracting Authority (if specified), backfill, compaction, and surface restoration to match the surrounding area.
- 5020, 1.08, K, 3 Valve Box Removal
Excavation, removal of each valve box, delivery of the valve box to the Contracting Authority (if specified), backfill, compaction, and surface restoration to match the surrounding area.

Section 5030 - Testing and Disinfection

- 5030, 1.08 Testing and disinfection of water systems is incidental to the construction of pipe and fittings.

Section 6010 - Structures for Sanitary and Storm Sewers

- 6010, 1.08, A, 3 Manhole
Excavation; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; base; structural concrete; reinforcing steel; precast units (if used); concrete fillets; pipe connections; infiltration barriers (sanitary sewer manholes only); castings; and adjustment rings.

J. Incidental or Included Items (Continued)

6010, 1.08, B, 3	<u>Intake</u> Excavation; furnishing and installing pipe; furnishing, placing, and compacting bedding and backfill material; base; structural concrete; reinforcing steel; precast units (if used); concrete fillets; pipe connections; castings; and adjustment rings.
6010, 1.08, C, 1, c	<u>Internal Drop Connection</u> Cutting the hole and installing a flexible watertight connector, providing and installing the receiving bowl, flexible coupler between the bowl and the drop pipe, the PVC drop pipe, pipe brackets and bolts, the bottom elbow, repair of fillet if required, and a splash guard if required.
6010, 1.08, C, 2, c	<u>External Drop Connection</u> The connection to the manhole and all pipe; fittings; concrete encasement; and furnishing, placing, and compacting bedding and backfill material.
6010, 1.08, E, 3	<u>Manhole or Intake Adjustment, Minor</u> Removing existing casting and existing adjustment rings, furnishing and installing adjustment rings, furnishing and installing new casting, and installing new infiltration barrier (sanitary sewer manholes only).
6010, 1.08, F, 3	<u>Manhole or Intake Adjustment, Major</u> Removal of existing casting, adjustment rings, top sections, and risers; excavation; concrete and reinforcing steel or precast sections; furnishing and installing new casting; installing new infiltration barrier (sanitary sewer manholes only); placing backfill material; and compaction.
6010, 1.08, G, 3	<u>Connection to Existing Manhole or Intake</u> Coring or cutting into the existing manhole or intake, pipe connectors, grout, and waterstop (when required).
6010, 1.08, H, 3	<u>Remove Manhole or Intake</u> Removal of casting, concrete, and reinforcement; plugging pipes; filling remaining structure with flowable mortar; and placing compacted fill over structure to finished grade.

Section 6020 - Rehabilitation of Existing Manholes

6020, 1.08, A, 1, c	<u>Infiltration Barrier, Rubber Chimney Seal</u> All necessary compression or expansion bands and extension sleeves as necessary to complete chimney seal.
6020, 1.08, A, 2, c	<u>Infiltration Barrier, Molded Shield</u> Sealant.
6020, 1.08, B, 3	<u>In-situ Manhole Replacement, Cast-in-place Concrete</u> Handling of sewer flows as required to properly complete the installation, invert overlay as recommended by the manufacturer, replacement of existing casting with a new casting, and testing the manhole upon completion.

J. Incidental or Included Items (Continued)

- 6020, 1.08, C, 3 In-situ Manhole Replacement, Cast-in-place Concrete with Plastic Liner
Handling of sewer flows as required to properly complete the installation, invert overlay as recommended by the manufacturer, replacement of existing casting with a new casting, sealing at the frame and cover, sealing pipe penetrations as recommended by the manufacturer, and testing the manhole upon completion.
- 6020, 1.08, D, 3 Manhole Lining with Centrifugally Cast Cementitious Mortar Liner with Epoxy Seal
Handling of sewer flows during lining operations as required to properly complete the installation, and replacement of the existing casting with a new casting.

Section 6030 - Cleaning, Inspection, and Testing of Structures

- 6030, 1.08 Cleaning, inspection, and testing of structures are incidental to construction of structures and will not be paid for separately.

Section 7010 - Portland Cement Concrete Pavement

- 7010, 1.08, A, 3 Pavement, PCC
Final trimming of subgrade or subbase, integral curb, bars and reinforcement, joints and sealing, surface curing and pavement protection, safety fencing, concrete for rigid headers, boxouts for fixtures, and pavement smoothness testing.
- 7010, 1.08, E, 3 Curb and Gutter
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.
- 7010, 1.08, F, 3 Beam Curb
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.
- 7010, 1.08, G, 3 Concrete Median
Final subgrade/subbase preparation, bars and reinforcement, joints and sealing, surface curing and pavement protection, and boxouts for fixtures.
- 7010, 1.08, H, 3 PCC Railroad Crossing Approach
Excavation for modified subbase and subdrain, furnishing and installing subdrain, furnishing and installing subdrain outlet or connection to storm sewer, furnishing and installing porous backfill material, furnishing and installing fiber board barrier, furnishing and placing modified subbase material, furnishing and installing reinforcing steel and tie bars, furnishing and placing concrete, furnishing, placing, and compacting HMA.
- 7010, 1.08, I, 3 PCC Pavement Samples and Testing
Certified plant inspection, pavement thickness cores, profilograph pavement smoothness measurement (when required by the contract documents), and maturity testing.

J. Incidental or Included Items (Continued)

- 7010, 1.08, K, 3 PCC Pavement Widening
Final subgrade/subbase preparation, integral curb, bars and reinforcement, joints and sealing, surface curing and pavement protection, safety fencing, concrete for rigid headers, boxouts for fixtures, and pavement smoothness.

Section 7011 - Portland Cement Concrete Overlays

- 7011, 1.08, A, 1, c PCC Overlay, Furnish Only
Furnishing the concrete mixture and delivery to the project site.
- 7011, 1.08, A, 2, c PCC Overlay, Place Only
Integral curb, bars and reinforcement, joints and sealing, finishing and texturing, surface curing and pavement protection, safety fencing, concrete for rigid headers, boxouts for fixtures, and pavement smoothness testing.
- 7011, 1.08, A, 3, c Surface Preparation for Bonded PCC Overlay
Sandblasting, shot blasting, scarification, and surface cleaning.
- 7011, 1.08, A, 4, c Surface Preparation for Unbonded PCC Overlay
Scarification and surface cleaning.
- 7011, 1.08, A, 5, c HMA Separation Layer for Unbonded PCC Overlay
HMA mix, including asphalt binder.
- 7011, 1.08, A, 6, c Geotextile Fabric Separation Layer for Unbonded PCC Overlay
Cleaning surface and furnishing, placing, and securing the geotextile fabric separation layer.

Section 7020 - Hot Mix Asphalt Pavement

- 7020, 1.08, A, 3 Pavement, HMA (by ton)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
- 7020, 1.08, B, 3 Pavement, HMA (by square yard)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
- 7020, 1.08, C, 3 HMA Base Widening (by ton)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.
- 7020, 1.08, D, 3 HMA Base Widening (by square yard)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.

J. Incidental or Included Items (Continued)

7020, 1.08, E, 3 HMA Railroad Crossing Approach
Excavation for modified subbase and subdrain, furnishing and installing subdrain, furnishing and installing subdrain outlet, furnishing and installing porous backfill material, furnishing and installing fiber board barrier, furnishing and placing modified subbase material, furnishing and applying tack coat, furnishing, placing, and compacting HMA.

7020, 1.08, I, 3 HMA Pavement Samples and Testing
Certified plant inspection, pavement thickness cores, density analysis, profilograph pavement smoothness measurement (when required by the contract documents), and air void testing.

Section 7021 - Hot Mix Asphalt Overlays

7021, 1.08, A, 3 HMA Overlay (by ton)
Asphalt mix with asphalt binder, tack coats between layers, construction zone protection, and quality control.

7021, 1.08, B, 3 HMA Overlay (by square yard)
Asphalt mix with asphalt binder, tack coat, construction zone protection, and quality control.

Section 7030 - Sidewalks, Shared Use Paths, and Driveways

7030, 1.08, A, 3 Removal of Sidewalk, Shared Use Path, or Driveway
Sawing, hauling, and disposal of materials removed.

7030, 1.08, B, 3 Removal of Curb
Hauling and disposal of materials removed.

7030, 1.08, C, 3 Shared Use Paths
Subgrade preparation, jointing, sampling, smoothness testing and correction, and testing.

7030, 1.08, D, 3 Special Subgrade Preparation for Shared Use Paths
Water required to bring subgrade moisture content to within the required limits.

7030, 1.08, E, 3 Sidewalk, PCC
Minor grade adjustments at driveways and other intersections, subgrade preparation, formwork, additional thickness at thickened edges, jointing, sampling, smoothness testing and correction, and testing.

7030, 1.08, F, 3 Brick/Paver Sidewalk with Pavement Base
Subgrade preparation, pavement base, setting bed, neoprene asphalt adhesive for asphalt setting bed, setting the bricks/pavers, installing weep holes and associated materials, and sand/cement joint filler.

7030, 1.08, G, 3 Detectable Warning
Steel bar supports and manufactured detectable warning panels.

J. Incidental or Included Items (Continued)

7030, 1.08, H, 1, c Driveway, Paved
Excavation, subgrade preparation, jointing, sampling, and testing.

7030, 1.08, H, 2, c Driveway, Granular
Excavation and preparation of subgrade.

Section 7040 - Pavement Rehabilitation

7040, 1.08, A, 3 Full Depth Patches
Sawing, removing, and disposing of existing pavement and reinforcing; restoring the subgrade; furnishing and installing tie bars and dowel bars; furnishing and placing the patch material, including the asphalt binder and tack coat; forming and constructing integral curb; surface curing and pavement protection; joint sawing and filling; and placing backfill and restoring disturbed surfaces.

7040, 1.08, B, 3 Subbase Over-excavation
Removal of existing subbase or subgrade, disposal of materials removed, furnishing and placing subbase material, and any additional excavation required for subbase placement.

7040, 1.08, C, 3 Partial Depth Patches
Sawing, removing, and disposing of existing pavement; furnishing tack coat or bonding agent; furnishing and placing the patch material; curing; joint filling (PCC patches only); placing backfill; and restoring disturbed surfaces.

7040, 1.08, D, 3 Crack and Joint Cleaning and Filling, Hot Pour
Furnishing crack and joint filler material and routing, sawing, cleaning, and filling joints or cracks.

7040, 1.08, E, 1, c Crack Cleaning and Filling, Emulsion
Furnishing emulsified crack filler material, cleaning cracks, placing soil sterilant, and filling cracks.

7040, 1.08, E, 2, c Hot Mix Asphalt for Crack Filling
Cleaning, applying tack coat, and furnishing and placing HMA for crack filling.

7040, 1.08, F, 3 Diamond Grinding
Diamond grinding pavement, testing for smoothness according to the contract documents, and removal of slurry and residue from the project site.

7040, 1.08, G, 3 Milling
Milling pavement; furnishing water; and salvaging, stockpiling, and removing cuttings and debris.

7040, 1.08, H, 3 Pavement Removal
Sawing, breaking, removing, and disposing of existing pavement and reinforcing steel.

J. Incidental or Included Items (Continued)

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| 7040, 1.08, I, 3 | <u>Curb and Gutter Removal</u>
Sawing, breaking, removing, and disposing of existing curb and gutter. |
| 7040, 1.08, J, 3 | <u>Dowel Bar Retrofit</u>
Cutting the slots, preparing the slots, placing and grouting the bars, and curing the surface. |
| 7040, 1.08, K | Required sampling and testing for pavement repair and rehabilitation work is incidental to other project costs and will not be paid for separately. |

Section 7050 - Asphalt Stabilization

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| 7050, 1.08, A, 3 | <u>Asphalt Stabilization</u>
Furnishing and spreading imported material, applying and incorporating asphalt stabilization, blending of the materials, grading and compacting the blended materials, and final clean up. |
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Section 7060 - Bituminous Seal Coat

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| 7060, 1.08, A, 3 | <u>Bituminous Seal Coat (by area)</u>
Surface preparation including protection of street fixtures; furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts; and final clean up. |
| 7060, 1.08, B, 1, c | <u>Bituminous Seal Coat (by units), Cover Aggregate</u>
Surface preparation including protection of street fixtures; furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts; and final clean up. |
| 7060, 1.08, B, 2, c | <u>Bituminous Seal Coat (by units), Binder Bitumen</u>
Furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts; and final clean up. |

Section 7070 - Emulsified Asphalt Slurry Seal

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| 7070, 1.08, A, 3 | <u>Emulsified Asphalt Slurry Seal (by area)</u>
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts. |
| 7070, 1.08, B, 1, c | <u>Emulsified Asphalt Slurry Seal (by units), Aggregate</u>
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts. |
| 7070, 1.08, B, 2, c | <u>Emulsified Asphalt Slurry Seal (by units), Asphalt Emulsion</u>
Surface preparation and furnishing and placing of materials, including fillets at intersecting streets, driveways, and turnouts. |

J. Incidental or Included Items (Continued)**Section 7080 - Permeable Interlocking Pavers**

- 7080, 1.08, B, 3 Engineering Fabric
Placing and securing filter fabric and any overlapped areas.
- 7080, 1.08, C, 3 Underdrain
Furnishing and placing pipe, cleanouts, observation wells, and pipe fittings.
- 7080, 1.08, D, 3 Storage Aggregate
Furnishing, hauling, placing, and compacting storage aggregate.
- 7080, 1.08, E, 3 Filter Aggregate
Furnishing, hauling, placing filter, and compacting aggregate.
- 7080, 1.08, F, 3 Permeable Interlocking Pavers
Testing, furnishing and placing bedding course, furnishing and installing permeable interlocking pavers, furnishing and placing joint/opening fill material, refilling joint after 6 months, and pavement protection.
- 7080, 1.08, G, 3 PCC Edge Restraint
Final trimming of subgrade or subbase, bars and reinforcement, joints and sealing, surface curing and pavement protection, safety fencing, and boxouts for fixtures.

Section 7090 - Cold-in-Place Pavement Recycling

- 7090, 1.08, A, 3 Cold-in-Place Recycling
Milling and sizing of existing asphalt layers; protecting street fixtures; development of a job mix formula; adding and mixing recycling agents and additives, if required; supplying and incorporating water; compacting the reclaimed mix; shaping of the mix; completing secondary compaction, if required; removing any loose or excess material; and final clean up.
- 7090, 1.08, B, 3 Bituminous Recycling Agents
Furnishing and placing of materials and mixing the agent into the recycled mix.
- 7090, 1.08, C, 3 Chemical Recycling Additives
Furnishing and placing of materials and mixing the agent into the recycled mix.

Section 7091 - Full Depth Reclamation

- 7091, 1.08, A, 3 Full Depth Reclamation
Pulverizing and sizing of existing asphalt layers; incorporating and mixing of existing underlying materials; protecting street fixtures; development of a job mix formula; adding and mixing stabilizing agents and additives, if required; compacting the reclaimed mix; shaping of the mix; removing any loose or excess material; curing; and final clean up.

J. Incidental or Included Items (Continued)

- 7091, 1.08, B, 3 Mechanical Stabilization Agents
Furnishing and placing of aggregate and blending of the aggregates.
- 7091, 1.08, C, 3 Bituminous Stabilization Agents
Furnishing and placing of materials and mixing the agent into the reclaimed mix.
- 7091, 1.08, D, 3 Chemical Stabilization Agents
Furnishing and placing of materials and mixing the agent into the reclaimed mix.
- 7091, 1.08, F, 3 Interlayer for Cement Stabilized Base
Surface cleaning, furnishing, and placing of the specified interlayer.

Section 8010 - Traffic Signals

- 8010, 1.08, B, 3 Temporary Traffic Signal
Furnishing, installing, maintaining, and removing poles; wiring; traffic signal control equipment including pedestrian equipment if specified; all modifications of signal timing due to changes in construction staging; relocation of trailer mounted temporary traffic signal systems; placement in another physical location to address changes in construction staging; and all appurtenances.

Section 8020 - Pavement Markings

- 8020, 1.08, B, 3 Painted Pavement Markings, Solvent/Waterborne
Reflectorizing spheres, layout, surface preparation, and application of marking paint.
- 8020, 1.08, C, 3 Painted Pavement Markings, Durable
Layout, surface preparation, and application of marking paint.
- 8020, 1.08, D, 3 Painted Pavement Markings, High-Build
Layout, surface preparation, and application of marking paint.
- 8020, 1.08, E, 3 Permanent Tape Markings
Layout, surface preparation, and application of marking tape.
- 8020, 1.08, F, 3 Wet, Retroreflective Removable Tape Markings
Layout, surface preparation, application, and removal.
- 8020, 1.08, G, 3 Painted Symbols and Legends
Layout, surface preparation, and application of each symbol and legend.
- 8020, 1.08, H, 3 Precut Symbols and Legends
Layout, surface preparation, and application of each symbol and legend.
- 8020, 1.08, I, 3 Temporary Delineators
Installation and removal of delineators.

J. Incidental or Included Items (Continued)

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| 8020, 1.08, J, 3 | <u>Raised Pavement Markers</u>
Installation and removal of pavement markers. |
| 8020, 1.08, K, 3 | <u>Pavement Markings Removed</u>
Pavement marking removal and waste material collection, removal, and disposal. |
| 8020, 1.08, L, 3 | <u>Symbols and Legends Removed</u>
Symbol and legend marking removal and waste material collection, removal, and disposal. |
| 8020, 1.08, M, 3 | <u>Grooves Cut for Pavement Markings</u>
Layout, cutting grooves, collection and disposal of removed material, and additional groove width and transition length beyond the pavement marking dimensions. |
| 8020, 1.08, N, 3 | <u>Grooves Cut for Symbols and Legends</u>
Layout, cutting grooves, and collection and disposal of removed material. |

Section 8030 - Temporary Traffic Control

- | | |
|------------------|---|
| 8030, 1.08, A, 3 | <u>Temporary Traffic Control</u>
Installation, maintenance, and removal of temporary traffic control; total roadway closures with installation and removal of detour signing as shown in the contract documents; removal and reinstallation or covering of permanent traffic control devices that conflict with the temporary traffic control plan; monitoring and documenting traffic control conditions; and flaggers. When required in the contract documents, the following are also included in traffic control unless a separate bid item is provided: portable dynamic message signs, temporary barrier rail, temporary flood lighting, and pilot cars. |
|------------------|---|

Section 9010 - Seeding

- | | |
|---------------------|---|
| 9010, 1.08, A, 1, c | <u>Conventional Seeding, Seeding</u>
Removal of rock and other debris from the area; repairing rills and washes; preparing the seedbed; furnishing and placing seed, including any treatment required; furnishing and placing fertilizer and mulch; and furnishing water and other care during the care period, unless these items are bid separately. |
| 9010, 1.08, B, 3 | <u>Hydraulic Seeding, Seeding, Fertilizing, and Mulching</u>
Removal of rock and other debris from the area; repairing rills and washes; preparing the seedbed; furnishing and placing seed, including any treatment required; furnishing and placing fertilizer and mulch; and furnishing water and other care during the care period, unless these items are bid separately. |

J. Incidental or Included Items (Continued)

9010, 1.08, C, 3 Pneumatic Seeding , Seeding, Fertilizing, and Mulching
Removal of rock and other debris from the area; repairing rills and washes; preparing the seedbed; furnishing and placing seed, including any treatment required; furnishing and placing fertilizer and mulch; and furnishing water and other care during the care period, unless these items are bid separately.

9010, 1.08, E, 3 Warranty
All work required to correct any defects in the original placement of the seeding for the period of time designated.

Section 9020 - Sodding

9020, 1.08, A, 3 Sod
Preparation of sod and sodbed, stakes, fertilizing, watering, maintenance, and clean-up. Also includes any necessary sod replacements during maintenance period.

Section 9030 - Plant Material and Planting

9030, 1.08, A, 3 Plants (by count)
Delivery, excavation, installation, watering, placing backfill material, mulching, wrapping, staking or guying, herbicide, maintenance during the establishment period, and replacements.

9030, 1.08, B, 3 Plants (by count), With Warranty
Delivery, excavation, installation, watering, placing backfill material, mulching, wrapping, staking or guying, herbicide, maintenance during the establishment and warranty periods, and replacements.

9030, 1.08, C, 3 Plants (by lump sum)
Delivery, excavation, installation, watering, placing backfill material, mulching, wrapping, staking or guying, herbicide, maintenance during the establishment period, and replacements.

9030, 1.08, D, 3 Plants (by lump sum), With Warranty
Delivery, excavation, installation, watering, placing backfill material, mulching, wrapping, staking or guying, herbicide, maintenance during the establishment and warranty period, and replacements.

9030, 1.08, E, 3 Tree Drainage Wells
Excavation, furnishing and placing rock, engineering fabric, and placing backfill material.

Section 9040 - Erosion and Sediment Control

9040, 1.07, C When applicable, conduct all operations in compliance with the Iowa DNR NPDES General Permit No. 2. Labor, equipment, or materials not included as a bid item, but necessary to prevent stormwater contamination from construction related sources, are considered incidental. Incidental work related to compliance with the permit may include, but is not limited to: hazardous materials protection, fuel containment, waste disposal, and providing employee sanitary facilities.

J. Incidental or Included Items (Continued)

9040, 1.08, A, 1, c	<u>SWPPP Preparation</u> Development of a SWPPP by the Contractor meeting local and state agency requirements, filing the required public notices, filing a Notice of Intent for coverage of the project under the Iowa DNR NPDES General Permit No. 2, and payment of associated NPDES permit fees.
9040, 1.08, A, 2, c	<u>SWPPP Management</u> All work required to comply with the administrative provisions of the Iowa DNR NPDES General Permit No. 2; including record keeping, documentation, updating the SWPPP, filing the Notice of Discontinuation, etc. Item also includes weekly inspections required to satisfy the provisions of General Permit No. 2, unless otherwise specified in the contract documents.
9040, 1.08, D, 1, c	<u>Filter Socks, Installation</u> Anchoring stakes.
9040, 1.08, D, 2, c	<u>Filter Socks, Removal</u> Restoration of the area to finished grade and off-site disposal of filter socks and accumulated sediment.
9040, 1.08, E, 3	<u>Temporary RECP</u> Excavation, staples, anchoring devices, and material for anchoring slots.
9040, 1.08, F, 1, c	<u>Wattles, Installation</u> Anchoring stakes.
9040, 1.08, F, 2, c	<u>Wattles, Removal</u> Restoration of the area to finished grade and off-site disposal of wattle and accumulated sediment.
9040, 1.08, G, 1, c	<u>Check Dams, Rock</u> Engineering fabric.
9040, 1.08, G, 2, a, 3)	<u>Check Dams, Manufactured, Installation</u> Anchoring stakes.
9040, 1.08, G, 2, b, 3)	<u>Check Dams, Manufactured, Removal</u> Restoration of the area to finished grade and off-site disposal of manufactured check dam and accumulated sediment.
9040, 1.08, H, 3	<u>Temporary Earth Diversion Structures</u> Removal of the structure upon completion of the project.
9040, 1.08, I, 3	<u>Level Spreaders</u> Maintaining the spreader during the period of construction and removal upon completion of the project, unless otherwise specified in the contract documents.
9040, 1.08, J, 3	<u>Rip Rap</u> Engineering fabric.

J. Incidental or Included Items (Continued)

9040, 1.08, K, 3	<u>Temporary Pipe Slope Drains</u> Excavation, furnishing and installing pipe and pipe aprons, grading, and removal of the slope drain upon completion of the project.
9040, 1.08, L, 1, c	<u>Sediment Basin, Outlet Structure</u> Concrete base, dewatering device, anti-vortex device, outlet pipe, and anti-seep collars (if specified).
9040, 1.08, L, 2, c	<u>Sediment Basin, Removal of Sediment</u> Dewatering and removal and off-site disposal of accumulated sediment.
9040, 1.08, L, 3, c	<u>Sediment Basin, Removal of Outlet Structure</u> Dewatering and off-site disposal of the outlet structure, concrete base, emergency spillway, and accumulated sediment.
9040, 1.08, M, 1, c	<u>Sediment Trap Outlet, Installation</u> Engineering fabric.
9040, 1.08, M, 2, c	<u>Sediment Trap Outlet, Removal of Sediment</u> Dewatering and removal and off-site disposal of accumulated sediment.
9040, 1.08, M, 3, c	<u>Sediment Trap Outlet, Removal of Device</u> Dewatering and off-site disposal of sediment trap outlet and accumulated sediment.
9040, 1.08, N, 1, c	<u>Silt Fence or Silt Fence Ditch Check, Installation</u> Anchoring posts.
9040, 1.08, N, 2, c	<u>Silt Fence or Silt Fence Ditch Check, Removal of Sediment</u> Anchoring posts.
9040, 1.08, N, 3, c	<u>Silt Fence or Silt Fence Ditch Check, Removal of Device</u> Restoration of the area to finished grade and off-site disposal of fence, posts, and accumulated sediment.
9040, 1.08, O, 1, c	<u>Stabilized Construction Entrance (by Square Yard)</u> Subgrade stabilization fabric.
9040, 1.08, O, 2, c	<u>Stabilized Construction Entrance (by Ton)</u> Subgrade stabilization fabric.
9040, 1.08, P, 1, c	<u>Dust Control, Water</u> Furnishing, transporting, and distributing water to the haul road.
9040, 1.08, R, 3	<u>Turf Reinforcement Mats (TRM)</u> Excavation, staples, anchoring devices, and material for anchoring slots.
9040, 1.08, T, 1, c	<u>Inlet Protection Device, Installation</u> Removal of the device upon completion of the project.
9040, 1.08, T, 2, c	<u>Inlet Protection Device, Maintenance</u> Removal and off-site disposal of accumulated sediment.

J. Incidental or Included Items (Continued)

- 9040, 1.08, U, 3 Flow Transition Mat
Anchoring devices.

Section 9050 - Gabions and Revet Mattresses

- 9050, 1.08, A, 3 Gabions
Furnishing and assembling wire mesh baskets, PVC coating (if specified in the contract documents), fasteners, furnishing and placing gabion stone, engineering fabric, and anchor stakes.

- 9050, 1.08, B, 3 Revet Mattresses
Furnishing and assembling wire mesh baskets, PVC coating (if specified in the contract documents), fasteners, furnishing and placing mattress stone, engineering fabric, and anchor stakes.

Section 9060 - Chain Link Fence

- 9060, 1.08, A, 3 Chain Link Fence
Posts, fabric, rails, braces, truss rods, ties, tension wire, tension bands, tension bars, grounds, fittings, PVC coating (if specified in the contract documents), excavation of post holes, and concrete encasement of posts.

- 9060, 1.08, B, 3 Gates
Gate rails, fabric, stretcher bars, braces, vertical stay, hinges, latches, keepers, drop bar lock, center gate stop, and barbed wire (if specified).

- 9060, 1.08, C, 3 Barbed Wire
Furnishing and installing all necessary strands of barbed wire, anchors, and barbed wire supporting arms.

- 9060, 1.08, D, 3 Removal and Reinstallation of Existing Fence
Removing vegetation; removing all fence fabric, appurtenances, posts, and gates; removal of concrete encasement from posts; storage of the removed fencing materials to prevent damage; reinstallation of the posts, gates, and fabric, including all appurtenances; and replacement of any fence parts that are not able to be salvaged and reinstalled. Replace items damaged from Contractor's operations with new materials, at no additional cost to the Contracting Authority.

- 9060, 1.08, E, 3 Removal of Fence
Off-site disposal of fence (including posts, concrete encasement of posts, gates, grounds, and barbed wire) and placing and compacting backfill material in post holes.

- 9060, 1.08, F, 3 Temporary Fence
Furnishing, installing, and removing posts, fabric, ties, and fittings.

J. Incidental or Included Items (Continued)**Section 9070 - Landscape Retaining Walls**

- 9070, 1.08, A, 3 Modular Block Retaining Wall
Excavation, foundation preparation, furnishing and placing wall units, geogrid (if necessary), leveling pad, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, granular backfill material, suitable backfill material, and shoring as necessary.
- 9070, 1.08, B, 3 Limestone Retaining Wall
Excavation, foundation preparation, furnishing and placing leveling pad, limestone, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, suitable backfill material, and shoring as necessary.
- 9070, 1.08, C, 3 Landscape Timbers
Excavation, foundation preparation, furnishing and placing leveling pad, landscape timbers, spikes, reinforcing bar, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, suitable backfill material, and shoring as necessary.

Section 9071 - Segmental Block Retaining Walls

- 9071, 1.08, A, 3 Segmented Block Retaining Wall
Design by a Licensed Professional Engineer in the State of Iowa, excavation, foundation preparation, furnishing and placing wall units, geogrid, leveling pad, subdrain, porous backfill material for subdrain, engineering fabric for subdrain, suitable backfill material, and shoring as necessary.
- 9071, 1.08, C, 3 Granular Backfill Material
Furnishing, transporting, placing, and compacting material.

Section 9072 - Combined Concrete Sidewalk and Retaining Walls

- 9072, 1.08, A, 3 Combined Concrete Sidewalk and Retaining Wall
Excavation; foundation preparation; furnishing and placing concrete and reinforcing steel; joint material; subdrain; porous backfill material; suitable backfill material; finishing disturbed areas; and shoring as necessary.

Section 9080 - Concrete Steps, Handrails, and Safety Rail

- 9080, 1.08, A, 3 Concrete Steps
Reinforcement, expansion joint material, and preparation of subgrade.
- 9080, 1.08, B, 3 Handrail
Posts, mounting hardware or concrete grout, and finishing (painted, galvanized, or powder coated).

J. Incidental or Included Items (Continued)

9080, 1.08, C, 3

Safety Rail

Posts, pickets, mounting hardware, epoxy grout, and finishing (painted, galvanized, or powder coated).

Section 10,010 - Demolition

10,010, 1.08, A, 3

Demolition Work

Removal of trees, brush, vegetation, buildings, building materials, contents of buildings, appliances, trash, rubbish, basement walls, foundations, sidewalks, steps, and driveways from the site; disconnection of utilities; furnishing and compaction of backfill material; furnishing and placing topsoil; finish grading of disturbed areas; placing and removing safety fencing; removal of fuel and septic tanks and cisterns; seeding; and payment of any permit or disposal fees.

10,010, 1.08, B, 3

Plug or Abandon Well

Obtaining all permits; plug or abandon private wells according to local, state, and federal regulations.

Section 11,010 - Construction Survey

11,010, 1.08, A, 3

Construction Survey

The costs of resetting project control points, re-staking, and any additional staking requested beyond the requirements of this section.

11,010, 1.08, B, 3

Monument Preservation and Replacement

Property research and documentation, locating monuments prior to construction, replacement of disturbed monuments, and preparation and filing of the monument preservation certificate.

Section 11,020 - Mobilization

11,020, 1.07, B

When the proposal form does not include a bid item for mobilization, all costs incurred by the contractor for mobilization are incidental to other work and no separate payment will be made.

11,020, 1.08, A, 3

Mobilization

The movement of personnel, equipment, and supplies to the project site; the establishment of offices, buildings, and other facilities necessary for the project; and bonding, permits, and other expenses incurred prior to construction.

Section 11,040 - Temporary Sidewalk Access

11,040, 1.08, A, 3

Temporary Pedestrian Residential Access

Supplying and placing granular material, continuous maintenance of granular surface, removal of temporary granular sidewalk, and restoring disturbed surfaces to a condition equal to that which existed prior to construction.

J. Incidental or Included Items (Continued)

11,040, 1.08, B, 3

Temporary Granular Sidewalk

Excavation, grading, timber edging, supplying and placing granular material, continuous maintenance of granular surface, removal of temporary granular sidewalk, and restoring disturbed surfaces to a condition equal to that which existed prior to construction.

11,040, 1.08, C, 3

Temporary Longitudinal Channelizing Device

Construction, placement, maintenance, and removal of the device.

Section 11,050 - Concrete Washout

11,050, 1.08, A, 3

Concrete Washout

Providing concrete washwater containment, collection, and disposal.

K. Bid Items

The following is a list of standard bid items listed in the SUDAS Standard Specifications. The following are suggested bid items. This list may not be all-inclusive. The Engineer may make modifications as necessary.

Item Number	Bid Item	Unit
Section 2010 - Earthwork, Subgrade, and Subbase		
2010-108-A-0	Clearing and Grubbing	UNIT
2010-108-B-0	Clearing and Grubbing	AC
2010-108-C-0	Clearing and Grubbing	LS
2010-108-D-1	Topsoil, On-site	CY
2010-108-D-2	Topsoil, Compost-amended	CY
2010-108-D-3	Topsoil, Off-site	CY
2010-108-E-0	Excavation, Class 10, Class 12, or Class 13	CY
2010-108-G-0	Subgrade Preparation	SY
2010-108-H-0	Subgrade Treatment, ____ (Type)	SY
2010-108-I-0	Subbase, ____ (Type)	SY
2010-108-J-1	Removal of Structure, ____ (Type)	EA
2010-108-J-2-a	Removal of Known Box Culvert, ____ (Type), ____ (Size)	LF
2010-108-J-2-c	Removal of Known Pipe Culvert, ____ (Type), ____ (Size)	LF
2010-108-J-3-a	Removal of Known Pipe and Conduit, ____ (Type), ____ (Size)	LF
2010-108-K-1	Filling and Plugging of Known Pipe Culverts, Pipes, and Conduits, ____ (Type), ____ (Size)	LF
2010-108-L-0	Compaction Testing	LS
Section 3010 - Trench Excavation and Backfill		
3010-108-B-0	Rock Excavation	CY
3010-108-C-0	Trench Foundation	TON
3010-108-D-0	Replacement of Unsuitable Backfill Material	CY
3010-108-E-0	Special Pipe Embedment or Encasement	LF
3010-108-F-0	Trench Compaction Testing	LS
Section 4010 - Sanitary Sewers		
4010-108-A-1	Sanitary Sewer Gravity Main, Trenched, ____ (Type), ____ (Size)	LF
4010-108-A-2	Sanitary Sewer Gravity Main, Trenchless, ____ (Type), ____ (Size)	LF
4010-108-B-1	Sanitary Sewer Gravity Main with Casing Pipe, Trenched, ____ (Type), ____ (Size)	LF
4010-108-B-2	Sanitary Sewer Gravity Main with Casing Pipe, Trenchless, ____ (Type), ____ (Size)	LF
4010-108-C-1	Sanitary Sewer Force Main, Trenched, ____ (Type), ____ (Size)	LF
4010-108-C-2	Sanitary Sewer Force Main, Trenchless, ____ (Type), ____ (Size)	LF
4010-108-D-1	Sanitary Sewer Force Main with Casing Pipe, Trenched, ____ (Type), ____ (Size)	LF
4010-108-D-2	Sanitary Sewer Force Main with Casing Pipe, Trenchless, ____ (Type), ____ (Size)	LF

K. Bid Items (Continued)

Item Number	Bid Item	Unit
4010-108-E-0	Sanitary Sewer Service Stub, ____ (Type), ____ (Size)	LF
4010-108-F-0	Sanitary Sewer Service Relocation	EA
4010-108-G-0	Sewage Air Release Valve and Pit	EA
4010-108-H-0	Removal of Sanitary Sewer, ____ (Type), ____ (Size)	LF
4010-108-I-0	Sanitary Sewer Cleanout	EA
4010-108-K-0	Sanitary Sewer Abandonment, Plug	EA
4010-108-L-0	Sanitary Sewer Abandonment, Fill and Plug	LF
	Section 4020 - Storm Sewers	
4020-108-A-1	Storm Sewer, Trenched, ____ (Type), ____ (Size)	LF
4020-108-A-2	Storm Sewer, Trenchless, ____ (Type), ____ (Size)	LF
4020-108-B-1	Storm Sewer with Casing Pipe, Trenched, ____ (Type), ____ (Size)	LF
4020-108-B-2	Storm Sewer with Casing Pipe, Trenchless, ____ (Type), ____ (Size)	LF
4020-108-C-0	Linear Trench Drain	LF
4020-108-D-0	Removal of Storm Sewer, ____ (Type), ____ (Size)	LF
4020-108-F-0	Storm Sewer Abandonment, Plug	EA
4020-108-G-0	Storm Sewer Abandonment, Fill and Plug	LF
	Section 4030 - Pipe Culverts	
4030-108-A-1	Pipe Culvert, Trenched, ____ (Type), ____ (Size)	LF
4030-108-A-2	Pipe Culvert, Trenchless, ____ (Type), ____ (Size)	LF
4030-108-B-0	Pipe Apron, ____ (Type), ____ (Size)	EA
4030-108-C-0	Footing for Concrete Pipe Apron, ____ (Type), ____ (Size)	EA
4030-108-D-0	Pipe Apron Guard	EA
	Section 4040 - Subdrains and Footing Drain Collectors	
4040-108-A-0	Subdrain, ____ (Type), ____ (Size)	LF
4040-108-B-0	Footing Drain Collector, ____ (Type), ____ (Size)	LF
4040-108-C-0	Subdrain Cleanout, ____ (Type), ____ (Size)	EA
4040-108-C-0	Footing Drain Cleanout, ____ (Type), ____ (Size)	EA
4040-108-D-0	Subdrain Outlets and Connections, ____ (Type), ____ (Size)	EA
4040-108-D-0	Footing Drain Outlets and Connections, ____ (Type), ____ (Size)	EA
4040-108-E-0	Storm Sewer Service Stub, ____ (Type), ____ (Size)	LF
	Section 4050 - Pipe Rehabilitation	
4050-108-A-1	Pre-Rehabilitation Cleaning and Inspection, ____ (Size)	LF
4050-108-A-2	Additional Sewer Cleaning	HOURL
4050-108-B-0	Remove Protruding Service Connections	EA
4050-108-C-1	CIPP Main Lining	LF
4050-108-C-2	Building Sanitary Sewer Service Reinstatement	EA
4050-108-C-3	CIPP End Seal	EA
4050-108-D-0	CIPP Point Repair, ____ (Size)	EA

K. Bid Items (Continued)

Item Number	Bid Item	Unit
4050-108-E-1	CIPP Service Pipe, Connection, ____ (Size)	EA
4050-108-E-2	CIPP Service Repair, Partial Pipe, ____ (Size)	EA
4050-108-F-1	Pressure Testing of Mainline Sewer Joints, ____ (Size)	EA
4050-108-F-2	Injection Grouting of Mainline Sewer Joints, ____ (Size)	EA
4050-108-F-3	Pressure Testing of Service Connections, ____ (Size)	EA
4050-108-F-4	Injection Grouting of Service Connections, ____ (Size)	EA
4050-108-F-5	Chemical Grout	EA
4050-108-G-3	Bypass Pumping	LS
4050-108-H-1	Spot Repairs by Pipe Replacement	EA
4050-108-H-2	Spot Repairs by Pipe Replacement	LF
	Section 5010 - Pipe and Fittings	
5010-108-A-1	Water Main, Trenched, ____ (Type), ____ (Size)	LF
5010-108-A-2	Water Main, Trenchless, ____ (Type), ____ (Size)	LF
5010-108-B-1	Water Main with Casing Pipe, Trenched, ____ (Type), ____ (Size)	LF
5010-108-B-2	Water Main with Casing Pipe, Trenchless, ____ (Type), ____ (Size)	LF
5010-108-C-1	Fitting, ____ (Type), ____ (Size)	EA
5010-108-C-2	Fitting, ____ (Type), ____ (Size)	LB
5010-108-D-0	Water Service Stub, ____ (Type), ____ (Size)	EA
5010-108-E-1	Water Service Pipe, ____ (Type), ____ (Size)	LF
5010-108-E-2	Water Service Corporation, ____ (Type), ____ (Size)	EA
5010-108-E-3	Water Service Curb Stop and Box, ____ (Type), ____ (Size)	EA
	Section 5020 - Valves, Fire Hydrants, and Appurtenances	
5020-108-A-0	Valve, ____ (Type), ____ (Size)	EA
5020-108-B-0	Tapping Valve Assembly, ____ (Size)	EA
5020-108-C-0	Fire Hydrant Assembly	EA
5020-108-D-0	Flushing Device (Blowoff), ____ (Size)	EA
5020-108-F-0	Valve Box Extension	EA
5020-108-G-0	Valve Box Replacement	EA
5020-108-H-0	Fire Hydrant Adjustment	EA
5020-108-I-0	Fire Hydrant Assembly Removal	EA
5020-108-J-0	Valve Removal	EA
5020-108-K-0	Valve Box Removal	EA
	Section 6010 - Structures for Sanitary and Storm Sewers	
6010-108-A-0	Manhole, ____ (Type), ____ (Size)	EA
6010-108-B-0	Intake, ____ (Type), ____ (Size)	EA
6010-108-C-1	Internal Drop Connection	EA
6010-108-C-2	External Drop Connection	EA
6010-108-D-0	Casting Extension Ring	EA
6010-108-E-0	Manhole Adjustment, Minor	EA
6010-108-E-0	Intake Adjustment, Minor	EA

K. Bid Items (Continued)

Item Number	Bid Item	Unit
6010-108-F-0	Manhole Adjustment, Major	EA
6010-108-F-0	Intake Adjustment, Major	EA
6010-108-G-0	Connection to Existing Manhole	EA
6010-108-G-0	Connection to Existing Intake	EA
6010-108-H-0	Remove Manhole	EA
6010-108-H-0	Remove Intake	EA
	Section 6020 - Rehabilitation of Existing Manholes	
6020-108-A-0	Infiltration Barrier, ____ (Type)	EA
6020-108-B-0	In-situ Manhole Replacement, Cast-in-place Concrete	VF
6020-108-C-0	In-situ Manhole Replacement, Cast-in-place Concrete with Plastic Liner	VF
6020-108-D-0	Manhole Lining with Centrifugally Cast Cementitious Mortar Liner with Epoxy Seal	VF
	Section 7010 - Portland Cement Concrete Pavement	
7010-108-A-0	Pavement, PCC, ____ (Thickness)	SY
7010-108-E-0	Curb and Gutter, ____ (Width), ____ (Thickness)	LF
7010-108-F-0	Beam Curb	LF
7010-108-G-0	Concrete Median	SY
7010-108-H-0	PCC Railroad Crossing Approach	SY
7010-108-I-0	PCC Pavement Samples and Testing	LS
7010-108-K-0	PCC Pavement Widening, ____ (Thickness)	SY
	Section 7011 - Portland Cement Concrete Overlays	
7011-108-A-1	PCC Overlay, Furnish Only	CY
7011-108-A-2	PCC Overlay, Place Only	SY
7011-108-A-3	Surface Preparation for Bonded PCC Overlay	SY
7011-108-A-4	Surface Preparation for Unbonded PCC Overlay	SY
7011-108-A-5	HMA Separation Layer for Unbonded PCC Overlay	SY
7011-108-A-6	Geotextile Fabric Separation Layer for Unbonded PCC Overlay	SY
	Section 7020 - Hot Mix Asphalt Pavement	
7020-108-A-0	Pavement, HMA	TON
7020-108-B-0	Pavement, HMA, ____ (Thickness)	SY
7020-108-C-0	HMA Base Widening	TON
7020-108-D-0	HMA Base Widening, ____ (Thickness)	SY
7020-108-E-0	HMA Railroad Crossing Approach	SY
7020-108-I-0	HMA Pavement Samples and Testing	LS
	Section 7021 - Hot Mix Asphalt Overlays	
7021-108-A-0	HMA Overlay	TON
7021-108-B-0	HMA Overlay, ____ (Thickness)	SY

K. Bid Items (Continued)

Item Number	Bid Item	Unit
	Section 7030 - Sidewalks, Shared Use Paths, and Driveways	
7030-108-A-0	Removal of Sidewalk	SY
7030-108-A-0	Removal of Shared Use Path	SY
7030-108-A-0	Removal of Driveway	SY
7030-108-B-0	Removal of Curb	LF
7030-108-C-0	Shared Use Path, ____ (Type), ____ (Thickness)	SY
7030-108-D-0	Special Subgrade Preparation for Shared Use Path	SY
7030-108-E-0	Sidewalk, PCC, ____ (Thickness)	SY
7030-108-F-0	Brick/Paver Sidewalk with Pavement Base	SY
7030-108-G-0	Detectable Warnings	SF
7030-108-H-1	Driveway, Paved, ____ (Type), ____ (Thickness)	SY
7030-108-H-2	Driveway, Granular	SY or TON
7030-108-I-0	Sidewalk Assurance Testing	LS
7030-108-I-0	Shared Use Path Assurance Testing	LS
7030-108-I-0	Driveway Assurance Testing	LS
	Section 7040 - Pavement Rehabilitation	
7040-108-A-0	Full Depth Patches	SY
7040-108-B-0	Subbase Over-excavation	TON
7040-108-C-0	Partial Depth Patches	SF
7040-108-D-0	Crack and Joint Cleaning and Filling, Hot Pour	LF
7040-108-E-1	Crack Cleaning and Filling, Emulsion	LF
7040-108-E-2	Hot Mix Asphalt for Crack Filling	TON
7040-108-F-0	Diamond Grinding	SY
7040-108-G-0	Milling	SY
7040-108-H-0	Pavement Removal	SY
7040-108-I-0	Curb and Gutter Removal	LF
7040-108-J-0	Dowel Bar Retrofit	EA
	Section 7050 - Asphalt Stabilization	
7050-108-A-0	Asphalt Stabilization	SY
	Section 7060 - Bituminous Seal Coat	
7060-108-A-0	Bituminous Seal Coat	SY
7060-108-B-1	Cover Aggregate, ____ (Size)	TON
7060-108-B-2	Binder Bitumen	GAL
	Section 7070 - Emulsified Asphalt Slurry Seal	
7070-108-A-0	Emulsified Asphalt Slurry Seal	SY
7070-108-B-1	Aggregate, ____ (Size)	TON
7070-108-B-2	Asphalt Emulsion	GAL

K. Bid Items (Continued)

Item Number	Bid Item	Unit
	Section 7080 - Permeable Interlocking Pavers	
7080-108-B-0	Engineering Fabric	SY
7080-108-C-0	Underdrain, ____ (Type), ____ (Size)	LF
7080-108-D-0	Storage Aggregate	TON
7080-108-E-0	Filter Aggregate	TON
7080-108-F-0	Permeable Interlocking Pavers, ____ (Type)	SY
7080-108-G-0	PCC Edge Restraint, ____ (Type), ____ (Size)	LF
	Section 7090 - Cold-in-Place Pavement Recycling	
7090-108-A-0	Cold-in-Place Recycling	SY
7090-108-B-0	Bituminous Recycling Agents	GAL
7090-108-C-0	Chemical Recycling Additives	TON
	Section 7091 - Full Depth Reclamation	
7091-108-A-0	Full Depth Reclamation	SY
7091-108-B-0	Mechanical Stabilization Agents	TON
7091-108-C-0	Bituminous Stabilization Agents	GAL
7091-108-D-0	Chemical Stabilization Agents	TON
7091-108-E-0	Microcracking	SY
7091-108-F-0	Interlayer for Cement Stabilized Base, ____ (Type), ____ (Thickness)	SY
	Section 8010 - Traffic Control	
8010-108-A-0	Traffic Signal	LS
8010-108-B-0	Temporary Traffic Signal	LS
	Section 8020 - Pavement Markings	
8020-108-B-0	Painted Pavement Markings, Solvent/Waterborne	STA
8020-108-C-0	Painted Pavement Markings, Durable	STA
8020-108-D-0	Painted Pavement Markings, High-Build	STA
8020-108-E-0	Permanent Tape Markings	STA
8020-108-F-0	Wet, Retroreflective Removable Tape Markings	STA
8020-108-G-0	Painted Symbols and Legends	EA
8020-108-H-0	Precut Symbols and Legends	EA
8020-108-I-0	Temporary Delineators	EA
8020-108-J-0	Raised Pavement Markers	EA
8020-108-K-0	Pavement Markings Removed	STA
8020-108-L-0	Symbols and Legends Removed	EA
8020-108-M-0	Grooves Cut for Pavement Markings	STA
8020-108-N-0	Grooves Cut for Symbols and Legends	EA
	Section 8030 - Temporary Traffic Control	
8030-108-A-0	Temporary Traffic Control	LS

K. Bid Items (Continued)

Item Number	Bid Item	Unit
	Section 9010 - Seeding	
9010-108-A-0	Conventional Seeding, Seeding, Fertilizing, and Mulching	AC
9010-108-B-0	Hydraulic Seeding, Seeding, Fertilizing, and Mulching	AC
9010-108-C-0	Pneumatic Seeding, Seeding, Fertilizing, and Mulching	AC
9010-108-D-0	Watering	MGAL
9010-108-E-0	Warranty	LS
	Section 9020 - Sodding	
9020-108-A-0	Sod	SQ
	Section 9030 - Plant Material and Planting	
9030-108-A-0	Plants, ____ (Type)	EA
9030-108-B-0	Plants with Warranty, ____ (Type)	EA
9030-108-C-0	Plants	LS
9030-108-D-0	Plants with Warranty	LS
9030-108-E-0	Tree Drainage Wells	EA
	Section 9040 - Erosion and Sediment Control	
9040-108-A-1	SWPPP Preparation	LS
9040-108-A-2	SWPPP Management	LS
9040-108-B-0	Compost Blanket, ____ (Thickness)	SF
9040-108-C-0	Filter Berm, ____ (Size)	LF
9040-108-D-1	Filter Sock, ____ (Size)	LF
9040-108-D-2	Filter Sock, Removal	LF
9040-108-E-0	Temporary RECP, ____ (Type)	SY
9040-108-F-1	Wattle, ____ (Type), ____ (Size)	LF
9040-108-F-2	Wattle, Removal	LF
9040-108-G-1	Check Dam, Rock	TON
9040-108-G-2-a	Check Dam, Manufactured, ____ (Type), ____ (Size)	LF
9040-108-G-2-b	Check Dam, Manufactured, Removal, ____ (Type)	LF
9040-108-H-0	Temporary Earth Diversion Structure, ____ (Type), ____ (Size)	LF
9040-108-I-0	Level Spreader	LF
9040-108-J-0	Rip Rap, ____ (Type)	TON
9040-108-K-0	Temporary Pipe Slope Drain, ____ (Type), ____ (Size)	LF
9040-108-L-1	Sediment Basin, Outlet Structure, ____ (Size)	EA
9040-108-L-2	Sediment Basin, Removal of Sediment	EA
9040-108-L-3	Sediment Basin, Removal of Outlet Structure	EA
9040-108-M-1	Sediment Trap Outlet	TON
9040-108-M-2	Sediment Trap Outlet, Removal of Sediment	EA
9040-108-M-3	Sediment Trap Outlet, Removal of Device	EA
9040-108-N-1	Silt Fence or Silt Fence Ditch Check	LF
9040-108-N-2	Silt Fence or Silt Fence Ditch Check, Removal of Sediment	LF
9040-108-N-3	Silt Fence or Silt Fence Ditch Check, Removal of Device	LF

K. Bid Items (Continued)

Item Number	Bid Item	Unit
9040-108-O-1	Stabilized Construction Entrance	SY
9040-108-O-2	Stabilized Construction Entrance	TON
9040-108-P-1	Dust Control, Water	MGAL
9040-108-P-2	Dust Control, Product	SY
9040-108-Q-1	Erosion Control Mulching, Conventional	AC
9040-108-Q-2	Erosion Control Mulching, Hydromulching	AC
9040-108-R-0	Turf Reinforcement Mats, ____ (Type)	SQ
9040-108-S-0	Surface Roughening	SF
9040-108-T-1	Inlet Protection Device, ____ (Type)	EA
9040-108-T-2	Inlet Protection Device, Maintenance	EA
9040-108-U-0	Flow Transition Mat	SF
	Section 9050 - Gabions and Revet Mattresses	
9050-108-A-0	Gabions, ____ (Type)	CY
9050-108-B-0	Revet Mattresses, ____ (Type)	CY
	Section 9060 - Chain Link Fence	
9060-108-A-0	Chain Link Fence, ____ (Type), ____ (Size)	LF
9060-108-B-0	Gates, ____ (Type), ____ (Size)	EA
9060-108-C-0	Barbed Wire, ____ (Type of Supporting Arm)	LF
9060-108-D-0	Removal and Reinstallation of Existing Fence, ____ (Type), ____ (Size)	LF
9060-108-E-0	Removal of Fence	LF
9060-108-F-0	Temporary Fence, ____ (Type), ____ (Size)	LF
	Section 9070 - Landscape Retaining Walls	
9070-108-A-0	Modular Block Retaining Wall	SF
9070-108-B-0	Limestone Retaining Wall	SF
9070-108-C-0	Landscape Timbers	SF
	Section 9071 - Segmental Block Retaining Walls	
9071-108-A-0	Segmental Block Retaining Wall	SF
9071-108-C-0	Granular Backfill Material	TON
	Section 9072 - Combined Concrete Sidewalk and Retaining Wall	
9072-108-A-0	Combined Concrete Sidewalk and Retaining Wall	CY
	Section 9080 - Concrete Steps, Handrails, and Safety Rail	
9080-108-A-0	Concrete Steps, ____ (Type)	SF
9080-108-B-0	Handrail, ____ (Type)	LF
9080-108-C-0	Safety Rail	LF

K. Bid Items (Continued)

Item Number	Bid Item	Unit
	Section 10,010 - Demolition	
10,010-108-A	Demolition Work	LS
10,010-108-B	Plug or Abandon Well	EA
	Section 11,010 - Construction Survey	
11,010-108-A	Construction Survey	LS
11,010-108-B	Monument Preservation and Replacement	LS
	Section 11,020 - Mobilization	
11,020-108-A	Mobilization	LS
	Section 11,030 - Temporary Services During Construction	
11,030-108-A-0	Maintenance of Postal Service	LS
11,030-108-B-0	Maintenance of Solid Waste Collection	LS
	Section 11,040 - Temporary Sidewalk Access	
11,040-108-A-0	Temporary Pedestrian Residential Access	SY
11,040-108-B-0	Temporary Granular Sidewalk	SY
11,040-108-C-0	Temporary Longitudinal Channelizing Device	LF
	Section 11,050 - Concrete Washout	
11,050-108-A-0	Concrete Washout	LS

Pipe and Manhole Materials

Table 3D-1.01: Sanitary Sewer Pipe Materials

Typical Application	Pipe Material	Size Range	Standard	Thickness Class (min.)	Pipe Stiffness (min.)	Joints
Gravity Flow	Solid Wall PVC	8" to 15"	ASTM D 3034	SDR 26	115 psi	Bell and Spigot
Gravity Flow	Solid Wall PVC	8" to 15"	ASTM D 3034	SDR 35	46 psi	Bell and Spigot
Gravity Flow	Solid Wall PVC	18" to 27"	ASTM F 679	N/A	46 psi	Bell and Spigot
Gravity Flow	Corrugated PVC	8" to 10"	ASTM F 949	N/A	115 psi	Bell and Spigot
Gravity Flow	Corrugated PVC	12" to 36"	ASTM F 949	N/A	46 psi	Bell and Spigot
Gravity Flow	Closed Profile PVC	21" to 36"	ASTM F 1803	N/A	46 psi	Bell and Spigot
Gravity Flow	Truss Type PVC	8" to 15"	ASTM D 2680	N/A	200 psi	Bell and Spigot
Gravity Flow	RCP	18" to 144"	ASTM C 76	Class IV Wall B	4,000 psi	Tongue and Groove
Gravity Flow	Ductile Iron	8" to 54"	AWWA C151	Class 52	300 psi	MJ or Push on
Gravity Flow	VCP	8" to 42"	ASTM C 700	N/A	N/A	Bell and Spigot
Gravity Flow	Double Walled Polypropylene	12" to 30"	ASTM F 2736	N/A	46 psi	Bell and Spigot
Gravity Flow	Triple Walled Polypropylene	30" to 36"	ASTM F 2764	N/A	46 psi	Bell and Spigot
Force Main	Ductile Iron	4" to 64"	AWWA C151	Class 52	300 psi	MJ or Push on
Force Main	PVC	4" to 30"	AWWA C 900	DR 18	150 psi	Bell and Spigot

Gravity mains greater than 42 inches in diameter will be lined reinforced concrete pipe or ductile iron.
Force mains greater than 30 inches in diameter will be ductile iron.

Table 3D-1.02: Manhole Types

Figure No. ¹	Type	Description	Depth Restrictions
6010.301	SW-301	Circular Sanitary Sewer Manhole	N/A
6010.302	SW-302	Rectangular Sanitary Sewer Manhole	12' max.
6010.303	SW-303	Sanitary Sewer Manhole Over Existing Sewer	N/A
6010.304	SW-304	Rectangular Base/Circular Top Sanitary Sewer Manhole	12' min. to 22' max.
6010.305	SW-305	Tee-section Sanitary Sewer Manhole	N/A

¹ The figure numbers listed in this table refer to figures from the SUDAS Specifications.

Table 3D-1.03: Manhole Casting Types

	Figure No.	Casting Type	Number of Pieces	Ring/Cover	Bolted Frame	Bolted Cover (Floodable)	Gasket
Sanitary Sewer	6010.601	SW-601 , A	2	Fixed	Yes	No	Yes ¹
	6010.601	SW-601 , B	3	Adjustable	No	No	Yes ¹
	6010.601	SW-601 , C	2	Fixed	Yes	Yes	Yes ¹
	6010.601	SW-601 , D	3	Adjustable	No	Yes	Yes ¹
Storm Sewer	6010.602	SW-602 , E ²	2	Fixed	Yes	No	No
	6010.602	SW-602 , F ²	3	Adjustable	No	No	No
	6010.602	SW-602 , G ²	2	Fixed	No	No	No

¹ Machine bearing surfaces required.

² Storm sewer casting may include environmental symbols and/or messages such as "DUMP NO WASTE, DRAINS TO RIVER."

Facility Design

A. General

Water mains and appurtenances, including hydrants and valves, should be provided along all streets including connections to and extensions from existing water systems.

The location and spacing of water mains and their appurtenances is not only important for service and fire protection, but also maintenance requirements. Figures 4C-1.02 through 4C-1.03 show guidelines for the location of these facilities.

B. Water Mains

1. Water main pipe will typically be either polyvinyl chloride (PVC) pipe or ductile iron pipe (DIP); and meet AWWA Standards. For larger mains (24 inch and greater), prestressed concrete cylinder pipe meeting AWWA Standards can be used.

Where distribution systems and service connections are installed in areas of known groundwater contaminated by volatile organic compounds (LUST), pipe and joint materials (non-PVC pipe) that do not allow permeation of the volatile organic compounds must be used.

The Iowa DNR requires underground storage tank (UST) owners to meet specific design requirements for USTs installed within 1,000 feet of a community water system. The Project Engineer should determine if there is an UST within 1,000 feet of the project area. If so, the Designer should determine the need to design the water mains to prevent future permeation of any volatile organic compounds into the water system. There are various elements to consider, some of which include soil types, groundwater table depth, size of the UST, age of the UST, etc.

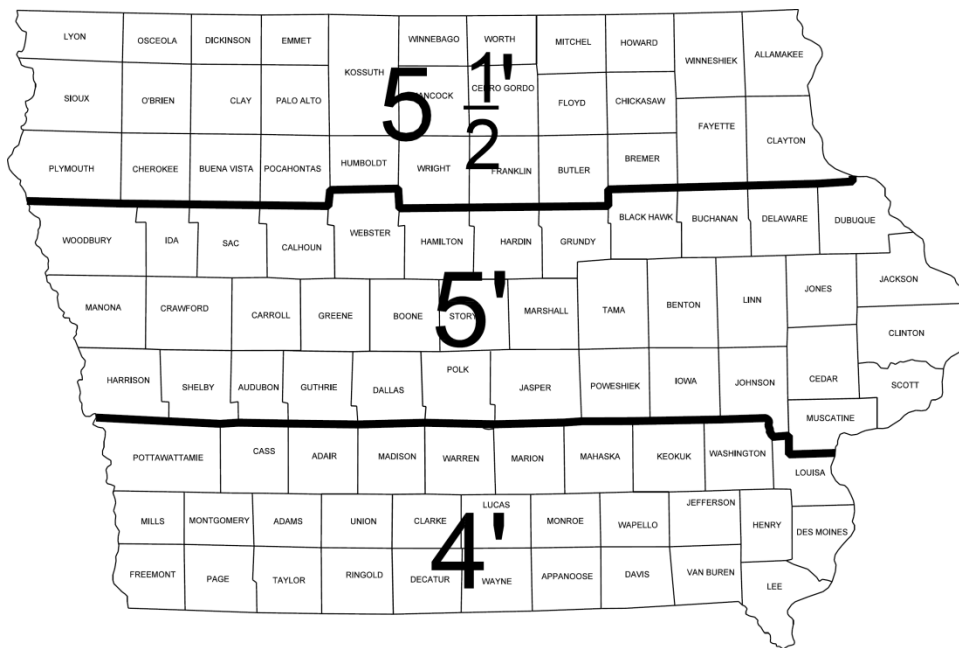
Consult with manufacturers concerning permeation of the pipe walls, jointing materials, valve seats, etc.

2. Water mains should be extended to the plat or property boundaries, to the next street, or as directed by the Jurisdiction.
3. New main installation should be located in the parking area (between the curb and the property line) of the right-of-way and minimum of 4 feet behind the curb. Where possible, water mains should be located along the south and east sides of the street.
4. Dead-ends should be minimized by looping mains whenever possible. Dead-ends should terminate with an approved flushing device (blowoff, hydrant, flushing hydrant). They may terminate with an approved fire hydrant when adequate pressure is available at required flows. For maintenance considerations and when adequate fire flows are not available, flushing hydrants may be allowed by the Jurisdiction with the hydrant outlet sized and arranged to prevent the attachment of fire hoses. Unless required by a Jurisdiction, permanent inline shut-off valves should not be placed at the end of dead-end mains. A valve may be placed one or two pipe lengths back from the end of the project. No services should be placed past the valve. These

pipes will provide sufficient support for the valve and allow a future extension to be made without impacting current water customers.

5. Water mains and extensions should be designed with a minimum cover as indicated on Figure 4C-1.01, unless more or less cover has been approved by the Jurisdictional Engineer. Greater depths of cover, surface loading conditions, or unusual trench conditions may require a stronger class of pipe according to the AWWA Standard regarding the type of pipe being installed. Where a dip must be placed in a main in order to pass under another utility, the length of the deeper main should be kept to a minimum, and bends should be considered to affect the desired offset.
6. Water mains should be adequately protected from corrosive soil environments. Comply with AWWA C105. Complete soil testing or check with the Jurisdictional Engineer to determine if corrosive soils are present within the project area. If so, include polyethylene encasement for ductile iron pipe, valves, and fittings or use of other nonmetallic pipe materials. If nonmetallic materials are used, be sure to provide polyethylene encasement for fittings and valves. In severe instances, cathodic protection may be required.

Figure 4C-1.01: Minimum Depth of Cover for Water Main Installation



C. Blowoffs

A blowoff or approved flushing device is required on all dead-end mains where a hydrant is not installed. The minimum riser assembly size should be no less than 2 diameter sizes smaller than the diameter of the water main. The flushing device should be sized to provide flows that will give a velocity of at least 2.5 feet per second in the main being flushed. When the water main is extended, the blowoff should be removed. A new valve should be placed between the existing and extended main.

D. Valves

1. As a minimum, valves should be located at intersections, such that only one unvalved pipe exists at the intersection. Valves should be equally spaced, if possible, with spacing no more than 800 feet in residential areas and no more than 400 feet in high density residential, commercial, and industrial areas. (See Figures 4C-1.02 through 4C-1.03 for valve locations at intersections).
2. Valves should not be located in the sidewalk line or in driveways.
3. All valves should be installed with valve boxes. Use slide type valve boxes in paved areas and screw type in all other areas. A screw type valve box that is located in an area to be paved should be changed to a slide type valve box as a part of the paving program.
4. No valves (except blowoff valves) should be placed at the end of a dead-end main unless required by a Jurisdiction. A valve should be installed between the existing main and new main when the main is extended. Intermediate valve locations between the end of a dead-end main and last valved street intersection may be required by the Jurisdiction to provide required valve spacing.
5. A tapping sleeve and valve should be used when making a perpendicular connection to an existing main.
6. If the project area has high water pressure, usually exceeding 100 psi, it may be appropriate to install system pressure relief valves as opposed to individual building controls. The potential for using a system pressure reducing valve is limited by the interconnected nature of a distribution system. Check with the Jurisdiction to determine the potential need for use of pressure reducing valves.

E. Fire Hydrants

1. Hydrants should comply with AWWA C502. The connecting pipe between the supply main and the hydrants should be a minimum of 6 inches in diameter and be independently valved. Fire hydrants should not be installed on water mains that do not provide a minimum pressure.
2. Hydrant drains should not be connected to or located within 10 feet of sanitary sewers.
3. Locations of fire hydrants are governed by the rules and regulations of the Iowa DNR and the local Jurisdiction and by the following principles. Satisfy each principle in the order they are listed. See Figures 4C-1.02 through 4C-1.03 for typical hydrant locations.

- a. Locate fire hydrants within 25 feet of each street intersection, measured from an end of a street paving return.

Locate fire hydrants outside street paving returns. Avoid conflicts with storm sewers, intakes, and sidewalks. Whenever possible, locate fire hydrants at the high point of the intersection.

- b. Locate fire hydrants between street intersections to provide spacings of no more than 450 feet in single family residential districts and no more than 300 feet in all other districts. Coverage radii for structures as noted below should be checked when determining hydrant placement.

Vary spacings slightly to place fire hydrants on extensions of property lines. When hydrants are required between intersections, they should be located at the high point of the main for air release or at a significant low point for flushing on the downhill side of an in-line valve.

When street curvature or grid patterns places a proposed protected structure at an unusual distance from the fire hydrant, the coverage radius should not exceed 300 feet in single family residential districts and 150 feet in all other districts. The Jurisdiction's fire marshall may have additional private fire protection requirements.

- c. On cul-de-sac streets, hydrants should be located at the intersection of the cul-de-sac street and cross-street and the end of the cul-de-sac.
 - 1) For cul-de-sacs between 300 feet and 500 feet in length, an additional hydrant should be located at the mid-block.
 - 2) For cul-de-sacs greater than 500 feet in length, hydrants should be placed at near equal spacings, but not exceeding the spacings described above.
- d. Hydrants must be located to provide the required fire flows. ISO evaluates fire hydrant locations within 1,000 feet of the test location, measured along the streets as fire hose can be laid, to evaluate the availability of water for fire protection. Hydrant capacity is credited as shown in the following table:

Hydrant Location	Credited Capacity
Within 300' of location	1,000 gpm
Within 301' to 600' of location	670 gpm
Within 601' to 1,000' of location	250 gpm

F. Water Service Stubs

Water service stubs for each building or platted lot should be provided, including corporation stop, service line, and curb stop (shut-off) with box. Check with the Jurisdiction to determine appropriate placement location. In no case should the shut-off be in the sidewalk. Avoid locations where driveway approaches are likely to be constructed in the future.

G. Separation of Water Mains from Sewer Mains

The following comply with the Iowa Department of Natural Resources separation requirements.

1. **Horizontal Separation of Gravity Sewers from Water Mains:** Separate gravity sewer mains from water mains by a horizontal distance of at least 10 feet unless:
 - the top of a sewer main is at least 18 inches below the bottom of the water main, and
 - the sewer is placed in a separate trench or in the same trench on a bench of undisturbed earth at a minimum horizontal separation of 3 feet from the water main.

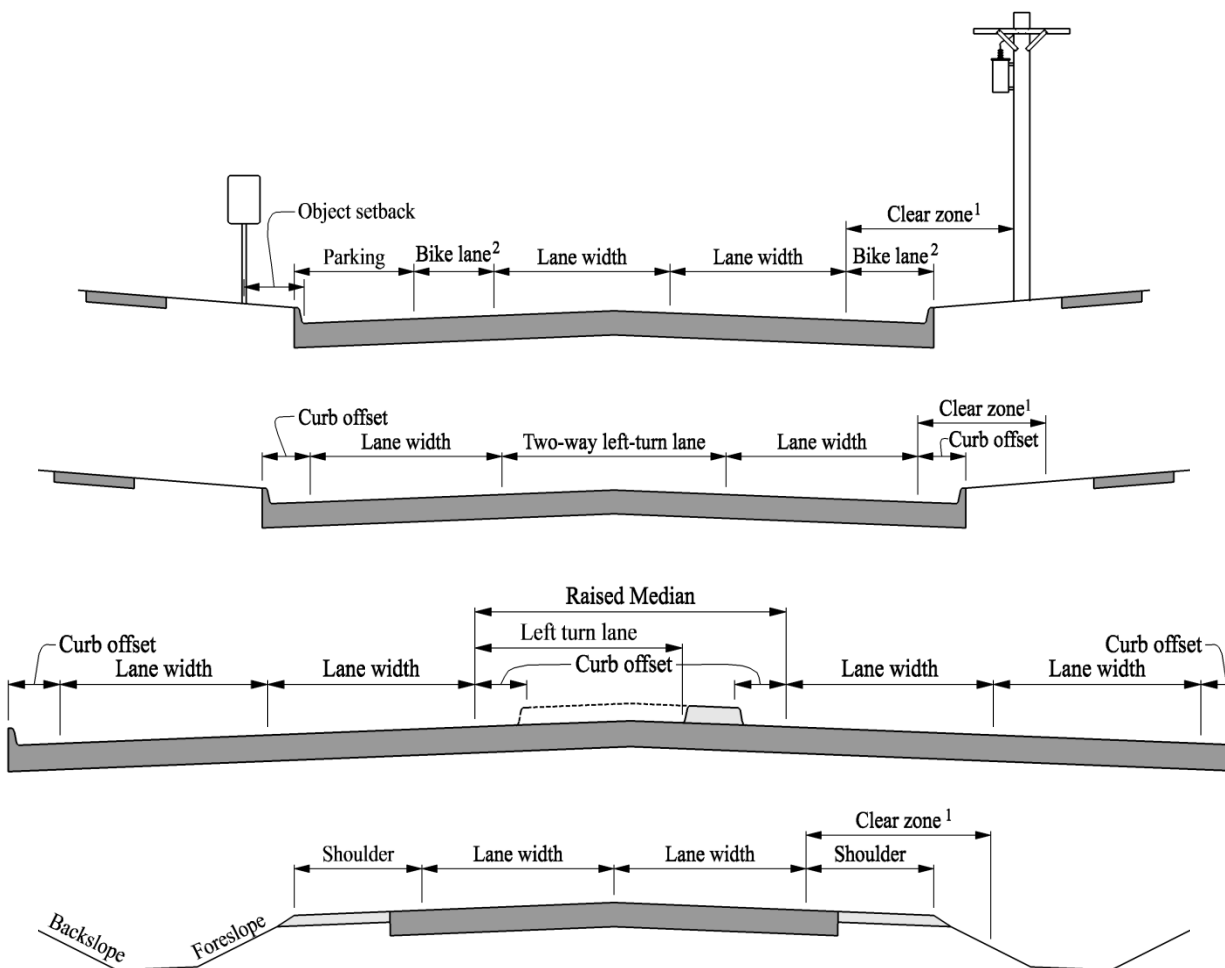
When it is impossible to obtain the required horizontal clearance of 3 feet and a vertical clearance of 18 inches between sewers and water mains, the sewers must be constructed of water main materials meeting the requirements of [SUDAS Specifications Section 5010, 2.01](#). However, provide a linear separation of at least 2 feet.

2. **Separation of Sewer Force Mains from Water Mains:** Separate sewer force mains and water mains by a horizontal distance of at least 10 feet unless:
 - the force main is constructed of water main materials meeting a minimum pressure rating of 150 psi and the requirements of [SUDAS Specifications Section 5010, 2.01](#), and
 - the sewer force main is laid at least 4 linear feet from the water main.

C. Roadway Design Tables

The following figures illustrate the location of various design elements of the roadway cross-section as specified in Tables 5C-1.01 and 5C-1.02.

Figure 5C-1.01: Roadway Design Elements



¹ Clear zone is measured from the edge of the traveled way.

² See [Chapter 12](#) for bike lane requirements.

Table 5C-1.01: Preferred Roadway Elements

Elements Related to Functional Classification

Design Element	Local		Collector		Arterial	
	Res.	C/I	Res.	C/I	Res.	C/I
General						
Design level of service ¹	D	D	C/D	C/D	C/D	C/D
Lane width (single lane) (ft) ²	10.5	12	12	12	12	12
Two-way left-turn lanes (TWLTL) (ft)	N/A	N/A	14	14	14	14
Width of new bridges (ft) ³	See Footnote 3					
Width of bridges to remain in place (ft) ⁴	-----	-----	-----	-----	-----	-----
Vertical clearance (ft) ⁵	14.5	14.5	14.5	14.5	16.5	16.5
Object setback (ft) ⁶	3	3	3	3	3	3
Clear zone (ft)	Refer to Table 5C-1.03, Table 5C-1.04, and 5C-1, C, 1					
Urban						
Curb offset (ft) ⁷	2	2	2	3	3	3
Parking lane width (ft)	8	8	8	10	N/A	N/A
Roadway width with parking on one side ⁸	26/31 ⁹	34	34	37	N/A	N/A
Roadway width without parking ¹⁰	26	31	31	31	31	31
Raised median with left-turn lane (ft) ¹¹	N/A	N/A	19.5	20.5	20.5	20.5
Cul-de-sac radius (ft)	45	45	N/A	N/A	N/A	N/A
Rural Sections in Urban Areas						
Shoulder width (ft)						
ADT: under 400	4	4	6	6	10	10
ADT: 400 to 1,500	6	6	6	6	10	10
ADT: 1,500 to 2000	8	8	8	8	10	10
ADT: above 2,000	8	8	8	8	10	10
Foreslope (H:V)	4:1	4:1	4:1	4:1	6:1	6:1
Backslope (H:V)	4:1	4:1	4:1	4:1	4:1	4:1

Res. = Residential, C/I = Commercial/Industrial

Elements Related to Design Speed

Design Element	Design Speed, mph ¹²							
	25	30	35	40	45	50	55	60
Stopping sight distance (ft)	155	200	250	305	360	425	495	570
Passing sight distance (ft)	900	1090	1,280	1,470	1,625	1,835	1,985	2,135
Min. horizontal curve radius (ft) ¹³	198	333	510	762	1,039	926	1,190	1,500
Min. vertical curve length (ft)	50	75	105	120	135	150	165	180
Min. rate of vertical curvature, Crest (K) ¹⁴	18	30	47	71	98	136	185	245
Min. rate of vertical curvature, Sag (K)	26	37	49	64	79	96	115	136
Minimum gradient (percent)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Maximum gradient (percent)	5	5	5	5	5	5	5	5

Note: For federal-aid projects, documentation must be provided to explain why the preferred values are not being met. For non-federal aid projects, the designer must contact the Jurisdiction to determine what level of documentation, if any, is required prior to utilizing design values between the “Preferred” and “Acceptable” tables.

Table 5C-1.01 Footnotes:

- ¹ Number of traffic lanes, turn lanes, intersection configuration, etc. should be designed to provide the overall specified LOS at the design year ADT. Two LOS values are shown for collectors and arterials. The first indicates the minimum overall LOS for the roadway as a whole; the second is the minimum LOS for individual movements at intersections.
- ² Width shown is for through lanes and turn lanes.
- ³ Bridge width is measured as the clear width between curbs or railings. Minimum bridge width is based upon the width of the traveled way (lane widths) plus 4 feet clearance on each side; but no less than the curb-face to curb-face width of the approaching roadway. Minimum bridge widths do not include medians, turn lanes, parking, or sidewalks. At least one sidewalk should be extended across the bridge.
- ⁴ See Table 5C-1.02, for acceptable values for width of bridges to remain in place.
- ⁵ Vertical clearance includes a 0.5 foot allowance for future resurfacing.
- ⁶ Object setback does not apply to mailboxes constructed and installed according to US Postal Service regulations, including breakaway supports.
- ⁷ Values shown are measured from the edge of the traveled way to the back of curb. Curb offset is not required for turn lanes. On roadways with an anticipated posted speed of 45 mph or greater, mountable curbs are required. For pavements with gutterline jointing, the curb offset should be equal to or greater than the distance between the back of curb and longitudinal gutterline joint.
- ⁸ Parking is allowed along one side of local or collector streets unless restricted by the Jurisdiction. Some jurisdictions allow parking on both sides of the street. When this occurs, each jurisdiction will set their own standards to allow for proper clearances, including passage of large emergency vehicles. Parking is normally not allowed along arterial roadways.
- ⁹ For local, low volume residential streets, two free flowing lanes are not required and a 26 foot or 31 foot (back to back) roadway may be used where parking is allowed on one side or both sides respectively. For higher volume residential streets, which require two continuously free flowing traffic lanes, a 31 foot or 37 foot roadway should be used for one sided or two sided parking respectively.
- ¹⁰ Some minimum roadway widths have been increased to match standard roadway widths. Unless approved by the Jurisdiction, all two lane roadways must comply with standard widths of 26, 31, 34, or 37 feet.
- ¹¹ Median width is measured between the edges of the traveled way of the inside lanes and includes the curb offset on each side of the median. Values include a left turn lane with a 6 foot raised median as required to accommodate a pedestrian access route (refer to [Chapter 12](#)) through the median (crosswalk cut through). At locations where a crosswalk does not cut through the median, the widths shown can be reduced by 2 feet to provide a 4 foot raised median.
- ¹² It is preferred to select a design speed that is at least 5 mph greater than the anticipated posted speed limit of the roadway. Selecting a design speed equal to the posted speed limit may also be acceptable and should be evaluated on a project by project basis, subject to approval of the Engineer.
- ¹³ Values for low design speed (<50 mph) assume no removal of crown (i.e. negative 2% superelevation on outside of curve). Radii for design speeds of 50 mph or greater are based upon a superelevation rate of 4%. For radii corresponding to other superelevation rates, refer to the AASHTO's "Green Book."
- ¹⁴ Assumes stopping sight distance with 6 inch object.

Table 5C-1.02: Acceptable Roadway Elements

Elements Related to Functional Classification

Design Element	Local		Collector		Arterial	
	Res.	C/I	Res.	C/I	Res.	C/I
General						
Design Level-of-Service ¹	D	D	D/E	D/E	D/E	D/E
Lane width (single lane) (ft) ²	10	11	11	11	11	11
Two-Way Left-Turn Lanes (TWLTL) (ft)	N/A	N/A	12	12	12	12
Width of new bridges, (ft) ³	See Footnote 3					
Width of bridges to remain in place (ft) ⁴	20	22	24	24	26	26
Vertical clearance (ft) ⁵	14.5	14.5	14.5	14.5	14.5	14.5
Object setback (ft) ⁶	1.5	1.5	1.5	1.5	1.5	1.5
Clear zone (ft)	Refer to Table 5C-1.03, Table 5C-1.04, and 5C-1, C, 1					
Urban						
Curb offset (ft) ⁷	1.5 ⁸	1.5 ⁸	1.5 ⁸	1.5 ⁸	2	2
Parking lane width (ft)	7.5	7.5	7.5	9	10	10
Roadway width with parking ^{9, 11}	26/31 ¹⁰	31	31	34 ¹¹	34	34
Roadway width without parking ¹¹	26 ¹⁰	26	26	26	26	26
Raised median with left-turn lane (ft) ¹²	N/A	N/A	18	18	18.5	18.5
Cul-de-sac radius (ft)	45	45	N/A	N/A	N/A	N/A
Rural Sections in Urban Areas						
Shoulder width (ft)						
ADT: under 400	2	2	2	2	8	8
ADT: 400 to 1,500	5	5	5	5	8	8
ADT: 1,500 to 2,000	6	6	6	6	8	8
ADT: over 2,000	8	8	8	8	8	8
Foreslope (H:V) ¹³	3:1	3:1	3:1	3:1	4:1	4:1
Backslope (H:V)	3:1	3:1	3:1	3:1	3:1	3:1

Res. = Residential, C/I = Commercial/Industrial

Elements Related to Design Speed

Design Element	Design Speed, mph ¹⁴															
	25		30		35		40		45		50		55		60	
Stopping sight distance (ft)	155		200		250		305		360		425		495		570	
Passing sight distance (ft)	900		1,090		1,280		1,470		1,625		1,835		1,985		2,135	
Min. horizontal curve radius (ft) ¹⁵	198		333		510		762		1,039		833		1,060		1,330	
Min. vertical curve length (ft)	50		75		105		120		135		150		165		180	
Min. rate of vert. curve, Crest (K) ¹⁶	12		19		29		44		61		84		114		151	
Min. rate of vert. curve, Sag (K)	26		37		49		64		79		96		115		136	
Min. rate of vert. curve, Sag (K) based on driver comfort/overhead lighting ¹⁷	14		20		27		35		44		54		66		78	
Minimum gradient (percent) ¹⁸	0.5		0.5		0.5		0.5		0.5		0.5		0.5		0.5	
Maximum gradient (percent) ¹⁹	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I	R	C/I
Local	12	10	12	9	11	9	11	9	10	8	9	8	N/A	N/A	N/A	N/A
Collector	12	9	11	9	10	9	10	9	9	8	8	7	N/A	N/A	N/A	N/A
Arterial	N/A	N/A	9	9	8	8	8	8	N/A	7	N/A	7	N/A	6	N/A	6

R = Residential, C/I = Commercial/Industrial

Note: For federal-aid projects, proposed design values that do not meet the “Acceptable” table may require design exceptions. Design exceptions will be considered on a project-by-project basis and must have concurrence of the Iowa DOT when applicable. For non-federal aid projects, the designer should contact the Jurisdiction to determine what level of documentation, if any, is required prior to utilizing design values that do not meet the “Acceptable” table.

Table 5C-1.02 Footnotes:

- ¹ Number of traffic lanes, turn lanes, intersection configuration, etc. should be designed to provide the specified LOS at the design year ADT.
- ² Width shown is for through lanes and turn lanes.
- ³ Bridge width is measured as the clear width between curbs or railings. Minimum bridge width is based upon the width of the traveled way (lane widths) plus 3 feet clearance on each side; but no less than the curb-face to curb-face width of the approaching roadway. Minimum bridge widths do not include medians, turn lanes, parking, or sidewalks. At least one sidewalk should be extended across the bridge.
- ⁴ The values shown are the clear width across the bridge between curbs or railings. Values are based upon the width of the traveled way (lane width) and include a 1 foot and 2 foot offset on each side for collectors and arterials respectively. Values do not include medians, turn lanes, parking, or sidewalks. In no case should the minimum clear width across the bridge be less than the width of the traveled way of the approach road.
- ⁵ Vertical clearance includes a 0.5 foot allowance for future resurfacing. Vertical clearance of 14.5 feet on arterials is allowed only if an alternate route with 16 feet of clearance is available.
- ⁶ Object setback does not apply to mailboxes constructed and installed according to US Postal Service regulations, including breakaway supports.
- ⁷ Values shown are measured from the edge of the traveled way to the back of curb. Curb offset is not required for turn lanes. On roadways with an anticipated posted speed of 45 mph or greater, mountable curbs are required. For pavements with gutterline jointing, the curb offset should be equal to or greater than the distance between the back of curb and longitudinal gutterline joint.
- ⁸ At locations where a 1.5 foot curb offset is used, an alternative intake boxout, with the intake set back a minimum of 6 inches from the curb line, must be used to prevent intake grates from encroaching into the traveled way.
- ⁹ Some jurisdictions allow parking on both sides of the street. When this occurs, each jurisdiction will set their own standards to allow for proper clearances, including passage of large emergency vehicles.
- ¹⁰ For low volume residential streets, two free flowing lanes are not required and a 26 foot roadway may be used where parking is allowed on one side only. For higher volume residential streets, which require two continuously free flowing traffic lanes, a 31foot roadway should be used.
- ¹¹ Some minimum roadway widths have been increased to match standard roadway widths. Unless approved by Jurisdiction, all two lane roadways must comply with standard widths of 26, 31, 34, or 37 feet.
- ¹² Median width is measured between the edges of the traveled way of the inside lanes and includes the curb offset on each side of the median. Values include a left turn lane with a 6 foot raised median as required to accommodate a pedestrian access route (refer to [Chapter 12](#)) through the median (crosswalk cut through). At locations where a crosswalk does not cut through the median, the widths shown can be reduced by 2 feet to provide a 4 foot raised median.
- ¹³ The use of 3:1 foreslopes is allowed, as shown, but may require a wider clear zone as slopes steeper than 4:1 are not considered recoverable by errant vehicles.
- ¹⁴ It is preferred to select a design speed that is at least 5 mph greater than the anticipated posted speed limit of the roadway. Selecting a design speed equal to the posted speed limit may also be acceptable and should be evaluated on a project by project basis, subject to approval of the Engineer
- ¹⁵ Values for low design speed (<50 mph) assume no removal of crown (i.e. negative 2% superelevation on outside of curve). According to the AASHTO Green Book (Table 3-1 and 3-13b) for low volume roadways with 10 or less units beyond the curve and projected traffic volumes of less than 100 vehicles per day beyond the curve, the horizontal curve radius may be a minimum of 107 feet if at least 115 feet of stopping sight distance is provided or the radius may be a minimum of 50 feet if at least 80 feet of stopping sight distance is available. Radii for design speeds of 50 mph or greater are based upon a superelevation rate of 6%. For radii corresponding to other superelevation rates, refer to the AASHTO’s “Green Book.”
- ¹⁶ Assumes stopping sight distance with 2 foot high object.
- ¹⁷ Use only if roadway has continuous overhead lighting.
- ¹⁸ A typical minimum grade is 0.5%, but a grade of 0.4% may be used in isolated areas where the pavement is accurately crowned and supported on firm subgrade.
- ¹⁹ Maximum gradient may be steepened by 2% for short distances and for one way downgrades.

Table 5C-1.03: Preferred Clear Zone Distances for Rural and Urban Roadways

Design Speed mph	Design Traffic ADT	Foreslope			Backslope or Parking		
		6:1 or flatter	5:1 to 4:1	3:1	6:1 or flatter	5:1 to 4:1	3:1
		In feet from edge of traveled way					
Urban 40 or less	All	For low-speed urban roadways, refer to 5C-1, C, 1.					
Rural 40 or less	Under 750	10	10	*	10	10	10
	750 to 1,500	12	14	*	12	12	12
	1,500 to 6,000	14	16	*	14	14	14
	Over 6,000	16	18	*	16	16	16
Rural and Urban 45 to 50	Under 750	12	14	*	12	10	10
	750 to 1,500	16	20	*	16	14	12
	1,500 to 6,000	18	26	*	18	16	14
	Over 6,000	22	28	*	22	20	16
Rural and Urban 55	Under 750	14	18	*	12	12	10
	750 to 1,500	18	24	*	18	16	12
	1,500 to 6,000	22	30	*	22	18	16
	Over 6,000	24	32	*	24	22	18
Rural and Urban 60	Under 750	18	24	*	16	14	12
	750 to 1,500	24	32	*	22	18	14
	1,500 to 6,000	30	40	*	26	22	18
	Over 6,000	32	44	*	28	26	22

Source: Adapted from the *Roadside Design Guide*, 2006**Table 5C-1.04:** Acceptable Clear Zone Distances for Rural and Urban Roadways

Design Speed mph	Design Traffic ADT	Foreslope			Backslope or Parking		
		6:1 or flatter	5:1 to 4:1	3:1	6:1 or flatter	5:1 to 4:1	3:1
		In feet from edge of traveled way					
Urban 40 or less	All	For low-speed urban roadways, refer to 5C-1, C, 1.					
Rural 40 or less	Under 750	7	7	*	7	7	7
	750 to 1,500	10	12	*	10	10	10
	1,500 to 6,000	12	14	*	12	12	12
	Over 6,000	14	16	*	14	14	14
Rural and Urban 45 to 50	Under 750	10	12	*	10	8	8
	750 to 1,500	14	16	*	14	12	10
	1,500 to 6,000	16	20	*	16	14	12
	Over 6,000	20	24	*	20	18	14
Rural and Urban 55	Under 750	12	14	*	10	10	8
	750 to 1,500	16	20	*	16	14	10
	1,500 to 6,000	20	24	*	20	16	14
	Over 6,000	22	26	*	22	20	16
Rural and Urban 60	Under 750	16	20	*	14	12	10
	750 to 1,500	20	26	*	20	16	12
	1,500 to 6,000	26	32	*	24	18	14
	Over 6,000	30	36	*	26	24	20

Source: Adapted from the *Roadside Design Guide*, 2006

- * Foreslopes steeper than 4:1 are considered traversable, but not recoverable. An errant vehicle can safely travel across a 3:1 slope, but it is unlikely the driver would recover control of the vehicle before reaching the bottom of the slope; therefore, fixed objects should not be present on these slopes or at the toe of these slopes.

1. **Clear Zone for Low-speed (40 mph or less Design Speed) Urban Roadways with Curbs:** A minimum clear zone behind the back of curb of 6 feet (preferred) or 4 feet (acceptable) should be provided regardless of roadway classification. Clear zone requirements also apply along medians of divided roadways (Maze, 2008; AASHTO *Roadside Design Guide*, 4th Edition).

D. References

American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide*. 4th Edition. Washington, DC. 2011.

Maze T. Hawkins N. et al. Clear Zone - A Synthesis of Practice and an Evaluation of the Benefits of Meeting the 10ft Clear Zone Goal on Urban Streets. Center for Transportation Research and Education. Iowa State University. 2008.

General Information for Joints

A. General Information

The need for a jointing system in concrete pavements results from the desire to control the location and geometry of transverse and longitudinal cracking. Without jointing, uncontrolled cracking occurs due to stresses in the pavement from shrinkage, temperature and moisture differentials, and applied traffic loadings.

A good jointing plan will ease construction by providing clear guidance. The development of a jointing plan requires the designer to think about not only the specific project requirements but also the entire project jointing system. Jointing layouts in some parts of a project can have a substantial impact on other parts. In order to control concrete pavement cracking and subsequently maintain structural integrity, designers need to develop an understanding of how to complete jointing layouts of mainline pavements and intersections to obtain a comprehensive jointing system. This will allow a check on the pattern, type of joints, and matching joints to their purpose.

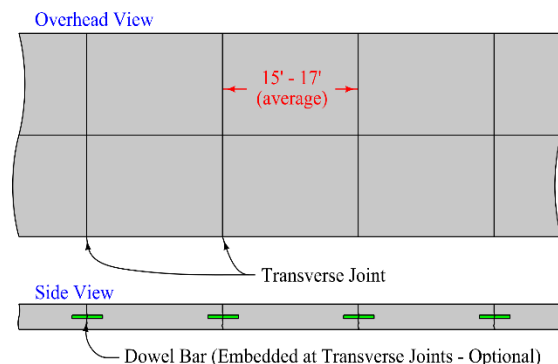
There are three types of jointing systems for concrete pavements, including:

- Jointed plain concrete pavement
- Jointed reinforced concrete pavement
- Continuously reinforced concrete pavement

This section deals primarily with jointed plain concrete pavements (JPCP) with tie bars or dowel bars only at joints as shown in Figure 5G-1.01. The function of the bars in JPCP is to provide load transfer across the joints, either through tie bars that hold the adjacent slabs together and maintain aggregate interlock or through dowel bars that provide mechanical load transfer even with slab movement.

Some cities specify jointed reinforced concrete pavements (JRCP), sometimes referred to as distributed steel reinforcing pavements. [Section 5G-2](#) discusses jointed reinforced pavements. Jointed reinforced pavements allow for longer spacing between transverse joints by utilizing bar mats to hold midpanel cracks together and maintain structural integrity of the slab. Jointed reinforced pavements should not be confused with continuously reinforced concrete pavement, CRCP, which has very few or no joints.

Figure 5G-1.01: Jointed Plain Concrete Pavement (JPCP)



The primary benefits of jointing include:

- Crack control.
- Accommodating slab movements.
- Providing desirable load transfer.

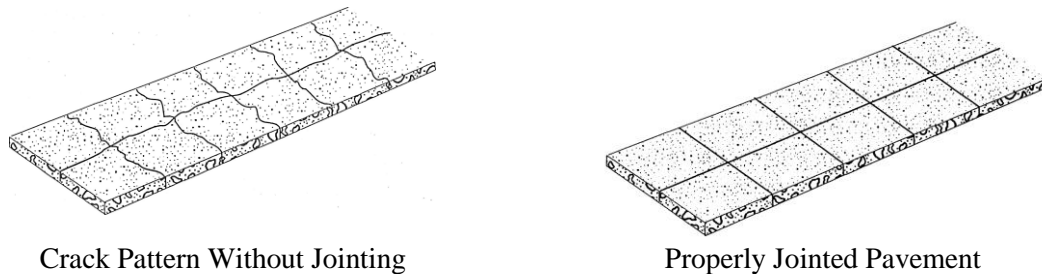
Secondary benefits of jointing include:

- Dividing the pavement into practical construction increments (i.e. traffic lanes, pavement widening).
- Providing traffic guidance.

B. Crack Development

Crack development results from stress that exceeds the strength of the concrete due to concrete drying shrinkage, subgrade restraint, temperature/moisture differentials, applied traffic loads, and the combined effects of restrained curling and warping. It is highly desirable to control the location and geometry of transverse and longitudinal cracking in pavements by using properly designed and constructed joints. Without this control, cracking occurs in a random pattern similar to Figure 5G-1.02.

Figure 5G-1.02: Effect of Jointing on Crack Control



Cracking can be broken into two categories - initial and mature.

1. **Initial Cracking:** Initial cracking occurs within a few hours to a few months after the pavement has been placed. It may be caused by the following conditions.
 - a. **Concrete Shrinkage (loss of volume):** Concrete shrinkage is caused by contraction of concrete from the following.
 - 1) **Temperature Change During Hydration:** The heat of hydration and temperature of pavement normally peak a short time after final set. After peaking, the temperature of concrete declines due to reduced hydration activity and lower air temperature during the first night of pavement life. As the temperature of concrete drops, the concrete contracts or shrinks. If severe air temperature changes occur within the first few hours after construction, high tensile stresses may cause transverse cracking to occur.
 - 2) **Loss of Water During Hydration (drying shrinkage):** Drying shrinkage results from the reduction of volume through loss of mix water. Concrete mixes for roadway applications require more mix water than is required for hydration (water consumed through chemical reactions with cement). The extra water helps provide adequate workability for placing and finishing operations. During consolidation and hardening, most of the excess water bleeds to the surface and evaporates. With the loss of the water, the concrete has less volume.

Types of Joints

A. Jointing

PCC pavement joints are necessary primarily to control the location of cracks that occur from natural and dynamic loading stresses. They accommodate stresses that develop from slab curling and warping due to moisture and temperature differentials and traffic loading. In addition, joints divide the pavement into suitable construction increments or elements. Standard design considerations include joint types, spacing, load transfer, and sealing. This section deals with the proper selection and layout of contraction, construction, and isolation joints.

B. Joint Spacing

Joint spacing for unreinforced concrete pavements depends on slab thickness, concrete aggregate, subgrade/subbase support, and environmental conditions. Transverse joint spacing should be limited to 24T (T is slab thickness) for pavements on subgrades and granular subbases or 21T if the pavement is placed on stabilized subbases, existing concrete, or asphalt. Transverse joint spacing is 12 feet for pavements 6 inches thick, 15 feet for pavements 7 to 9 inches thick, and 17 feet for pavements over 9 inches thick. Longitudinal joint spacing for two lane streets, where lane delineation is not necessary, should be limited to a maximum of 10 feet. For multi-lane streets, where lane delineation is desired, longitudinal joint spacing is typically 10 to 12 feet. Generally, transverse joint spacing should not exceed 150% of the longitudinal joint spacing. Table 5G-2.01 provides transverse joint spacings for standard two lane streets.

Table 5G-2.01: Transverse Joint Requirements

Pavement Thickness	Transverse Joint Type	Transverse Joint Spacing
6"	C	12'
7"	C	15'
8"	CD ¹	15'
9"	CD ¹	15'
≥ 10"	CD ¹	17'

¹ No dowels within 24" of the back of curb

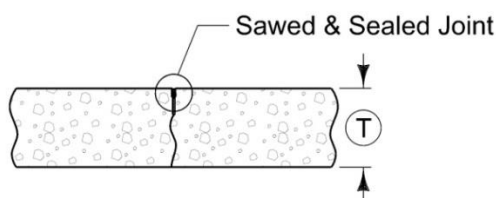
Source: [SUDAS Specifications Figure 7010.901](#)

C. Joint Types

Contraction joints for concrete pavements are generally sawed. Transverse joints can be sawed with conventional sawing or early concrete sawing equipment. Longitudinal joints are formed with conventional sawing. Some joints, including construction joints, are formed. The figures in this subsection are derived from [SUDAS Specifications Figure 7010.101](#).

1. **Transverse Contraction Joints:** Contraction joints constructed transversely across pavement lanes are spaced to control natural initial and mature cracking of the concrete pavement. Under certain conditions, such as rapidly dropping air temperature during the night, transverse cracks may occur early. Therefore, early formation of the transverse joints is required.
 - a. **Plain Contraction Joints:** Plain contraction joints are normally used in local streets and minor collectors where load transfer is not a major factor. Load transfer for plain contraction joints occurs through the adjacent irregular fractured faces. Generally, they are used when the slab thickness is less than 8 inches. The joints are constructed by sawing to a depth of $T/4$. Plain contraction joints are sometimes used when the pavement thickness is 9 inches or greater such as at intersections in boxouts near curbs where load transfer is not a concern. Approved early concrete sawing equipment may be used to cut the joint to a depth of 1 1/4 inch. For sealing, the joint width must be a minimum of 1/4 inch wide.

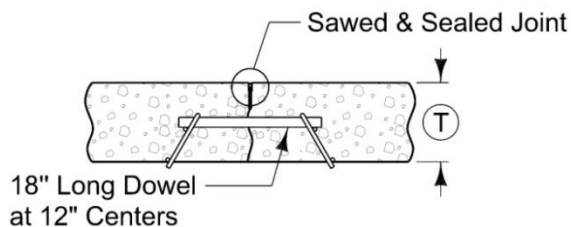
Figure 5G-2.01: 'C' Plain Contraction Joint



- b. **Doweled Contraction Joints:** Dowel bars are used to supplement the load transfer produced by aggregate interlock. The joints are sawed to a depth of $T/3$ and are spaced at 15 foot intervals for slab thickness of 9 inches or less and 17 feet for slabs greater than 9 inches thick. The dowels are placed at the mid-depth in the slab so they can resist shear forces as traffic loads cross the joint; thus helping reduce deflection and stress of the joint. The need for doweled contraction joints depends on subgrade/subbase support and the truck traffic loadings the roadway is to provide. They are usually used on streets or roadways where the pavement thickness is 8 inches or greater and where the pavement is subject to heavier truck traffic, generally more than 100 trucks per lane per day. Early entry concrete sawing can be used for 'CD' joints.

Dowels should not be placed closer than 24 inches from the back of the curb on streets with quarter point or third point jointing. If gutterline jointing is used, place the first dowel in the traffic lane 6 inches from the joint.

Figure 5G-2.02: 'CD' Doweled Contraction Joint

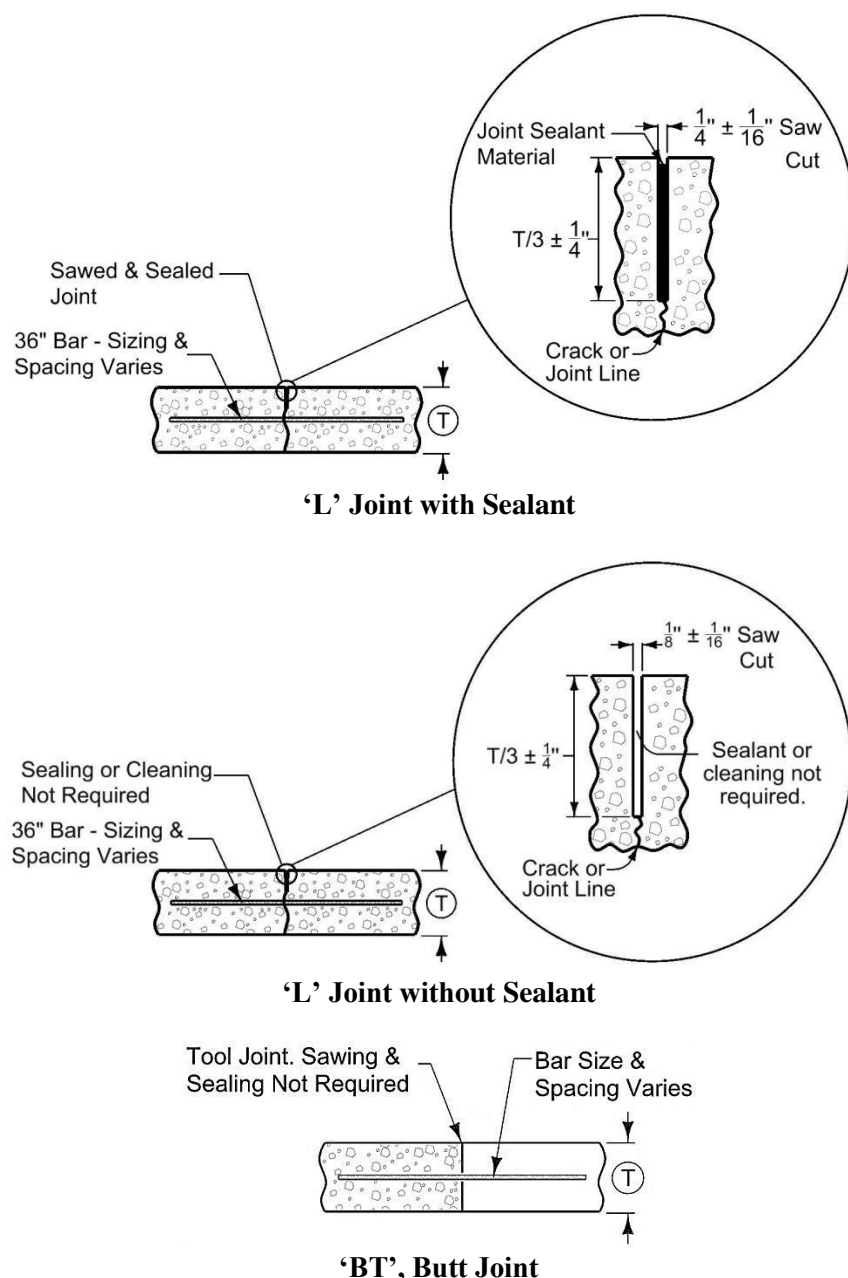


2. **Longitudinal Contraction Joints:** Longitudinal contraction joints release stresses from restrained warping and dynamic loading. Under certain conditions, such as rapidly dropping air temperature during the night, longitudinal cracks may occur early. Therefore, early formation of the joint is required.

Typically, sawed longitudinal joints are sealed. However, since the slabs on either side of the longitudinal contraction joint are tied by a reinforcing bar, the Jurisdictional Engineer may approve not sealing the joint. The need to seal the joint is reduced due to the tied connection and the fact the joint will not open. The depth of cut for sawed longitudinal joints is $T/3$, regardless of the method of sawing used. The width of the sealed joints is $1/4 \text{ inch} \pm 1/16 \text{ inch}$. The maximum width of the unsealed joints is $1/8 \text{ inch} \pm 1/16 \text{ inch}$.

A longitudinal joint is usually placed at the center of the pavement to allow the pavement to hinge due to lane loading and help delineate separation of opposing traffic. Controlling cracking and proper constructability are the primary functions of longitudinal contraction joints. Lane delineation is a secondary function.

Figure 5G-2.03: Longitudinal Contraction Joints

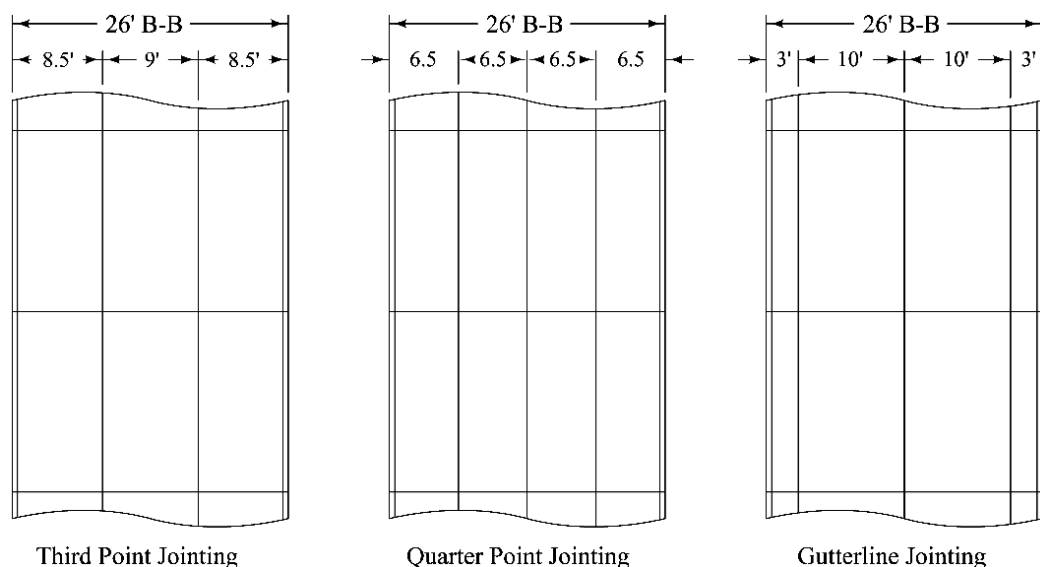


An important consideration when establishing the distance between longitudinal joints for jointed plain concrete pavements is the prevention of random longitudinal cracking at the quarter point, which is the midpoint between the centerline and the back of the curb. Pavements less than 9 inches thick may not crack through a longitudinal joint placed close to the gutter, which could cause longitudinal cracks at the quarter point. For this reason, it is preferred to use quarter point jointing for 31 foot wide pavements. Third point jointing, which eliminates the centerline joint, is frequently used for pavement narrower than 30 feet because of the narrower panel width and for 31 foot wide pavements with a depth greater than 8 inches. However, some jurisdictions desire a centerline joint and a gutterline joint, typically 3 to 3 1/2 feet from the back of curb. A gutterline joint should only be used if the pavement has depth of at least 9 inches or pavement widening is likely to occur.

The following examples depict jointing options for 26 foot and 31 foot wide pavements. The principles involved with jointing for these pavement widths can be extended to other pavement widths.

- a. 26 Foot B-B Pavement:** Three longitudinal joint options for 26 foot wide plain jointed concrete pavements are provided:
- 1) Third point jointing provides for a single 9 foot center panel with two joints, each 8 1/2 feet from the back of curb.
 - 2) Quarter point jointing includes a centerline joint and two joints at the quarter points. This option is used when centerline crack control is desired.
 - 3) Gutterline jointing provides two 10 foot lanes with a centerline joint and gutterline joints 3 feet from the back of curb. As stated above, care must be exercised with this option to prevent random cracking at the quarter point. This option is typically used for streets 9 inches or greater in thickness.

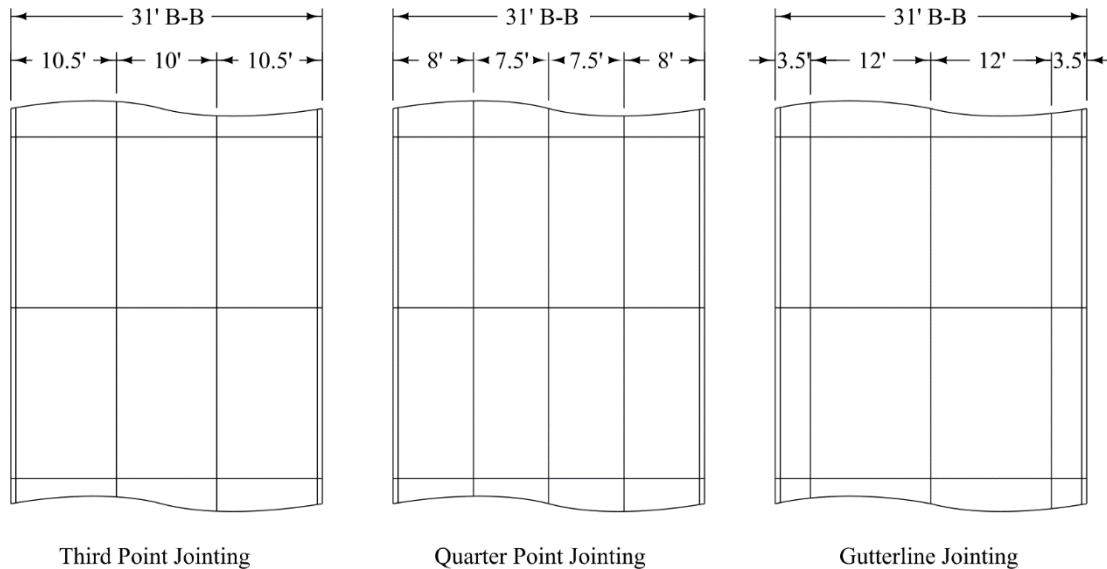
Figure 5G-2.04: 26 Foot B-B Pavement



- b. 31 Foot B-B Pavements:** Three longitudinal joint options for 31 foot wide pavements are provided.
- 1) Quarter point jointing provides for a centerline longitudinal joint and two quarter point joints and is not intended to delineate driving lanes.
 - 2) Third point jointing provides three nearly equally spaced panels, without a centerline joint. It typically is used as an option to quarter point jointing to minimize the number of longitudinal joints.

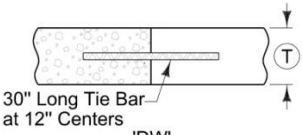
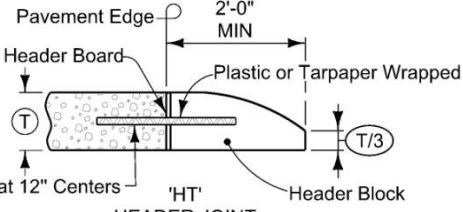
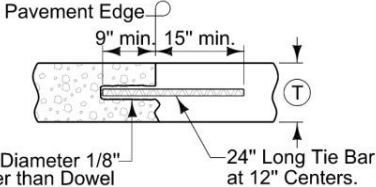
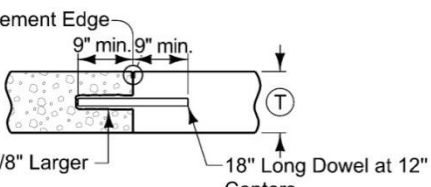
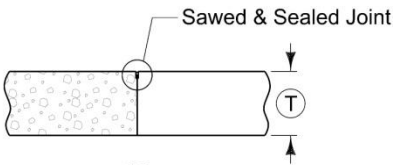
- 3) Gutterline jointing utilizes a centerline joint and gutterline joints 3 to 3 1/2 feet from the back of curb that delineate driving lanes.. This jointing pattern is typically used when the pavement may be widened in the future, and the delineation of the lanes is desired. Care must be exercised with this option to prevent random cracking at the quarter point. Typically, gutterline jointing is used on streets with pavement thickness greater than or equal to 9 inches.

Figure 5G-2.05: 31 Foot B-B Pavements



- 3. Transverse and Longitudinal Construction Joints:** Construction joints are necessary for planned construction interruptions or widening/extending a pavement. Examples include construction of adjacent lanes at different times; box-outs for structures, radii, etc.; planned gaps in the paving operation such as at driveways, bridges, and intersections; paving operation stoppages for over 30 minutes; and when a joint is needed between dissimilar materials. Construction joints are also used between an existing pavement and a new pavement. The joint is formed with the existing slab and is not sawed, except to accommodate joint sealing when required. Sawing and sealing of the joints are not required for those tied with deformed bars.
- a. Transverse Construction Joints:** These types of joints are usually butt-type joints with deformed tie bars or dowels to provide load transfer and prevent vertical movement. Because DW joints are tied, they should be located mid-panel or no closer than 5 feet to a planned contraction joint. When joint sealing is required, the depth of the saw cut (1 1/4 inches) is just deep enough to provide a reservoir for the joint sealant. The following are typical transverse construction joints.

Figure 5G-2.06: Transverse Construction Joints

 <p>30" Long Tie Bar at 12" Centers</p> <p>'DW'</p> <p>DAY'S WORK JOINT (Non-working)</p>	<p>Used at planned or unplanned stopping points. Ideally, it should be located at mid-panel, but it should not be located less than 5 feet from a planned contraction joint.</p>
 <p>Pavement Edge</p> <p>Header Board</p> <p>2'-0" MIN</p> <p>Plastic or Tarpaper Wrapped</p> <p>30" Long Tie Bar at 12" Centers</p> <p>'HT'</p> <p>HEADER JOINT (End Rigid Pavement)</p> <p>Header Block</p> <p>T/3</p>	<p>Used when the pavement ends and traffic will cross the joint. The header is removed when the pavement is extended.</p>
 <p>Pavement Edge</p> <p>9" min. 15" min.</p> <p>Hole Diameter 1/8" Larger than Dowel</p> <p>24" Long Tie Bar at 12" Centers.</p> <p>'RT'</p> <p>ABUTTING PAVEMENT JOINT RIGID TIE</p>	<p>Typically used when an existing slab is extended.</p>
 <p>Pavement Edge</p> <p>9" min. 9" min.</p> <p>Hole Diameter 1/8" Larger than Dowel</p> <p>18" Long Dowel at 12" Centers</p> <p>'RD'</p> <p>ABUTTING PAVEMENT JOINT</p>	<p>Functions as a CD joint when an existing slab is extended. Normally used when the pavement is 8 inches or greater in thickness.</p>
 <p>Sawed & Sealed Joint</p> <p>'B'</p> <p>PLAIN JOINT (For Abutting Pavement Slabs)</p>	<p>Typically used when two different pavement types or thicknesses abut or at the inside longitudinal edge of intake boxouts.</p>

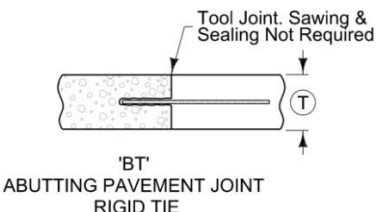
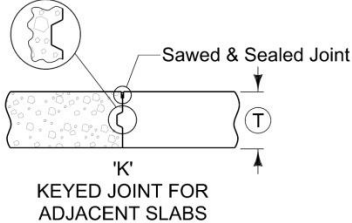
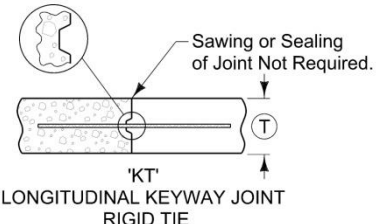
- b. Longitudinal Construction Joints:** These types of joints are used when adjacent lanes are constructed at different times. Tie-bars are primarily designed to resist horizontal movement but help with load transfer and vertical control. Under certain conditions, such as a drop in air temperature during the first night, longitudinal and transverse cracks may occur early. Early sawing of transverse joints is important when tied longitudinal construction joints are constructed in order to prevent the following two conditions from occurring.

- 1) Sympathy Transverse Cracking in New Lane Construction:** When a new slab is longitudinally tied to an existing pavement, the existing transverse contraction joints can cause adjacent lane cracking in the new slab if early sawing of the transverse joints is not done. If there are transverse random cracks in an existing slab, the longitudinal

construction joint should be a plain butt joint or keyed joint (with no tie bars), if one exists in the old slab, to prevent sympathy cracks in the new pavement.

- 2) **Longitudinal Tie-bar Stress in Cooler Weather Conditions:** Care must be exercised to control cracking when utilizing longitudinal construction joints with tie bars, particularly in cool temperatures. For example, when a lane is constructed one day and the adjacent lane is constructed the following day or later, the existing lane could be expanding, particularly in the morning. If the new lane is in its final set (contracting) at the same time the existing pavement is expanding, stresses in the concrete at the tie bars can be significant. If the strength of the new concrete has not developed enough to resist the stresses, cracking could occur in the new concrete at the tie bars. During cooler weather conditions, care should be exercised when paving the new lane. Ideally, the new paving operation should take place at mid-day or later when the existing lane expansion is reduced.

Figure 5G-2.07: Longitudinal Construction Joints

 <p>'BT' ABUTTING PAVEMENT JOINT RIGID TIE</p>	<p>Used to tie existing and new parallel pavements together to prevent horizontal movements; and will provide some load transfer and resist vertical movement.</p>
 <p>'K' KEYED JOINT FOR ADJACENT SLABS</p>	<p>Used when tie bars are not needed or desired and load transfer is required.</p>
 <p>'KT' LONGITUDINAL KEYWAY JOINT RIGID TIE</p>	<p>Used in pavements under heavier traffic conditions and typically where the pavement thickness is 8 inches or greater. Also used at intersections under heavy turning movements where the pavement is less than 8 inches.</p>

4. **Isolation Joints and Expansion Joints:** Expansion and isolation joints accommodate anticipated differential horizontal and vertical movements that occur between a pavement and structure. Their purpose is to allow movement without damaging adjacent structures or pavements. Contraction or control joints also absorb some movement; however, their main function is to control the location and geometry of the natural cracking pattern in the concrete slab. Because pavement performance can be significantly affected by the planned use and location of isolation and expansion joints, care should be taken in their design. Though the terms are sometimes used interchangeably, isolation joints are not expansion joints.

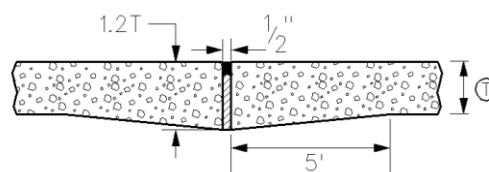
- a. Isolation Joints:** Isolation joints isolate the pavement from a structure, another paved area, or an immovable object. Isolation joints include full depth, full width joints found at bridge abutments, intersections, or between existing and new pavements. The term “isolation joint” also applies to joints around in-pavement structures such as drainage inlets, manholes, footings, and lighting structures. Isolation joints lessen compressive stresses that develop at T and unsymmetrical intersections, ramps, bridges, building foundations, drainage inlets, manholes, and anywhere differential movement between the pavement and a structure may take place. They are also placed adjacent to existing pavements, especially when it is not possible or desirable to match joint locations in the older pavement. Isolation joints should be 1/2 to 1 inch wide. Greater widths may cause excessive movement. They are filled with a pre-formed joint filler material to prevent infiltration of incompressibles.

At T-intersections, isolation joints should be used to isolate the T-intersecting street from the through street. Also, all legs of skewed streets should be isolated from the through street. Isolation joints used for this purpose should be placed one joint spacing back from the end of the intersection radii.

The joint filler material for expansion and isolation joints occupies the gap between the slabs and must be continuous from one pavement edge to the other and through curb and gutter sections. This filler material is usually a non-absorbent, non-reactive, non-extruding material typically made from either a closed-cell foam rubber or a bitumen-treated fiber board. No plug or sliver of concrete should extend over, under, through, around, or between sections of the filler, or it will cause spalling of the concrete. After the concrete hardens, the top of the filler may be recessed about 3/4 inch below the surface of the slab to allow space for the joint sealant to be placed later.

- 1) **Doweled Isolation Joints:** Isolation joints used at structures should have dowels to provide load transfer. The end of the dowel must be equipped with a closed-end expansion cap into which the dowel can move as the joint expands and contracts. The cap must be long enough to cover 2 inches of the dowel and have a suitable stop to hold the end of the cap at least the width of the isolation joint plus 1/4 inch away from the end of the dowel bar. The cap must fit the dowel bar tightly and be watertight. The half of the dowel with the capped end must be coated to prevent bonding and allow horizontal movement.
- 2) **Special Undoweled Isolation Joints:** Isolation joints at T and unsymmetrical intersections or ramps are not doweled so that horizontal movements can occur without damaging the abutting pavement. Undoweled isolation joints can be constructed with thickened edges to reduce the stresses developed at the slab bottom. The abutting edges of both pavements should be thickened by 20% starting with a taper 5 feet from the joint. The isolation filler material must extend completely through the entire thickened-edge slab.

Figure 5G-2.08: Thickened Edge Joint



- a) Undoweled Isolation Joints for Boxouts:** Isolation joints used at drainage inlets, manholes, and lighting structures do not have thickened edges or dowels.

- b) **Adjusting Isolation Joints for Utility Fixtures:** After developing the jointing plan, plot any catch basins, manholes, or other fixtures that are within the intersection. Non-telescoping manholes will require a boxout or isolation joint to allow for vertical and horizontal slab movement. Consider using rounded boxouts to avoid crack-inducing corners. Also, for square boxouts, wire mesh or small-diameter reinforcing bars in the concrete around any interior corners will hold cracks tight should they develop. Telescoping manholes can be cast integrally within the concrete, and do not necessarily require a boxout. The multiple piece casting does not inhibit vertical movement and is less likely to create cracks within the pavement.

When a joint is within 5 feet of a fixture, it is desirable to adjust the joint so that it will pass through the fixture or the boxout surrounding the fixture. The following diagram shows several acceptable ways to skew or shift a joint to meet fixtures.

- b. **Expansion Joints:** Expansion joints are defined as full depth, full width transverse joints placed at regular intervals of 50 to 500 feet (with contraction joints in between). This is an old practice that was used to relieve compressive forces in pavement. Unfortunately, this practice often caused other problems in the pavement such as spalling, pumping, faulting, and corner breaks.

Good design, construction, and maintenance of contraction joints has virtually eliminated the need for expansion joints, except under special conditions. In addition to the problems listed above, the improper use of expansion joints can lead to high construction and maintenance costs, opening of adjacent contraction joints, loss of aggregate interlock, sealant failure, joint infiltration, and pavement growth. By eliminating unnecessary expansion joints, these problems are removed and the pavement will provide better performance.

Pavement expansion joints are only needed when:

- 1) The pavement is divided into long panels (60 feet or more) without contraction joints in between to control transverse cracking.
- 2) The pavement is constructed while ambient temperatures are below 40°F.
- 3) The contraction joints are allowed to be infiltrated by large incompressible materials.
- 4) The pavement is constructed of materials that in the past have shown high expansion characteristics.

Under most normal concrete paving situations, these criteria do not apply. Therefore, expansion joints should not normally be used (PCA, 1992).

Figure 5G-2.09: Typical PCC Joint Layout at Manholes
([SUDAS Specifications Figure 7010.103](#))

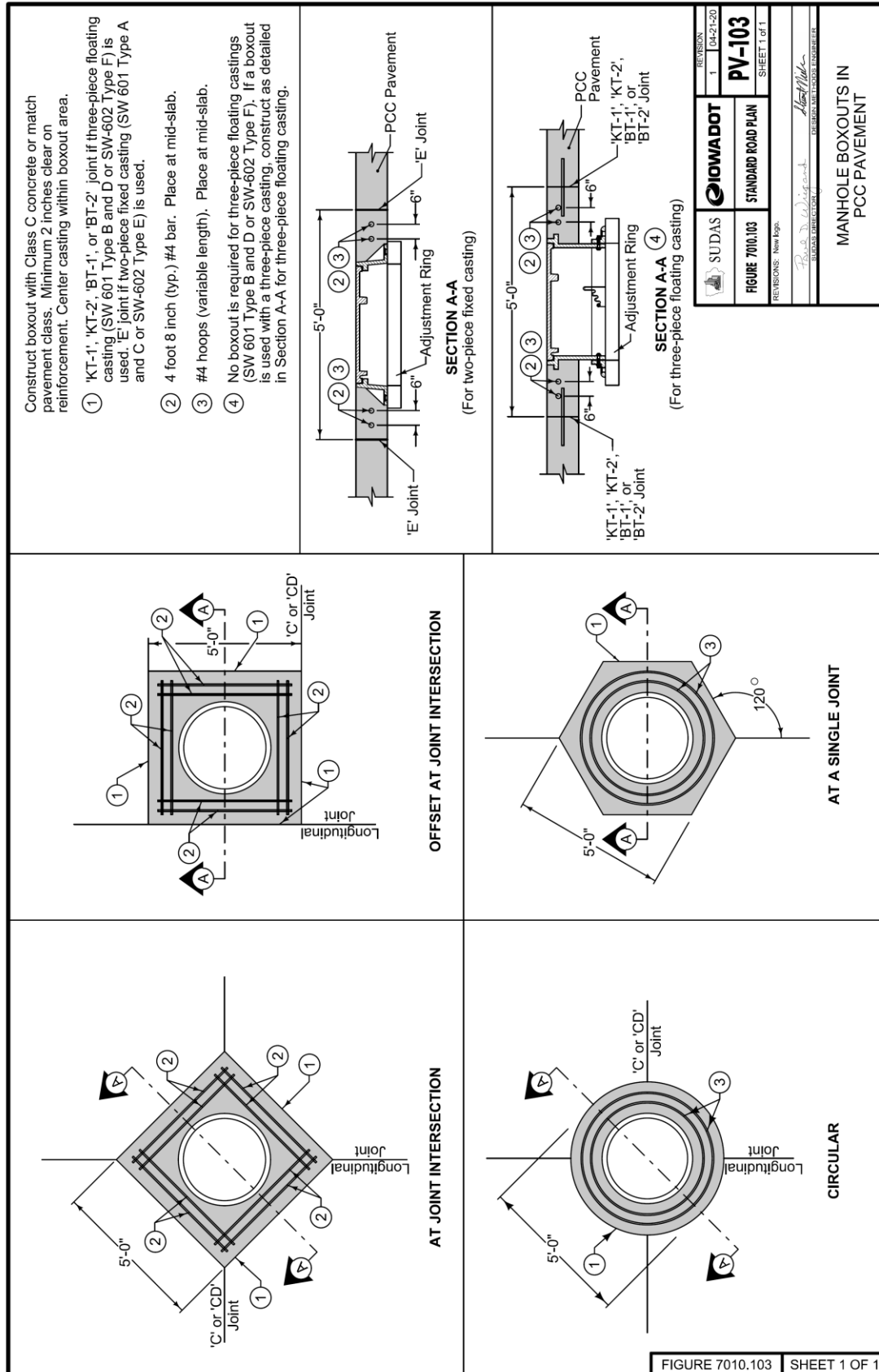
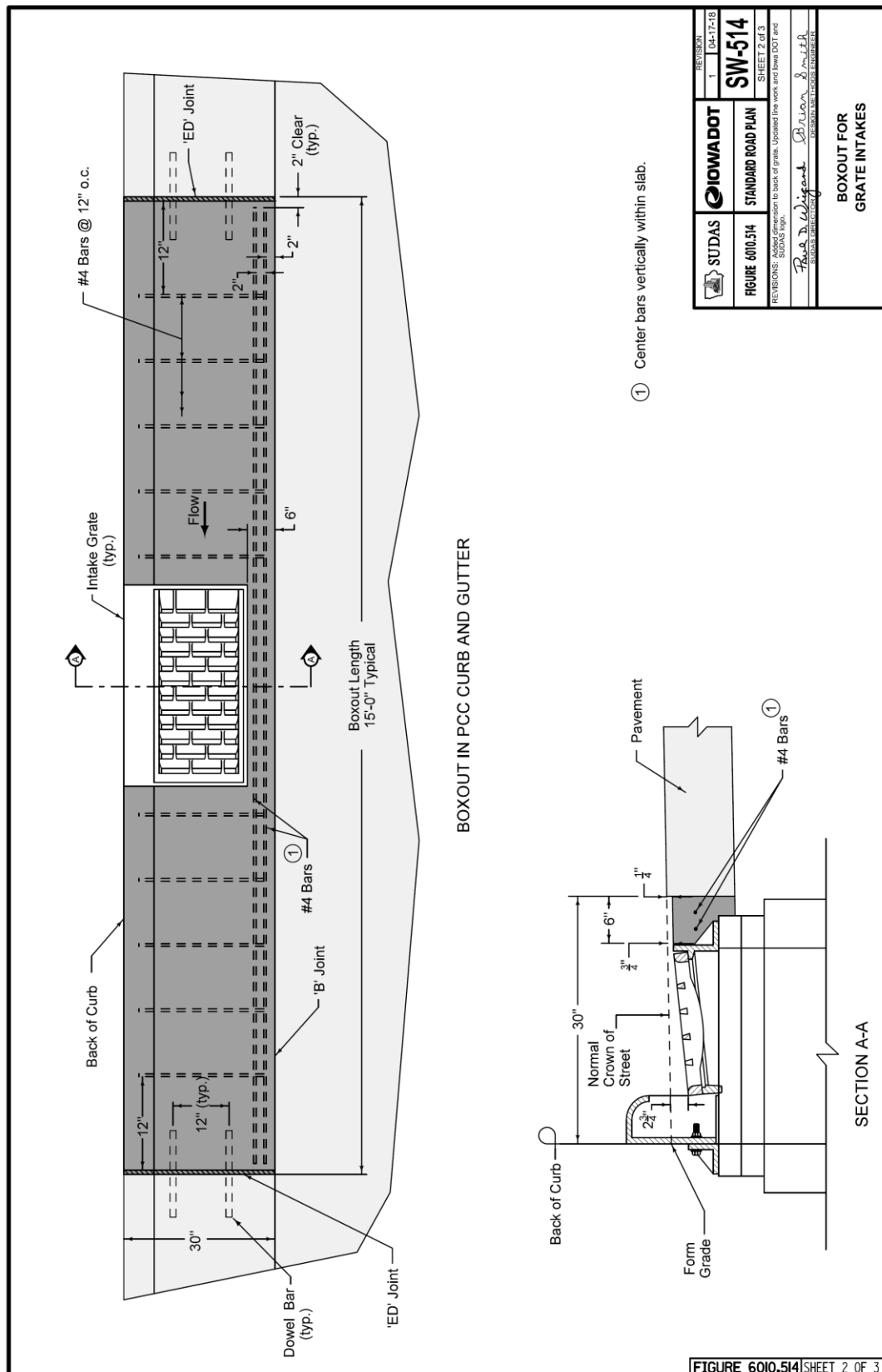
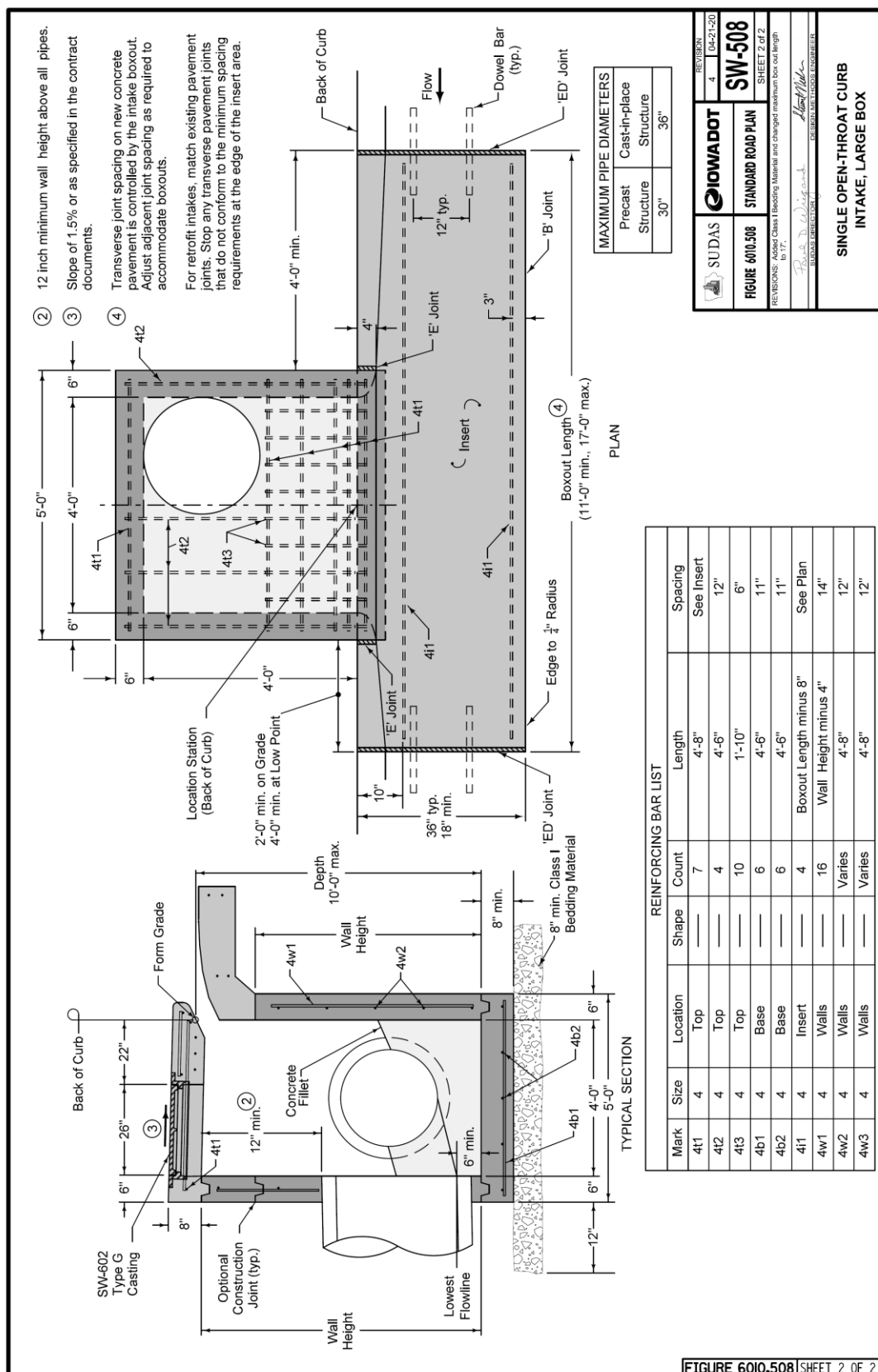


Figure 5G-2.10A: Typical PCC Joint Layout at Intakes - Boxout for Grate Intakes
([SUDAS Specifications Figure 6010.514, sheet 2*](#))



* [SUDAS Specifications Figure 6010.514](#), sheets 1 and 3 include more boxout options.

Figure 5G-2.10B: Typical PCC Joint Layout at Intakes - Boxout for Open-throat Curb Intakes
(SUDAS Specifications Figure 6010.508, sheet 2*)



* **SUDAS Specifications Figure 6010.508**, sheet 1 includes more information.

Table 5G-2.02: Summary of Joints
(Derived from the [Iowa DOT Design Manual, Section 7A-2](#), Tables 1 and 2)

	Type			Method of Load Transfer				Thermal Movement				Comments
Joint	Transverse	Longitudinal	Isolation/Expansion	Aggregate Interlock	Key	Tie Bar	Dowel Bar	Doweled to allow movement	Tied to prevent movement	Isolation/Expansion joint allows movement	Lack of reinforcing	
B	X	X									X	Used between dissimilar materials or when other joints are not suitable.
C	X			X							X	Transverse joint used when T < 8 inches.
CD	X			X			X	X				Transverse joint used when T ≥ 8 inches.
CT	X			X		X			X			Specialty tied contraction joint.
DW	X					X			X			Used by contractor as a stopping point.
HT	X					X			X			Used at the end of rigid pavement prior to placement of second slab.
RD	X						X	X				Joint between new and existing pavements, dowels are used.
RT	X					X			X			Joint between new and existing pavements, tie bars are used.
BT-1		X							X			Longitudinal joint used when T < 8 inches, interchangeable with L-1 depending on paving sequence.
BT-2		X							X			Used when L-2 and the KT-2 are not possible, T ≥ 8 inches.
BT-3		X							X			Joint used between new and existing pavements. Tie bars are used when T ≥ 8 inches.
BT-4		X							X			Joint used between new and existing pavements. Tie bars are used when T ≥ 8 inches.
BT-5		X							X			Joint used between new and existing pavements. Tie bars are used when T < 8 inches.
K		X			X						X	T > 8 inches, minimal usage.
KS		X			X				X			Used in reinforced pavements.
KT-1		X			X				X			Longitudinal joint used when T < 8 inches, interchangeable with L-1 depending on paving sequence.
KT-2		X			X				X			Longitudinal joint used when T ≥ 8 inches, interchangeable with L-2 depending on paving sequence.
KT-3		X			X				X			Longitudinal joint used when T ≥ 8 inches, interchangeable with L-3 depending on paving sequence.
L-1		X		X					X			Longitudinal joint used when T < 8 inches, interchangeable with BT-1.
L-2		X		X					X			Longitudinal joint used when T ≥ 8 inches, interchangeable with KT-2 depending on paving sequence.
L-3		X		X					X			Longitudinal joint used with pavements of large width, interchangeable with KT-3 depending on paving sequence.
CF	X		X							X		4 inch expansion joint.
E	X	X	X							X		1 inch expansion joint.
ED	X		X				X	X		X		1 inch doweled expansion joint.
EE	X		X				X	X		X		2 inch doweled expansion joint.
EF	X		X				X	X		X		4 inch doweled expansion joint.
ES			X							X		Used in curb to match expansion joint in pavement.

D. Transverse Dowel Bar Size and Length

Table 5G-2.03 reflects the dowel bar size and length based on the pavement thickness. This information was obtained from the Portland Cement Association, the American Concrete Paving Association, and American Highway Technology. The SUDAS and Iowa DOT Specifications call for dowels when the slab is 8 inches or greater. Dowels are typically set at 12 inch spacing. The designer should note that a dowel bar that is too small induces high bearing stresses and causes the concrete matrix around the dowel to deteriorate or elongate. Elongation of the dowel bar hole then reduces the load transfer capabilities. Under special circumstances, smaller diameter and different shaped dowel bars may be used in thinner slabs.

Table 5G-2.03: Dowel Bar Size and Length

Pavement Thickness (inches)	Dowel Size (diameter in inches)	Dowel Length (inches)
8	1 1/4	18
9	1 1/4	18
10	1 1/2	18
11	1 1/2	18
12	1 1/2	18

E. Jointed Reinforced Concrete Pavements

Jointed reinforced concrete pavements (JRCP), sometimes referred to as distributed steel reinforcing, are not commonly used in Iowa jurisdictions. However, variations of JRCP are used effectively by several jurisdictions in Iowa. Therefore, the following is provided as an explanation of JRCP.

JRCPs utilize bar mats between transverse joints. Typically, the bar mats extend full width across the pavement, but with traditional JRCPs, they do not extend through the transverse joints. JRCPs use many of the same types of joints as jointed plain concrete pavements (JPCP), but the tie bars for longitudinal joints are replaced with the bar mats. Transverse joints, including doweled joints, are the same for both types of pavements since the bar mats of traditional JRCP do not extend through the transverse joints. Because of the bar mats, transverse joint spacing can be much longer than with JPCP, usually 27 feet to 45 feet. JRCP should not be confused with continuously reinforced pavement, which has very few or no joints.

JRCPs are used primarily to control cracking of concrete pavements, to provide for load transfer between joints, and to maintain the structural integrity of the slab between transverse joints. Just like JPCPs, random cracking of JRCPs may still occasionally occur even though the steel is present. The steel serves to hold the cracks close together, thus preventing the progressive opening of the cracks over time.

The added cost of the additional reinforcement for JRCPs is often offset by specifying a somewhat thinner slab. However, as pointed out by the American Concrete Institute (ACI), “the use of reinforcing steel will not add to the load-carrying capacity of the pavement nor compensate for poor subgrade preparation or poor construction practices.” By holding random cracks tightly closed, it will maintain the shear resistance of the slab, and, consequently, will maintain its load carrying capacity. This improves the ride when the vertical displacement is controlled.

As mentioned previously, several jurisdictions in Iowa specify a variation of JRCP. The Iowa variations of JRCP typically include extending the longitudinal reinforcing bars through the ‘C’ plain transverse contraction joints. When ‘CD’ doweled transverse joints are specified, the longitudinal

reinforcement does not extend through the transverse joints. In addition, the transverse joint spacing is generally not lengthened as described for traditional JRCPs and follows the same guidelines as for JPCP. Figures 5G-2.11 and 5G-2.12 illustrate JRCP details typically used in Iowa.

Figure 5G-2.11: Iowa Jointed Reinforced Pavement Detail - 26' Back-To-Back Street

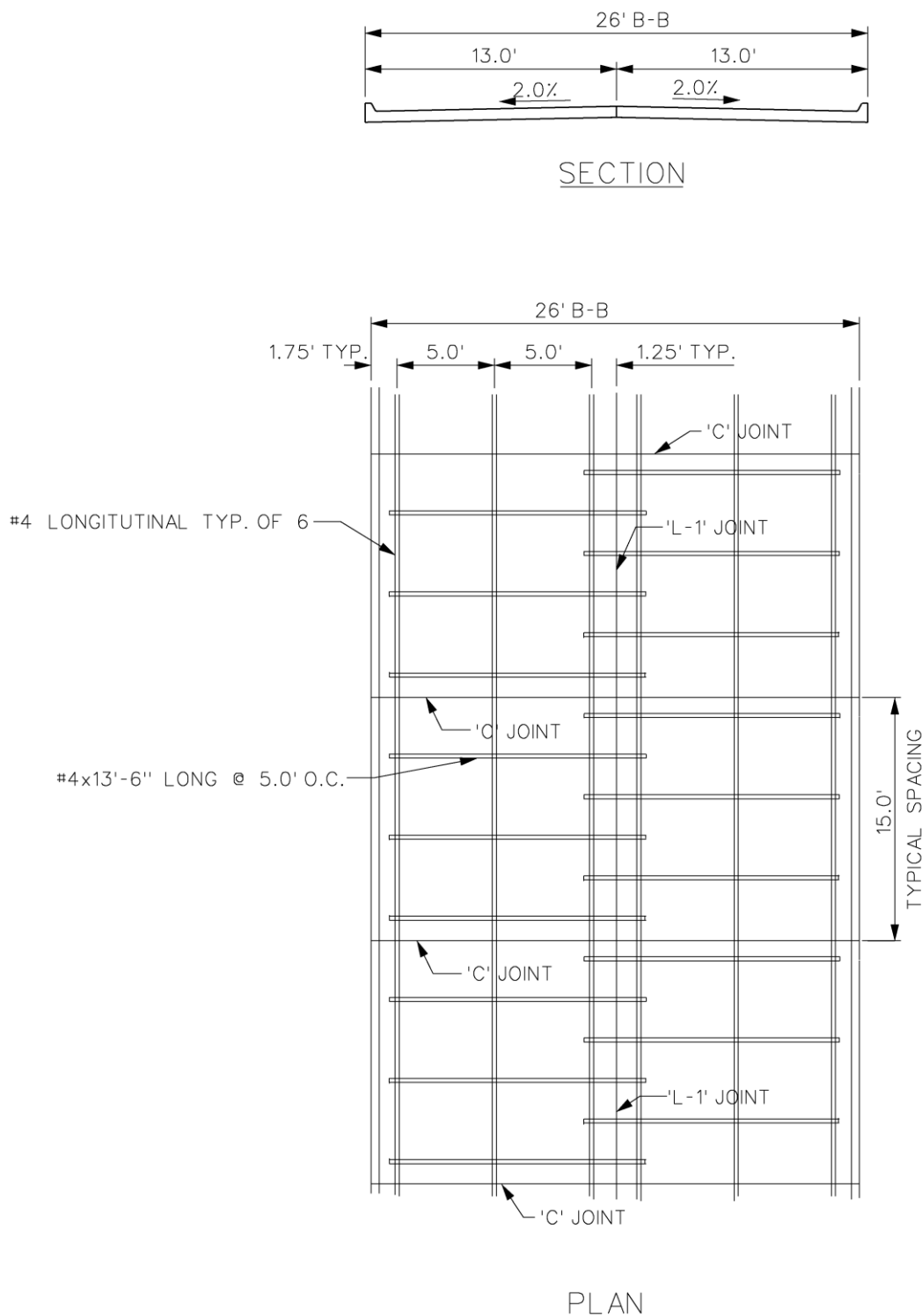
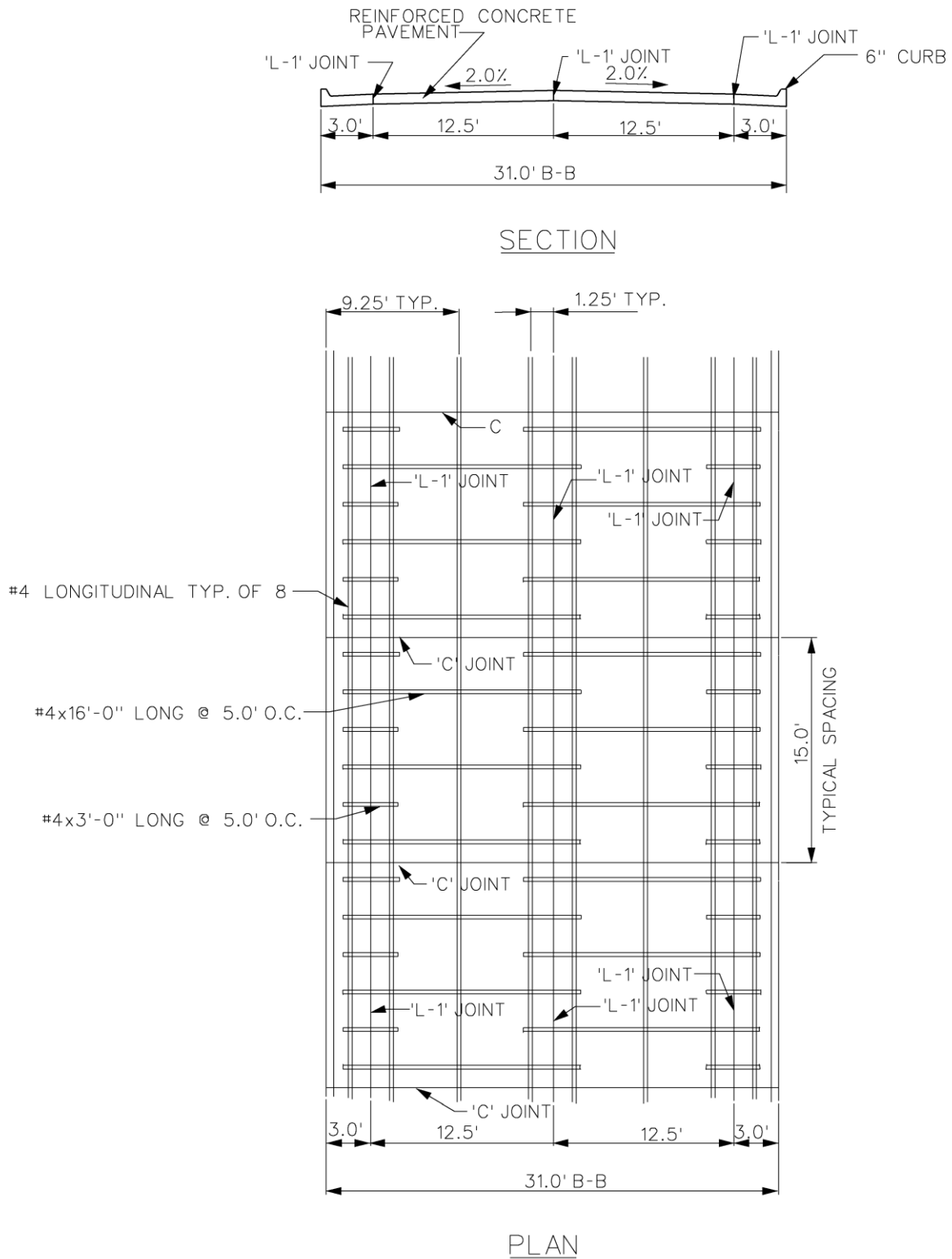


Figure 5G-2.12: Iowa Jointed Reinforced Pavement Detail - 31' Back-To-Back Street

F. Miscellaneous PCC Pavement Jointing Figures

Figure 5G-2.13: 49' B/B and 53' B/B PCC Pavement Jointing and Crown Detail

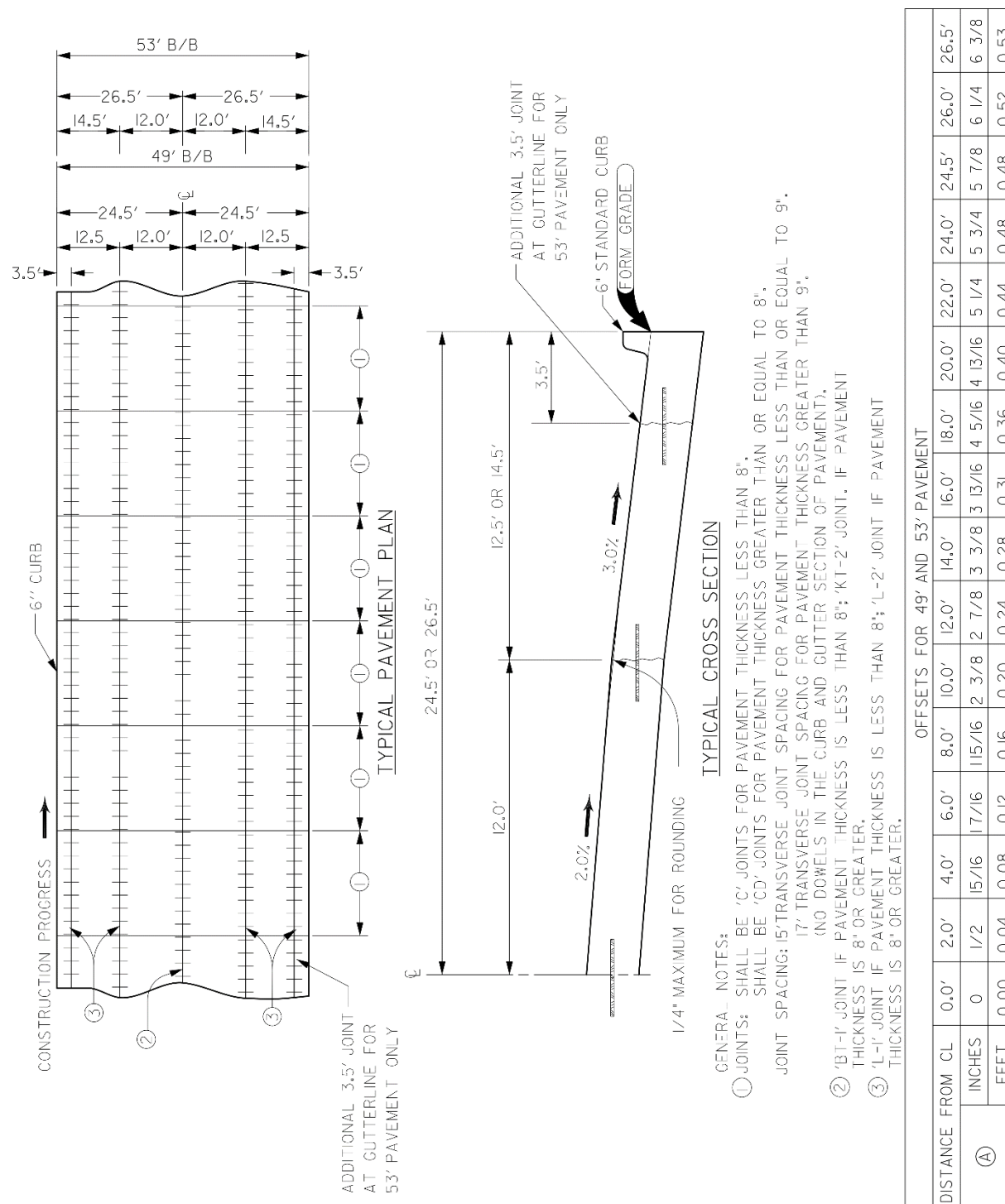


Figure 5G-2.14: 49' B/B and 53' B/B C&G/HMA Pavement

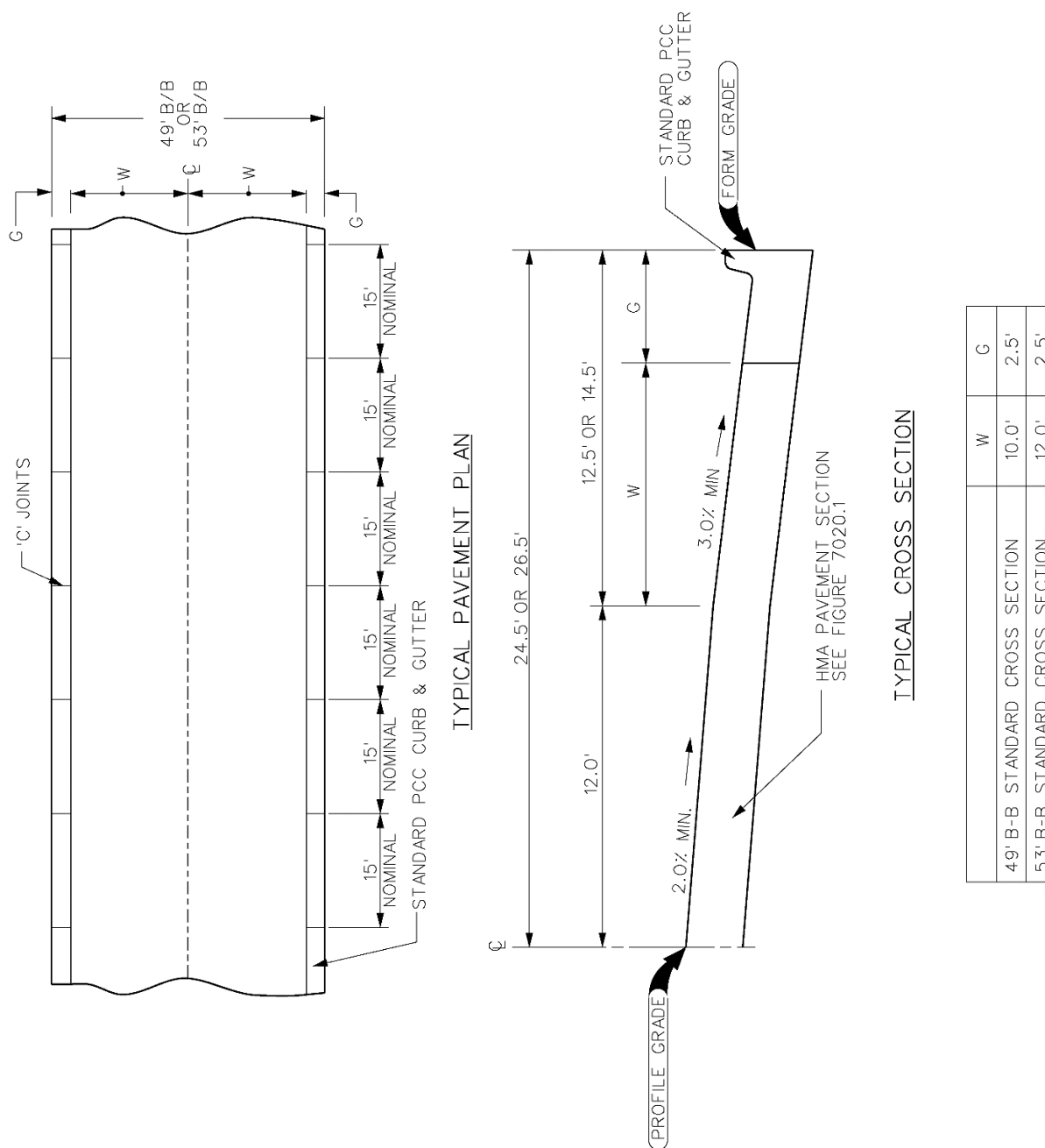


Figure 5G-2.15: 24' Rural PCC Pavement Jointing and Crown Detail

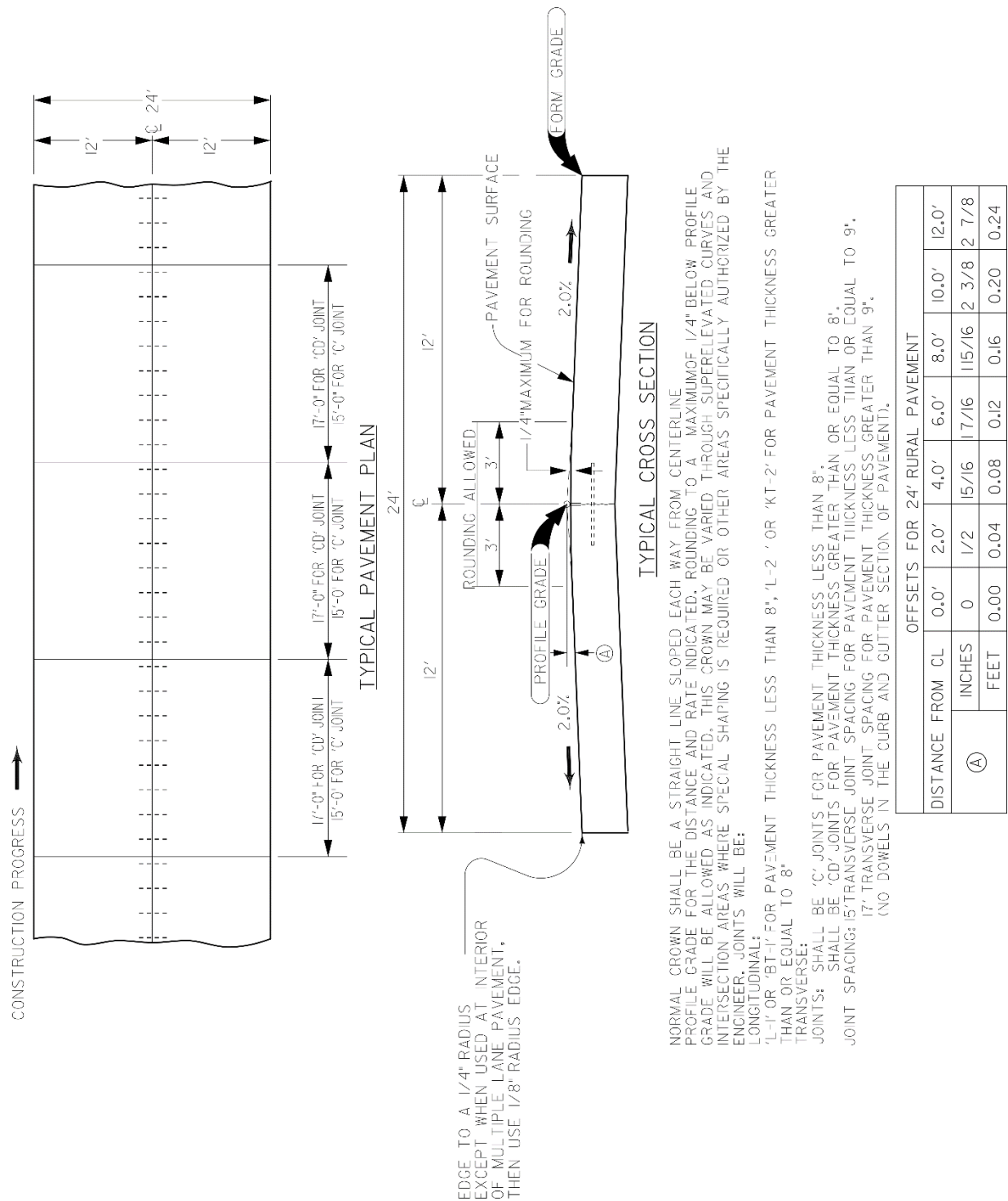


Figure 5G-2.16: 48' Rural PCC Pavement Jointing and Crown Detail

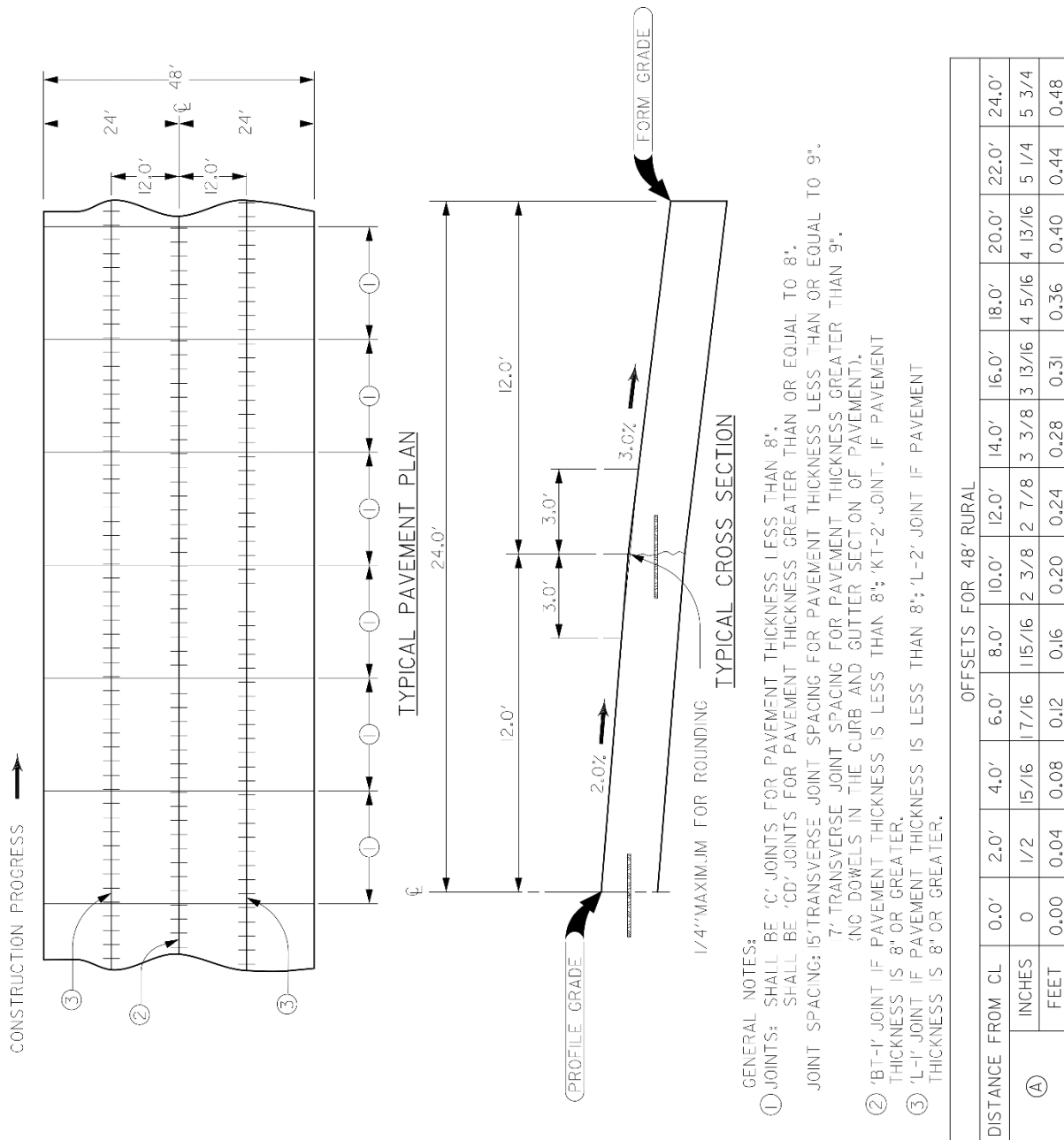
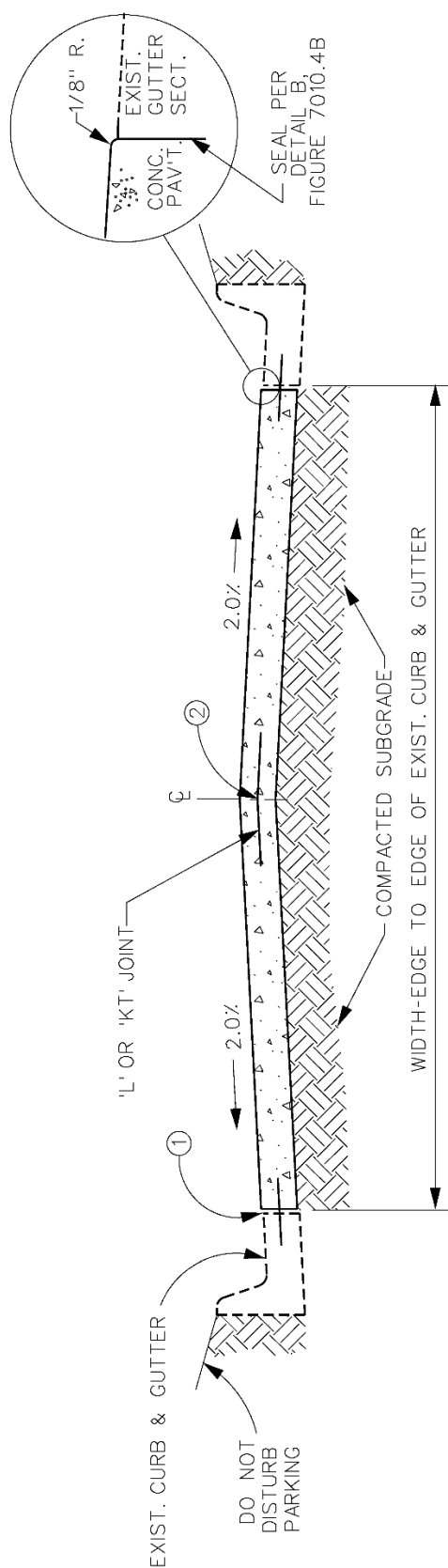


Figure 5G-2.17: PCC Pavement Section Between Existing Curb and Gutter

FOR CROWN SEE FIGURES 7010.1A (SHEET 1 OR 2) OR 7010.1B

- ① 'BT-1' JOINT IF PAVEMENT THICKNESS IS LESS THAN 8"; 'BT-2' JOINT IF PAVEMENT THICKNESS IS 8" OR GREATER.
- ② 'L-1' OR 'BT-1' JOINT IF PAVEMENT THICKNESS IS LESS THAN 8"; 'L-2' OR 'KT-2' JOINT IF PAVEMENT THICKNESS IS 8" OR GREATER.

G. References

Portland Cement Association. *Portland Cement Association Manual*.1992.

Jointing Urban Intersections

This section describes examples on how to joint urban intersections. The process will be illustrated through examples of different types of streets, pavement thickness, and intakes. Even though not all urban intersections will be exactly like the one used in these examples, the process described is applicable to other layouts.

During construction, it is likely that location changes will be necessary for some joints within an intersection. The primary reason is to ensure that joints pass through fixtures like manholes or drainage inlets that are embedded in the pavement. As a result, it will be desirable for the construction crew to adjust the location of some joints so they coincide with the actual location of a nearby manhole. The designer should consider placing a note on the plans to give the field engineer and contractor the latitude to make appropriate adjustments.

It is common practice for some designers to leave intersection joint layout to the field engineer and contractor. These designers often justify this practice by citing the many field adjustments that occur during construction, which they contend negates the usefulness of a jointing plan. However, it is not desirable to eliminate the jointing plan except for very simple intersections. A jointing plan and appropriate field adjustments are both necessary for more complex intersections because islands, medians, and turning lanes complicate joint layout and require some forethought before construction. The jointing plan will also enable contractors to more accurately bid the project.

Example: This example is an intersection of a multi-lane street and a two-lane side street. The intersection is curbed, includes several intakes, and the pavement thickness is 10 inches.

Step 1: Set Joints with Predetermined Locations

Because the location of longitudinal joints for both streets is normally predetermined, these joints should be set first.

Within the intersection, the street that is paved first determines which joints are longitudinal and which are transverse. Generally, the mainline street will be paved prior to the side street. Therefore, the longitudinal joints running down the side street define the locations of the first transverse joints for the mainline (see Figure 5G-3.01).

To determine an appropriate longitudinal joint to use, refer to SUDAS Specifications Figure 7010.901. The type of joint used may depend on the pavement thickness. Since the pavement thickness is greater than 8 inches in this case, either a KT-2 or an L-2 joint is appropriate.

Step 2: Locate Difficult Joints

Intake locations and the boxouts at the corner radii of the intersection are addressed next. After joints have been placed at these locations, the rest of the joints can be worked in around them.

1. **Joints at Intakes:** The location of intakes is determined before the joints are laid out, so joints have to be worked in around them. To start out with, straddle the intake with two transverse joints spaced according to the standard joint length. These joints can be repositioned later if it

helps with the placement of other joints. In the final layout, the intake should be centered between the joints, and adjacent joints should be adjusted accordingly. See the appropriate intake boxout figure in [SUDAS Specifications Section 6010](#) for boxout length requirements.

CD joints should be used on the mainline since the pavement thickness is greater than 8 inches. However, the CD joints straddling the intake do not extend all the way through the curb and gutter. The joints immediately surrounding the intake are specified on the detail plates and are shown in the example.

- 2. Joints at Boxouts:** Before the mainline is paved, small areas near the corners are boxed-out. These boxed-out areas (shaded in Figure 5G-3.01) are poured later, after the mainline has been paved. If the paver were to proceed straight through this area, instead of using boxouts, the returns of the city street would narrow to a point where they meet the mainline. Pavement less than 2 feet in width is weak and cracks readily. By using boxouts, this situation can be avoided without the expense of stopping the paver at the intersection.

Although the width of boxouts is normally the same as the roadway's gutter width, the size and shape of boxouts varies depending on where they are used. If placing joints around the boxout, remember to maintain intersecting angles greater than 70 degrees and joints at least 2 feet long. KT-2 or L-2 joints are used around the boxout. Figure 5G-3.01 illustrates joints properly placed, both around the boxouts and extending outward from them.

Step 3: Locate Remaining Joints

After the joints at intakes and boxouts are located, the remaining joints (generally transverse joints) are located in appropriate locations. The maximum spacing for CD joints is 17 feet (greater than 9 inch pavement) and the minimum spacing is typically 12 feet. Therefore, the remaining areas on the mainline that need transverse joints should have CD joints spaced within this range. Since the design year truck volume on the adjoining street is less than 200 vpd, C transverse joints are used there.

In Figure 5G-3.02, the C joints on the city street nearest the corners are skewed perpendicular to the free edge of the pavement. If this joint were carried straight through, instead of skewed, the acute angle between the joint and the free edge of the pavement would be less than 70 degrees, which is not acceptable.

After all joints are located, the layout should be checked to ensure that all joint spacings and angles are acceptable. Figure 5G-3.02 shows all of the transverse joints appropriately located.

Step 4: Label Joints

The completed jointing layout of the intersection is shown in Figure 5G-3.02. For pavements 8 inches or greater, the L-2 and KT-2 joints may be used interchangeably, at the contractor's discretion, depending on the paving sequence. Therefore, the designer may identify the longitudinal joints as either L-2 or KT-2 on the jointing layout.

It is not necessary to identify every joint on the jointing layout. A few key joints on the diagram should be identified and whenever a series of joints changes to a different type of joint, the joint at the location of the change should be identified. Also, any joint that may be a source of confusion should be identified.

Joint lengths are also shown on the jointing layout, normally rounded to the nearest foot. Similar to labeling joint types, not every length needs to be identified. However, any length that cannot be inferred from the diagram should be labeled.

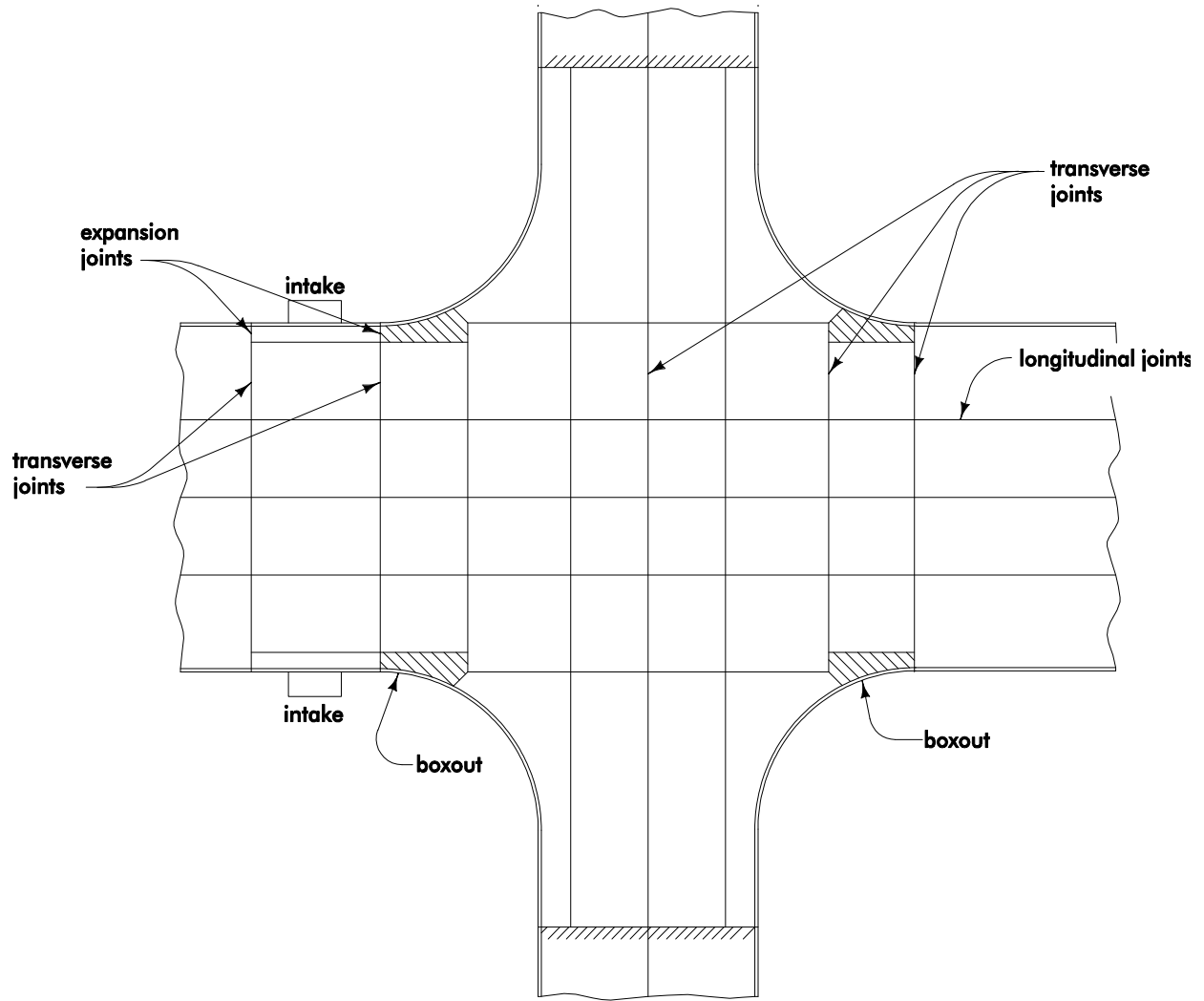
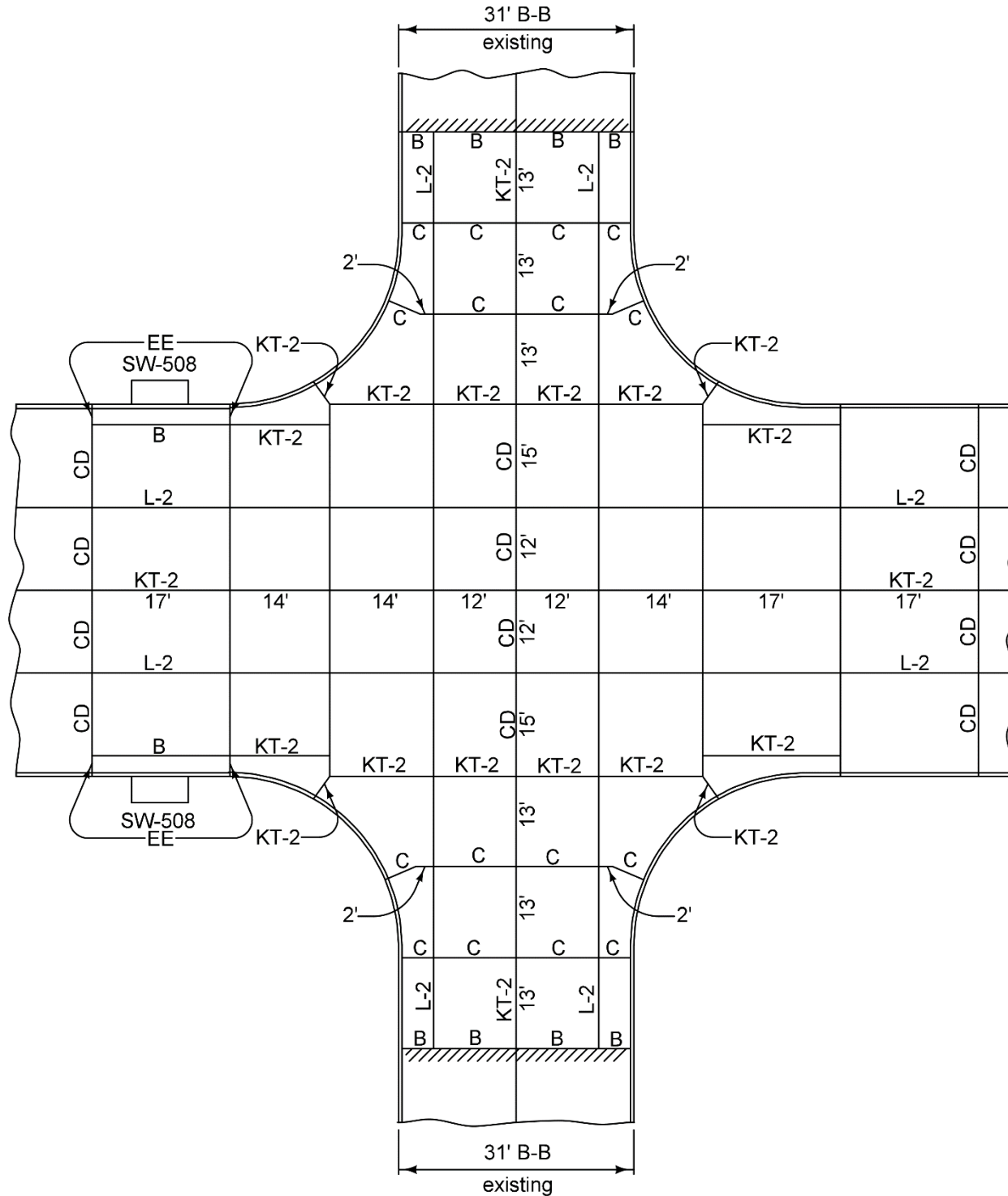
Figure 5G-3.01: Locating Predetermined and Difficult Joints

Figure 5G-3.02: Final Jointing Layout

Note:

- 1) All longitudinal joints will be either KT-2 or L-2 unless indicated otherwise.

Note: All longitudinal joints will be either KT-2 or L-2 unless otherwise indicated. SW-508 is also known as [SUDAS Specifications Figure 6010.508](#).

Figure 5G-3.10: Concentric Widening - Four Lane to Five Lane

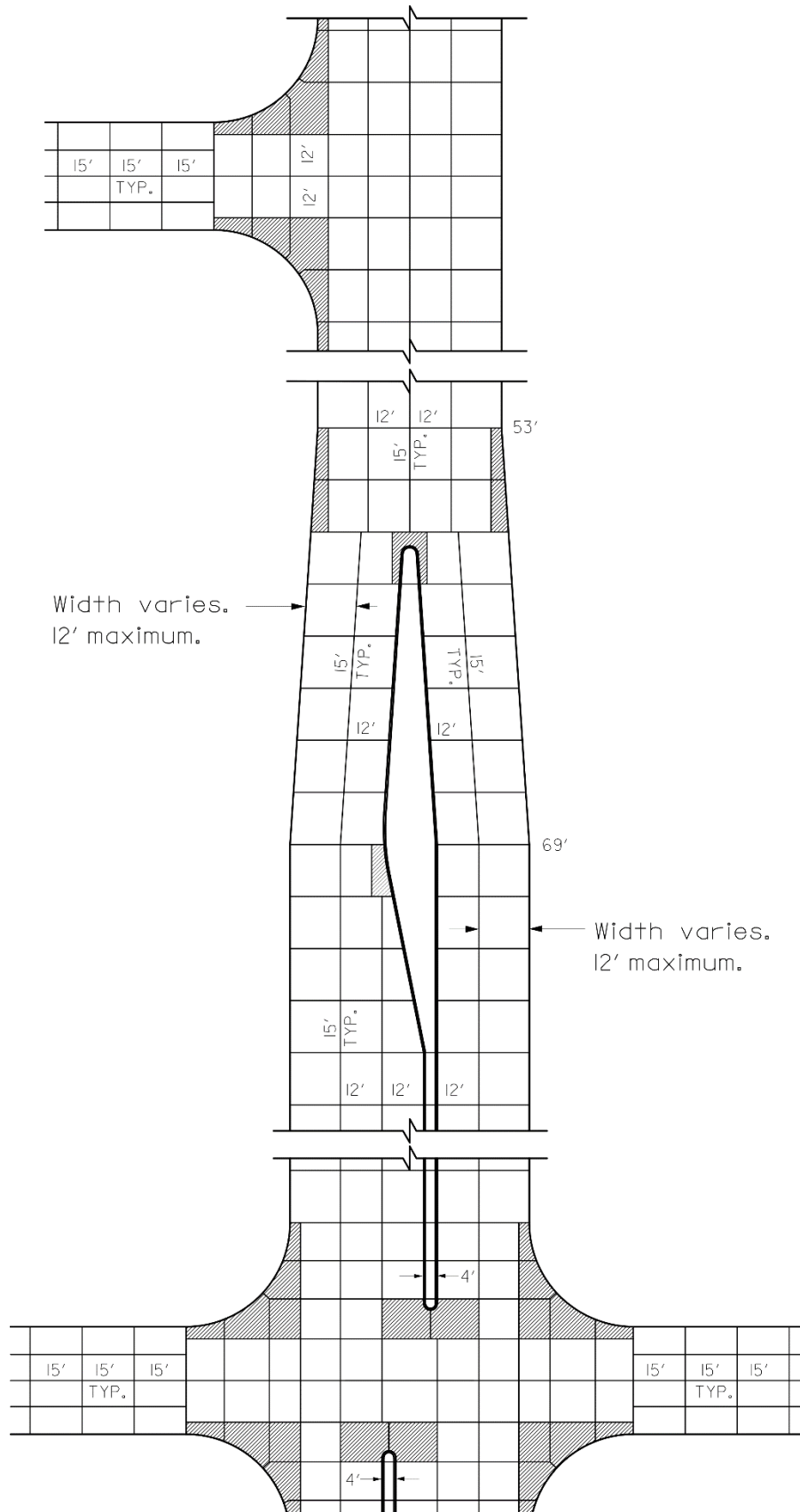
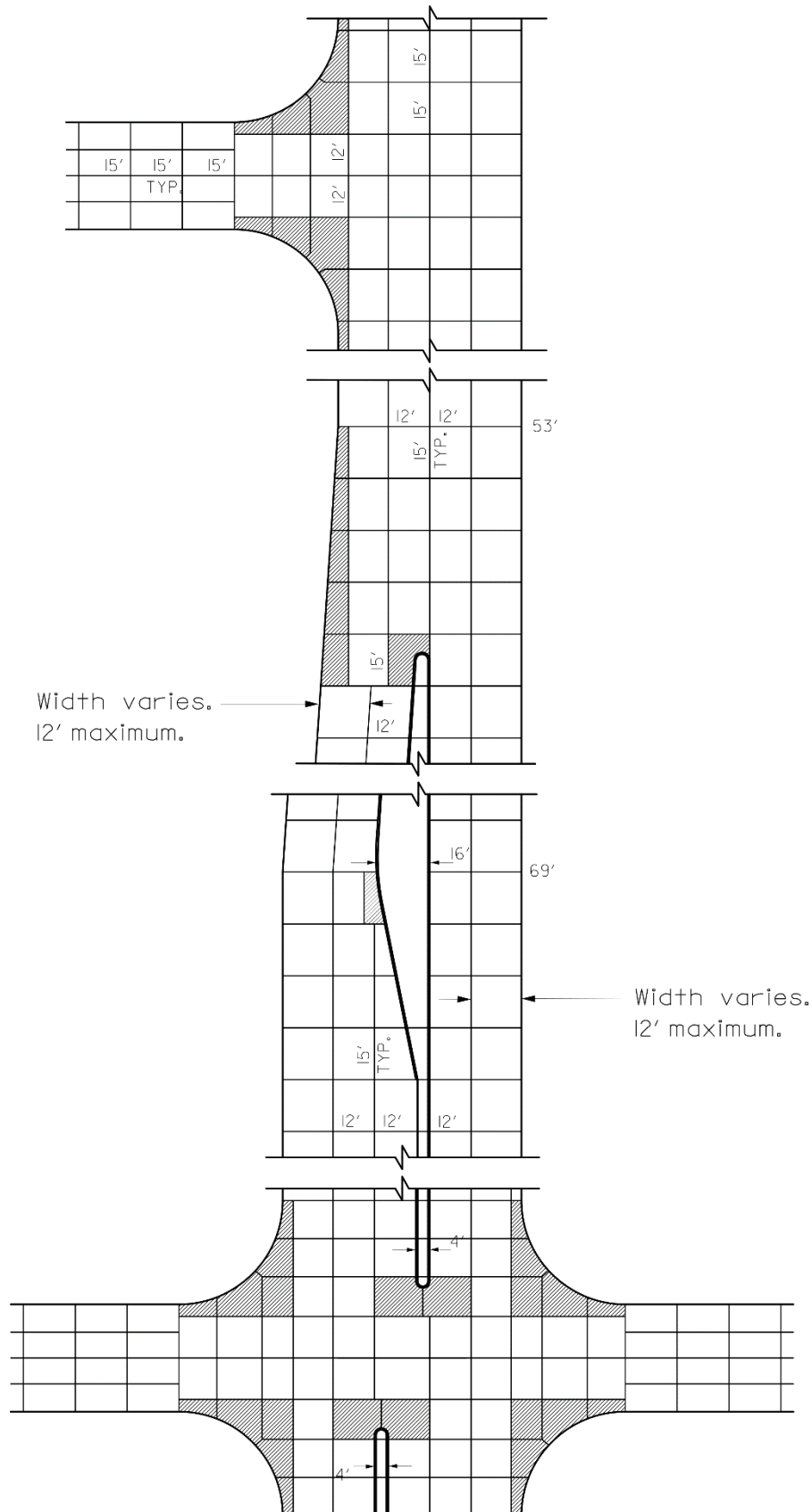


Figure 5G-3.11: Widening One Side - Four Lane to Five Lane

B. Jointing Cul-de-sacs

This section describes how to joint a cul-de-sac. The process is illustrated through an example of a street that is terminated with a cul-de-sac. Assume the pavement thickness is 7 inches.

Step 1: Locate Longitudinal Joints

The longitudinal joints running down the street should be extended into the cul-de-sac. The remaining longitudinal joints in the cul-de-sac should be placed roughly a lane width apart - somewhere in the range of 8 to 12 feet is acceptable.

A BT-1 or L-1 is an appropriate longitudinal joint, since the pavement thickness is less than 8 inches.

Step 2: Locate Transverse Joints

The next step is to place the transverse joints. The maximum spacing for transverse joints is 15 feet and the minimum spacing is 12 feet. Therefore, the joints within the cul-de-sac should be spaced within this range (see Figure 5G-3.12).

A C joint is the appropriate joint to use since the pavement thickness is less than 8 inches.

Step 3: Extend Joints Through the Free Edge of the Pavement

When extending the previously placed joints through the free edge of the pavement, the acute angle between the joint and the pavement edge (and between the joint and other joints) must be greater than or equal to 70 degrees. Also, all joints should be at least two feet long. Details A, B, and C in Figure 5G-3.13 illustrate how this can be accomplished.

- Detail A shows a transverse joint that is extended through the free edge of the pavement unaltered. These are acceptable because all angles between the transverse joint and the longitudinal joints and between the transverse joint and the free edge of the pavement are greater than 70 degrees.
- Detail B uses a dashed line to show the original position of a transverse joint whose angle, with the free edge of the pavement, is less than 70 degrees. This joint should be skewed to make it perpendicular to the free edge of the pavement, as shown by the solid line.
- Detail C illustrates a situation where skewing the joint to make it perpendicular to the free edge of the pavement would cause the angle between the joint and a longitudinal joint to be less than 70 degrees (shown by the dashed line). When this situation occurs, the joint is extended a minimum of two feet beyond the longitudinal joint, and then it is skewed to make it perpendicular to the free edge of the pavement. Both segments of the joint should be at least two feet long.

Step 4: Label Joints

The completed jointing layout for the cul-de-sac is shown in the figures that follow. The L-1 and BT-1 joints may be used interchangeably, at the contractor's discretion, depending on the paving sequence. Therefore, the designer may identify the longitudinal joints as either L-1 or BT-1 on the jointing layout.

Because the majority of the joints are either the C or the BT-1 or L-1, it is not necessary to identify every joint on the jointing layout. A note on the plan describing the transverse joints as C and longitudinal joints as L-1 or BT-1 except as noted otherwise is sufficient, provided that a few key joints on the diagram are identified. Whenever a series of joints changes to a different type of joint, the joint at the location of change is identified. Any joint that may be a source of confusion should also be labeled.

Joint lengths are also shown on the jointing layout, normally rounded to the nearest foot. Similar to labeling joint types, not every length needs to be indicated. However, any length that cannot be inferred from the diagram should be labeled.

Figure 5G-3.12: Placement of Longitudinal and Transverse Joints

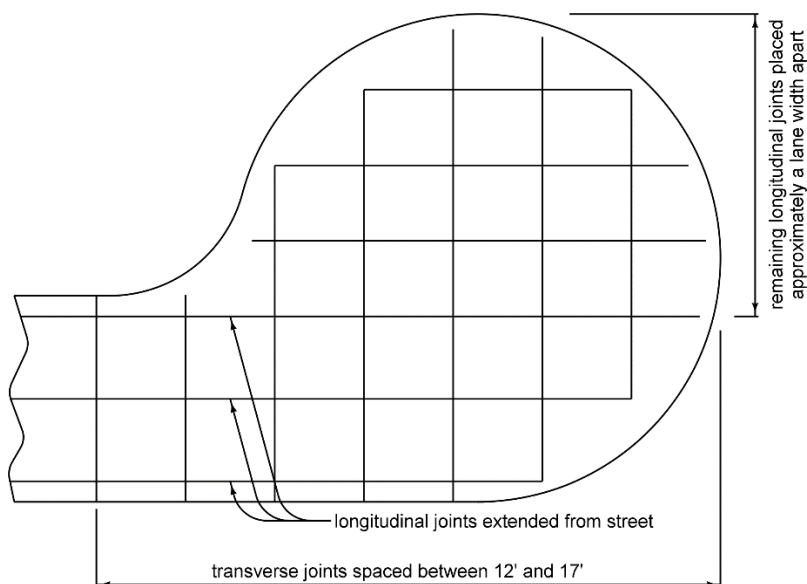
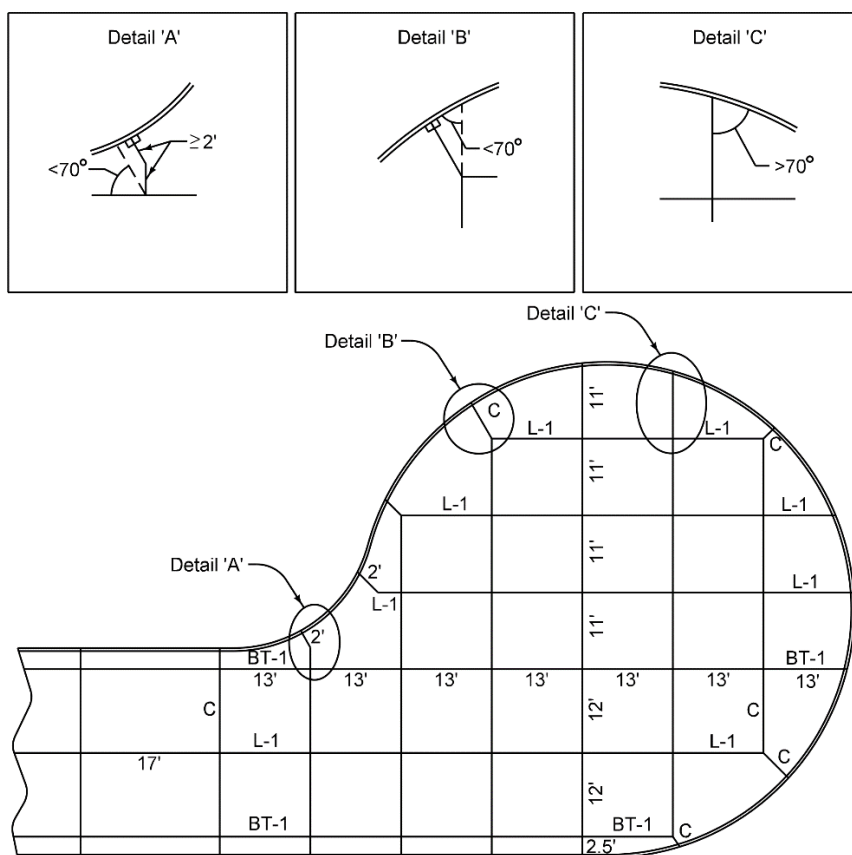


Figure 5G-3.13: Final Jointing Layout - Gutterline Jointing Examples



NOTE:

- 1) All transverse joints will be 'C' unless indicated otherwise.
- 2) All longitudinal joints will be either 'BT-1' or 'L-1' unless indicated otherwise.

Jointing Rural Intersections

This section describes how to joint rural intersections by following the guidelines outlined in [Iowa DOT Design Manual Section 7A-3](#). The first example illustrates a step-by-step process for jointing a T-intersection. The second example discusses the jointing of an intersection at a divided highway. Even though not all rural intersections will be exactly like the ones in these examples, the process described is applicable to other layouts.

A. Example 1: T-Intersection

The first example is a T-intersection of a rural two-lane highway and a paved sideroad. The intersection has returns on each side (see Figure 5G-4.01) and the pavement thickness is 10 inches. The design year truck volume on the sideroad is 250 vpd.

Step 1: Place Joints with Predetermined Locations

- 1. Longitudinal Joints:** Because the location of longitudinal joints for both the mainline and the sideroad are predetermined by the lane pavement width, these joints should be placed first. Within the intersection, the road that is paved first, or already exists, determines which joints are longitudinal and which are transverse. In this example, assume that the mainline is paved first. Since the mainline is a rural two lane highway, the longitudinal joints are spaced at the lane pavement width. The longitudinal joints running down the centerline and edges of the sideroad define the locations of the first transverse joints for the mainline (see Figure 5G-4.01).

To determine an appropriate longitudinal joint to use, refer to [SUDAS Specifications Figure 7010.101](#). Normally, the type of joint used depends on the pavement thickness. Since the pavement thickness is greater than 8 inches in this case, either a KT-2 or an L-2 joint is appropriate.

- 2. Joints at End-of-taper:** The only other joints with predetermined locations are the transverse joints that are placed where the end-of-taper sections terminate. End-of-taper sections are 2 foot wide sections placed at the ends of an intersection return (see Figure 5G-4.01). They are used to prevent the return from narrowing to a point as it intersects with the pavement. Concrete less than 2 feet in width is weak and cracks readily.

As Figure 5G-4.01 shows, normal practice is to place a transverse joint in the mainline or sideroad pavement where the end-of-taper section terminates. [Figure 5G-2.02 in Section 5G-2](#) indicates a CD joint should be used on the mainline if the pavement thickness is greater than or equal to 8 inches. On the sideroad, CD joints are also used since the design year truck volume is greater than 200 vpd (C joints could be used on the sideroad if the design year truck volume was less than 200 vpd).

Note that the transverse joints within the intersection are not skewed.

Step 2: Locating Difficult Joints

Difficult locations to joint, such as intersection returns and traffic islands, are addressed next. After joints have been placed in these locations, the rest of the joints can be worked in around them.

- 1. Intersection Returns:** The two intersection returns are shaded in Figure 5G-4.01. To help vehicles negotiate the turn, a curved longitudinal joint (normally offset 12 feet from the free edge of the pavement) is placed in the intersection return to delineate the turning path. A second curved longitudinal joint (normally offset 24 feet from the free edge of the pavement) is placed if enough area is available.
- 2. Traffic Islands:** Joint design at the traffic islands is not an exact process. It is done by trial-and-error until satisfactory results are achieved.

The first thought may be to place CD transverse joints at every radius point of the island (see Figure 5G-4.01, Detail A). However, with this layout, the 17 foot maximum and 12 foot minimum spacings for a CD joint are violated.

Detail B shows joints at the desired 17 foot interval. Although the spacing of this placement is correct, an awkward area of pavement is formed and a crack is likely to develop as shown in Detail B.

Detail C illustrates a combination of the methods used in the first two details. No rules of spacing are violated and no awkward areas of pavement exist.

The transverse joints attached to the island are extended across the sideroad and mainline pavements and across the intersection return adjacent to the island, as shown in Figure 5G-4.01. The joints used in one area must also be acceptable for any other areas into which they are extended. If the extended joints do not satisfy spacing or other criteria in any adjacent areas, they must be redesigned in the original area.

Step 3: Locating Remaining Joints

After the joints at difficult locations are located, the remaining joints (generally transverse joints) are placed in appropriate locations. As noted in Step 1, the appropriate transverse joint for both the mainline and the sideroad is the CD joint. The maximum spacing for CD joints is 17 feet and the minimum spacing is 12 feet. Therefore, the remaining areas that need transverse joints should have CD joints spaced within this range.

- 1. Mainline and Sideroad:** The location of the remaining transverse joints on the mainline and sideroad is largely determined by the location of joints already placed in Steps 1 and 2 (see Figure 5G-4.01). The remaining joints are spaced between 12 and 17 feet between these already-placed joints. However, you must also consider how these joints will be extended into the returns (described below).
- 2. Intersection Returns:** After the transverse joints have been located in the mainline and the sideroad, they are extended into the intersection returns to be used as transverse joints for those areas as well. As with other transverse joints, those in intersection returns must intersect with the free edge of the pavement. However, the acute angle between the joint and the pavement edge (and between the joint and other joints) must be greater than or equal to 70 degrees. Details A, B, C, and D in Figure 5G-4.02 illustrate how to intersect joints with the free edge of the pavement (and with other joints) under various conditions.

- Detail A shows a transverse joint that intersects with the free edge of the pavement unaltered. This is acceptable because all angles between the transverse joint and the longitudinal joints and between the transverse joint and the free edge of the pavement are greater than 70 degrees.
- Detail B uses a dashed line to show the original position of a transverse joint whose angle with the free edge of the pavement is less than 70 degrees. This joint should be skewed to make it perpendicular to the free edge of the pavement, as shown by the solid line.
- Detail C illustrates a situation where skewing the joint to make it perpendicular to the free edge of the pavement causes the angle between the joint and the edge of the mainline to be less than 70 degrees. When this situation occurs, the joint is extended a minimum of 2 feet beyond the edge of the mainline or sideroad, and then it is skewed to make it perpendicular to the free edge of the pavement.
- Detail D shows the curved longitudinal joints that were placed in the intersection return in Step 2. Each of these joints terminates at an intersection with a transverse joint. The intersection of these joints is required to be at least 2 feet from the edge of the mainline or sideroad. This requirement determines the appropriate transverse joint at which the longitudinal joint terminates. The dashed line in the detail indicates the position of the longitudinal joint if it is extended too far. Because the intersection with the transverse joint is less than 2 feet from the pavement edge, the longitudinal joint is terminated at the previous transverse joint.

After all joints are placed, the layout should be checked to ensure that all joint spacings and angles are acceptable. If they are not, the spacing of the mainline or sideroad joints may need to be changed, one or more joints may be added, or joints within the returns may be modified. Figure 5G-4.02 shows all of the transverse joints appropriately placed.

Step 4: Label Joints

The completed jointing layout of the T-intersection is shown in Figure 5G-4.03. As stated on [SUDAS Specifications Figure 7010.101](#), the L-2 and KT-2 joints may be used interchangeably at the contractor's discretion, depending on the paving sequence. Therefore, the designer may identify the longitudinal joints as either L-2 or KT-2 on the jointing layout. The transverse joints in the end-of-taper sections are C joints because they are only 2 feet long, which are not long enough to use a doweled transverse joint like the CD. The joints on the right side of the traffic island are also C joints.

It is not necessary to identify every joint on the jointing layout. A few key joints on the diagram should be identified and whenever a series of joints changes to a different type of joint, the joint at the location of the change should be identified. Also, any joint that may be a source of confusion should be identified.

Joint lengths are also shown on the jointing layout, normally rounded to the nearest foot. Similar to labeling joint types, not every length needs to be indicated. However, any length that cannot be inferred from the diagram should be labeled. For example, the distance the mainline or sideroad transverse joints extend into the intersection returns before being skewed perpendicular to the free edge of the pavement, should be dimensioned (see Figure 5G-4.03).

B. Example 2: Intersection at a Divided Highway

The jointing design process for a four-way intersection at a divided highway is basically the same as the T-intersection, except that there is also a paved median opening to deal with.

As with the T-intersection, start out by placing the longitudinal joints that are predetermined by the lane pavement width. After doing this, place longitudinal joints through the opening (see Figure 5G-4.04). The edges of the left-turn lanes define the location of two of these joints. The remaining longitudinal joints in the opening are spaced roughly a lane width apart - somewhere in the range of 10 to 16 feet is acceptable.

After this, the process is basically the same as the T-intersection:

- Place the transverse joints at the end-of-taper sections.
- Place the curved longitudinal joints in the return.
- Place the transverse joints around the islands. Figure 5G-4.04 illustrates the design through this point.
- Place the remaining transverse joints and extend them into the returns and into the median opening. Refer back to the T-intersection example for details on how the joints should intersect with the free edge of the pavement and with other joints.
- Label the joints.

Figure 5G-4.05 illustrates the final jointing layout.

Figure 5G-4.01: Placement of Predetermined and Difficult Joints

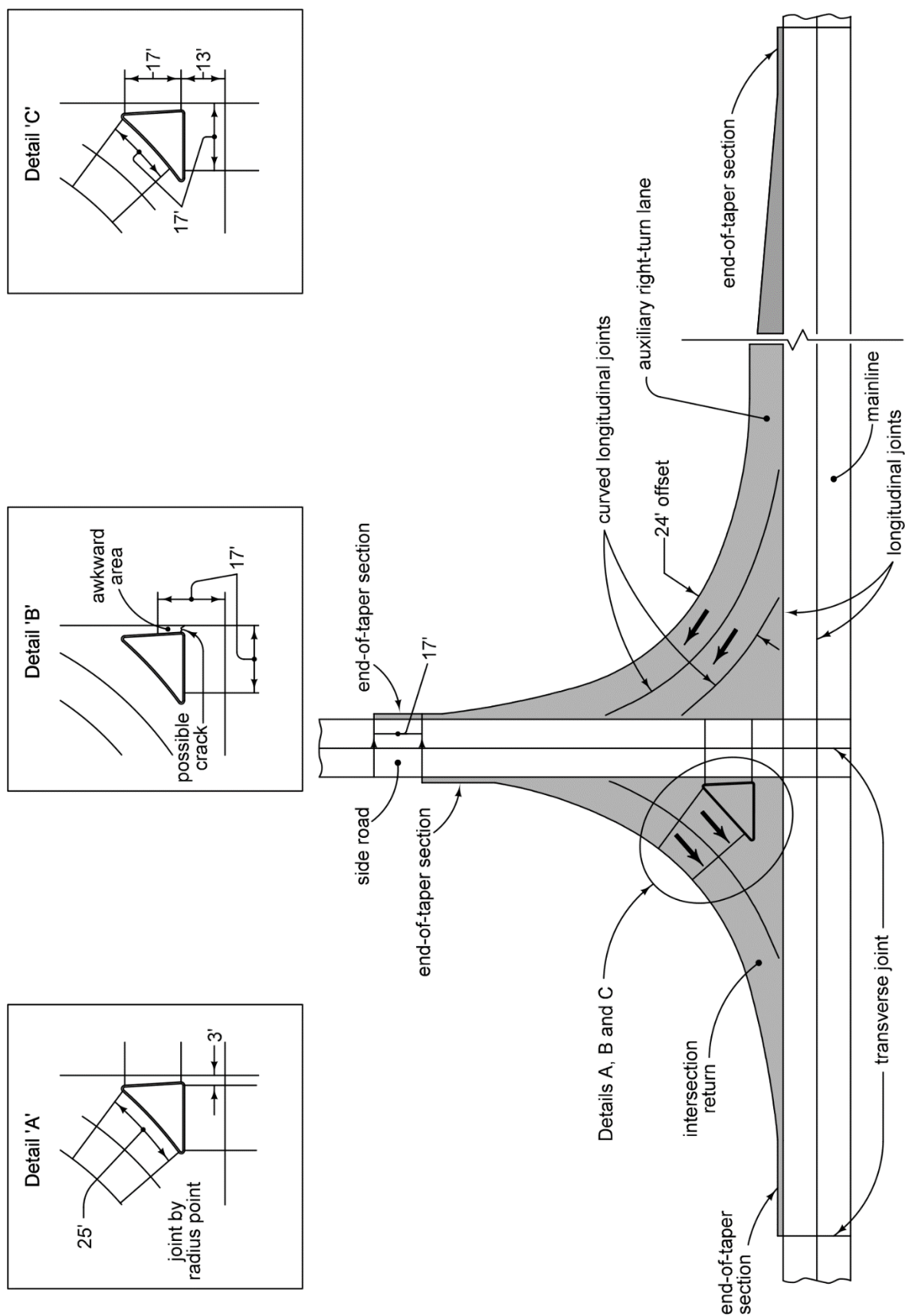


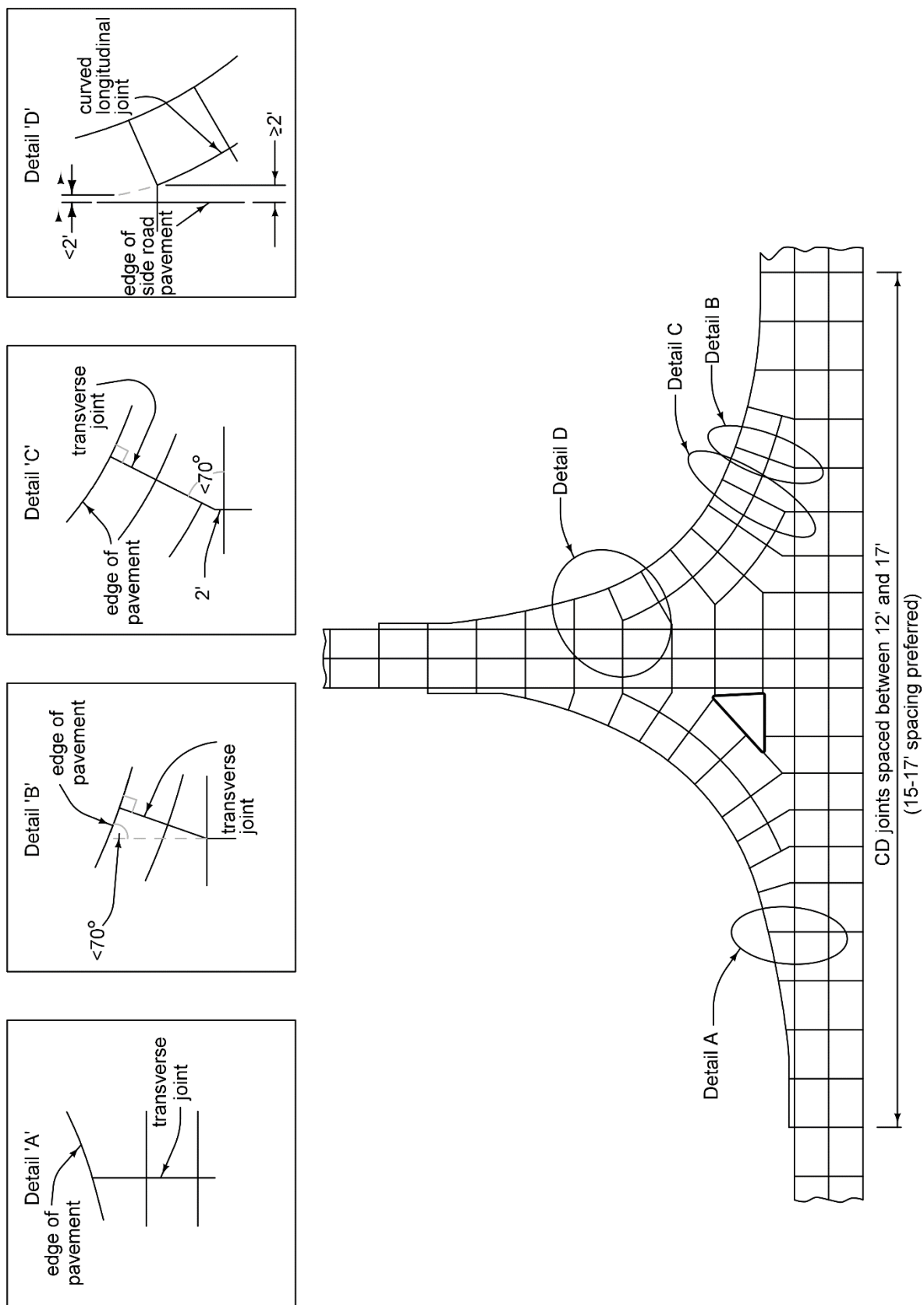
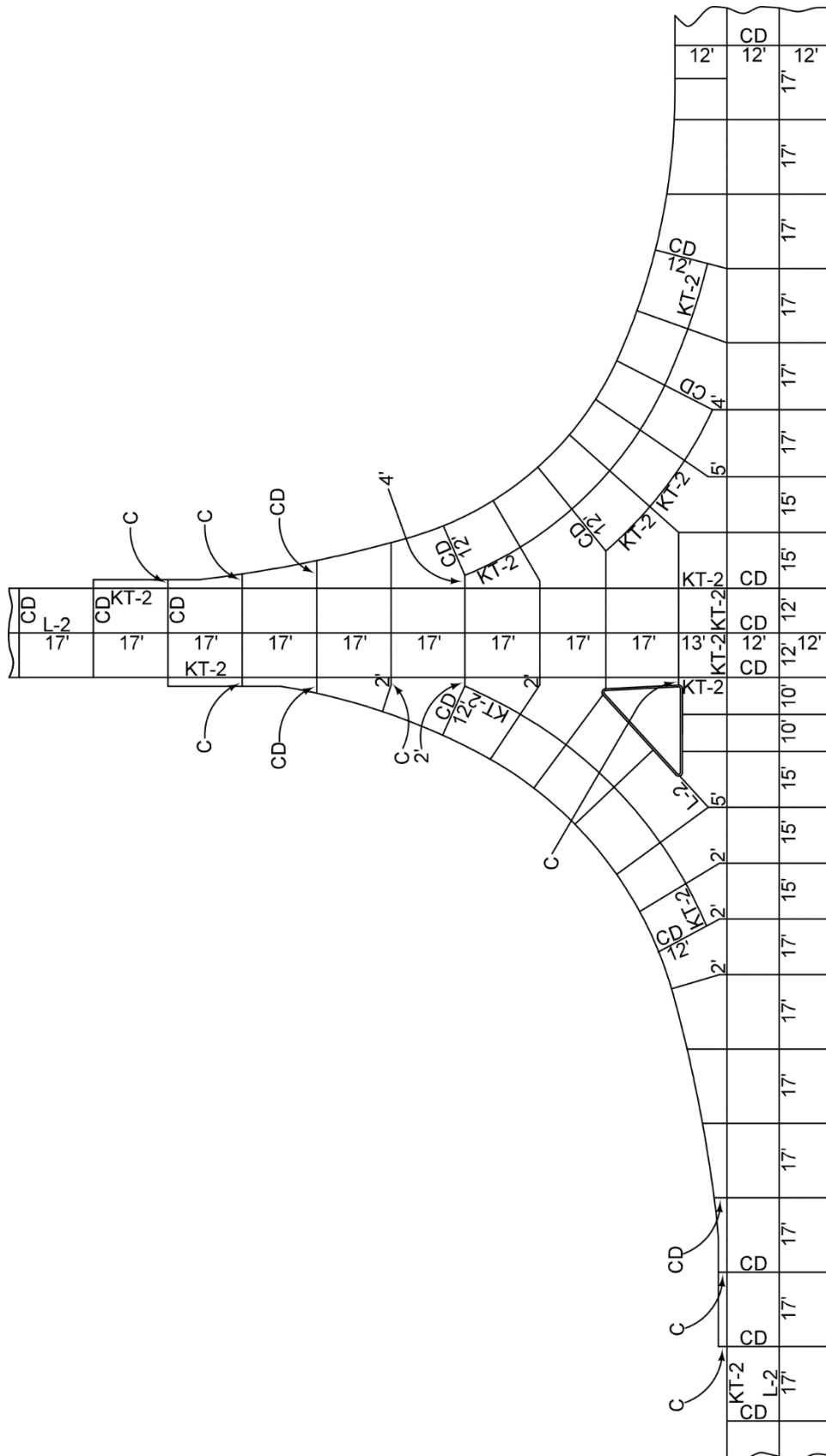
Figure 5G-4.02: Placement of Remaining Joints

Figure 5G-4.03: Final Joint Layout



NOTE: All longitudinal joints will be either KT-2 or L-2 unless indicated otherwise.

Figure 5G-4.04: Placement of Predetermined and Difficult Joints

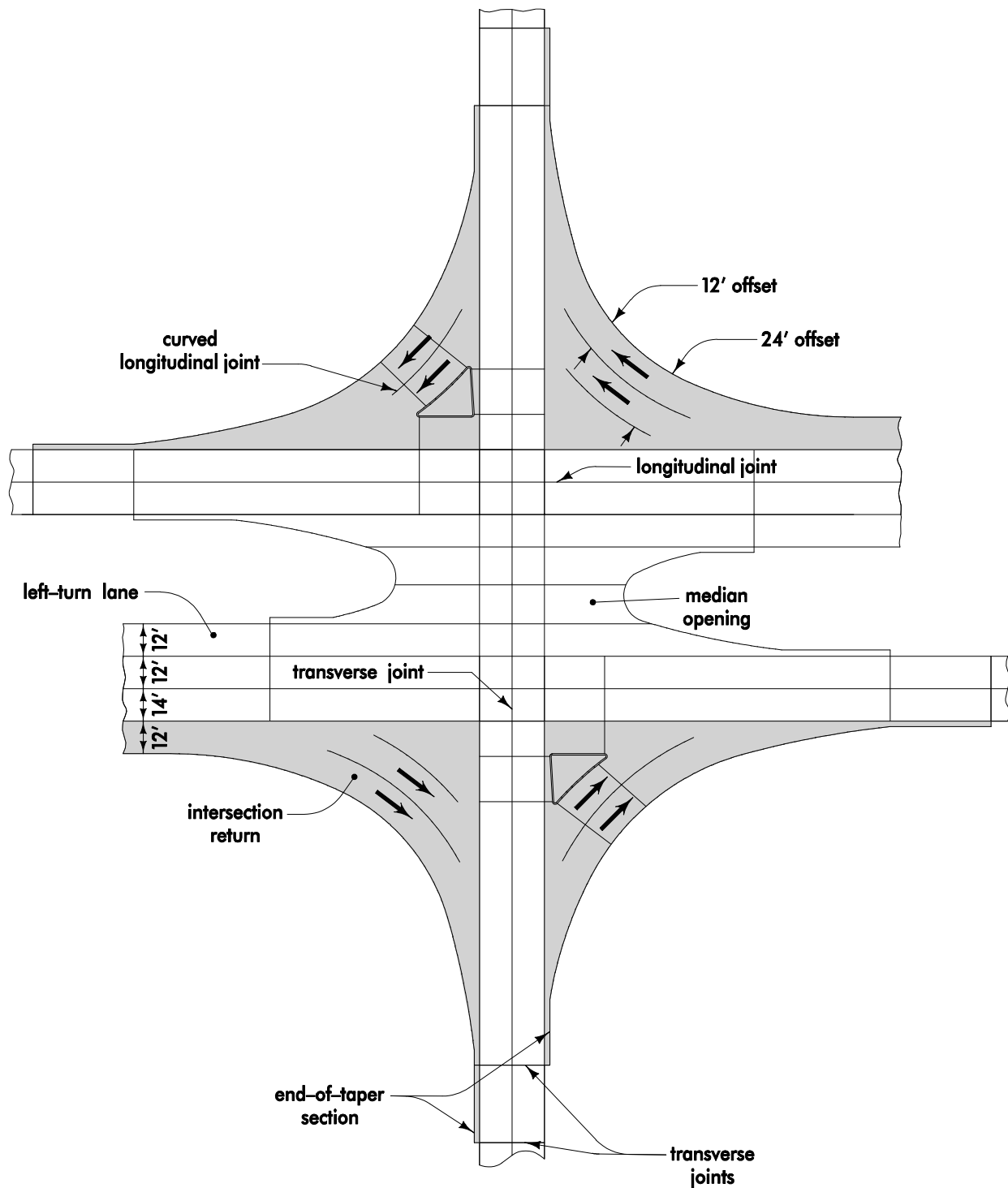
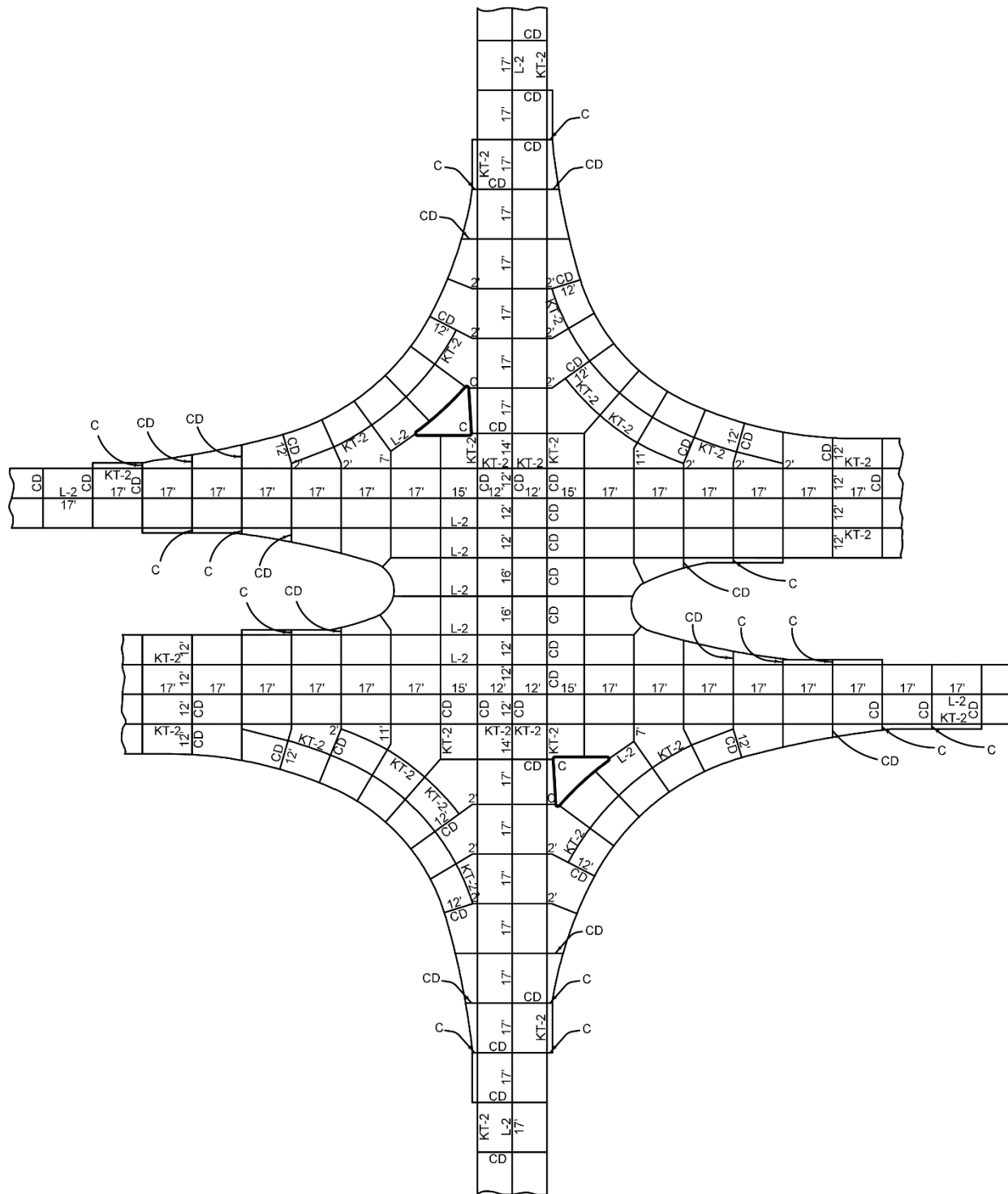


Figure 5G-4.05: Final Jointing Layout



Note: All longitudinal joints will be either KT-2 or L-2 unless indicated otherwise.

The fabric is secured to the existing pavement with pneumatic hammers at approximately 6 feet spacing or through the use of adhesives. It is critical that the fabric is free of wrinkles and no more than three edges overlap at one location. The weight of the fabric is dependent on the thickness of the overlay. Recommended weights for nonwoven geotextile fabrics for unbonded concrete overlays are as follows:

Overlays ≤ 4 inches – 13.3 oz/yd²

Overlays ≥ 5 inches – 14.7 oz/yd²

Temperature of the surface upon which the overlay is to be placed is critical to minimize fast drying out and shrinkage cracks in the PCC overlay. One method to assist in keeping the surface cooler is to specify a fabric interlayer that is white or light colored for the hot, summer months. A black or dark fabric interlayer can be used in the cooler spring and fall months.

Specifications for the nonwoven geotextile separation layer are included in [SUDAS Specifications Section 7011](#).

5. **Thickness Design:** There are several design procedures available for determining the thickness of concrete overlays. Designers should reference the *Guide to the Design of Concrete Overlays Using Existing Methodologies* (Torres et al. 2012) for recent guidance. This document provides guidance on the following design procedures, in addition to more recent software design. The following design methodologies are most common:
- Bonded Concrete Overlays on Asphalt (BCOA) Thickness Designer (ACPA 2012)
 - Bonded Concrete Overlays on Asphalt ME (Vandenbossche 2013) for overlays on asphalt
 - Guide for Design of Pavement Structures 4th Edition (AASHTO 1993)
 - StreetPave (ACPA 2012)

Table 10 from the *Guide to Concrete Overlays* provides a summary of typical design and software parameters.

6. **Construction:** Concrete overlays are constructed using conventional concrete paving equipment and procedures. Construction time for concrete overlays is significantly shorter than reconstruction due to the lack of earthwork required as well as the potential for the paving equipment to move faster due to the thinner layer. Payment for concrete overlays are typically based on square yards of concrete placement and cubic yards of concrete delivered to the site. Table 21 from the *Guide to Concrete Overlays* provides a detailed list of construction consideration items and how they relate to bonded and unbonded concrete overlays.

Joints are one of the most critical elements for overlay construction. Timing of joint sawing is critical and because of the smaller joint spacing, the sawing operation is likely to determine daily production limits. Joint spacing requires special consideration based on the type of overlay and the type of underlying pavement.

For bonded overlays over concrete pavement, the joints in the overlay need to match the joints in the underlying pavement. The joints should be cut full depth plus 1/2 inch for transverse joints and T/2 for longitudinal joints. The width of the transverse saw cut must be equal to or greater than the width of the crack at the bottom of the transverse joint in the existing pavement.

The recommended joint pattern for bonded overlays over asphalt pavement should not exceed 1 1/2 times the overlay thickness. Transverse joints should be sawed to T/3 using conventional saws and not less than 1 1/4 inches using an early entry saw. Longitudinal joints should be cut to T/3.

For unbonded overlays, it is generally a good practice to mismatch joints or cracks to maximize load transfer from the underlying pavement. Slab dimensions (in feet) should not exceed 1 1/2 times the overlay thickness for overlays less than 6 inches thick, and should not exceed 2 times the thickness with an absolute maximum of 15 feet for overlays greater than 6 inches thick. Transverse saw cuts for conventional saws and longitudinal joints should be T/3. Transverse cuts for early entry saws should be at least 1 1/4 inches deep.

C. HMA Overlays

1. HMA Overlays:

- a. **Conventional:** Conventional HMA overlays are typically 2 to 4 inches thick, placed in multiple lifts. Lift thickness varies but are typically 1 1/2 inches to 3 inches thick. The overlay is expected to improve rideability, surface friction, profile, crown, and cross slope. In addition, specific distress types of low severity cracking, raveling, roughness, low severity bleeding, and low severity block cracking are improved. HMA overlays rely on timely compaction to be successful. Typically, HMA overlays are dense-graded but may also be open-graded if a porous mix is desired.

In order for the aggregate in the HMA overlay to properly align itself during compaction and achieve required density, the nominal maximum aggregate size must be no larger than 1/3 the thickness of the overlay. For example, for a 1 1/2 inch thick asphalt lift, nominal aggregate size should be no larger than 1/2 inch. See [SUDAS Specifications Section 7020](#).

- b. **Thin Lift:** Sometimes called thinlays, thin lift overlays generally range from 3/4 inch to 1 1/2 inches thick. With the thin lift overlays, the nominal maximum aggregate size must be no larger than 1/3 the thickness of the overlay. The mix has more asphalt binder (approximately 8%) than a traditional mix in order to cover the surface area. The binder (PG 64-34E+) is formulated to be softer, which helps the mix be more durable and resistant to cracking than traditional mixes.

Because of its nature and the overlay being very thin, it is critical to have a sound underlying pavement for the thin lift overlay to perform properly. In addition to the condition of the underlying pavement, one of the biggest factors for success is cleanliness, especially if milling is involved.

In most cases, milling of the underlying pavement will help improve smoothness as well as remove defects that could reflect through the new thin lift overlay. Milling will roughen the surface, which should improve the bonding and thus the shear resistance. With or without milling, cleaning of the roadway is imperative. Any amount of dust will affect the tack coat. Due to the thin nature, tack failure will lead to debonding and slippage.

The smaller aggregate size used in thin lift overlays can present production and transport challenges. If the air temperatures are cooler and the transport distance long, the mix may lose heat quicker than standard mixes and thus workability and compaction can be compromised. Production temperatures may need to be greater for thin lift overlays because they cool more quickly. Production time for thin lift overlay mixes is generally slower than for standard mixes. Fine aggregates generally retain more moisture than coarse aggregates and thus require more drying time. In addition, the fine aggregates require more asphalt to fully coat the greater surface area they exhibit.

Driveway Design Criteria

A. General

For efficient and safe operations, access drives and minor public street intersections can be improved by the following:

- Smooth vertical geometrics
- Adequate driveway throat width and curb return radii
- Provide adequate sight distance
- Additional egress lane
- Quality driveway construction
- Define the ingress and egress sides of the access drive

Refer to NCHRP Report 659 - Guide for the Geometric Design of Driveways for supplemental information.

B. Width Measurement

1. The width of an entrance with a radius return or with a flared taper that connects to a curb and gutter roadway is measured at a point 10 feet back from the roadway curb. The curb opening may exceed the maximum allowable width of the entrance to accommodate the allowable radius or taper.
2. The width of an entrance that connects to a rural roadway (no curb and gutter) is measured across the top of the entrance at the culvert line or at the location where a culvert would normally be placed.

C. Dimensions

Figure 5L-4.01: Entrance Dimensions

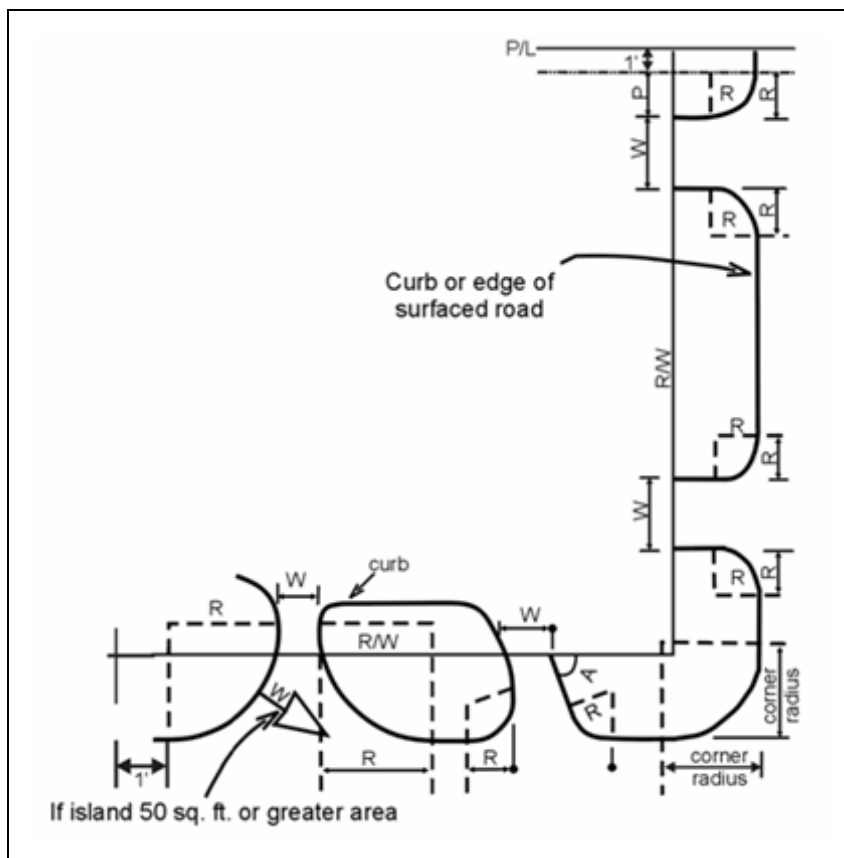


Table 5L-4.01: Driveway Dimensions¹
(all dimensions are in feet)

Dimension Reference (See Figure 5L-4.01)		Major Arterial Street				Minor Arterial Street				Collector (Major and Minor)				Local Street			
		Residential	Commercial	Industrial	Agricultural	Residential	Commercial	Industrial	Agricultural	Residential	Commercial	Industrial	Agricultural	Residential	Commercial	Industrial	Agricultural
Width																	
Minimum	W	15	24	24	20	15	24	24	20	10	24	24	20	10	24	24	20
Maximum		30	45	45	30	30	45	45	30	24	40	45	30	24	32	40	30
Right-turn Radius ²																	
Minimum	R	10	10	25	25	10	10	25	25	10	10	25	25	10	10	10	20
Maximum		25	35	50	35	25	35	50	35	25	35	50	35	15	20	30	35
Min. Acute Angle ³	A	60°	70°	70°	70°	60°	70°	70°	70°	60°	70°	70°	70°	60°	70°	70°	70°
Pref. Acute Angle		90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°	90°
Min. Pavement Thickness (inches)	T	6/8	7/9	*	6	6	7	*	6	6	7	*	6	6	7	*	6

¹ Major entrances require special design.

² 3 to 5 foot flares (F) may be used for residential and agricultural entrances.

³ Any variation from 90° will be evaluated on a case by case basis. The minimum acute angle (measured from the edge of the pavement) is 60°.

* Requires special design.

1. The width (W) shown applies to rural routes and city streets including neighborhood business, residential, and industrial streets. For joint entrances centered on property lines, the entrance width may increase 5 feet rounded to the nearest 5 foot interval but should not exceed 45 feet. In rural areas (open ditch roadways) widths for paved entrances should include an additional 4 feet for shoulders (Minimum 2 feet shoulders each side).
2. The radius (R) for agricultural uses will vary according to the following intersecting acute angles:

Table 5L-4.02: Agricultural Acute Angle and Radius

Acute Angle	Acute Radius Decrease (feet)	Obtuse Radius Increase (feet)
85° to 90°	0	0
75° to 85°	5 feet	5 feet
65° to 75°	5 feet	10 feet
60° to 65°	10 feet	15 feet

Where the entrance radius specified is greater than the distance between the back of curb and the front edge of the sidewalk the radius may be reduced to meet the available space but should be no less than 10 feet. An option to the radius under this condition is the use of flared entrances. When a flare is used, it should be 3 to 5 feet wide and should be constructed from the back of curb to the sidewalk. If no sidewalk exists, flares should be 10 feet long.

3. For individual properties, the number of entrances should be as follows:
 - a. **Single Family (SF) Residential:** Each SF residential property is limited to one access point. However, where houses are located on corner lots, have extra wide frontage, or on heavy traveled roadway more than one access point may be allowed to eliminate backing out on a heavily traveled roadway.
 - b. **Multi-family (MF) Residential:** Access is determined by information provided by the Owner/Developer in a Traffic Impact Report and by comments generated during the Jurisdiction Engineer's review and acceptance of that report.
 - c. **Commercial:** Commercial property having less than 150 feet of frontage and located mid-block is limited to one access point to the street. An exception to this rule may be where a building is constructed in the middle of a lot and parking is provided for each side of the building. A second access point may be allowed for commercial property having more than 150 feet of frontage. For commercial property located on a corner, one access to each street may be allowed, provided dimensions are adequate from the intersecting street to the proposed entrance. (See [Section 5L-3 - Access Location, Spacing, Turn Lanes, and Medians](#)).
 - d. **Industrial:** Access is determined on a case-by-case basis. The Jurisdiction will consider good traffic engineering practice and may require information to be provided by the applicant in a Traffic Impact Report. (See [Section 5L-3 - Access Location, Spacing, Turn Lanes, and Medians](#)).
 - e. **Agricultural:** Access with adequate frontage may be authorized with more than two accesses at not less than 300 feet intervals provided a minimum distance of 30 feet is maintained from the inlet and outlet of two adjacent culverts.

In all cases, the location of the access will be such that the taper or radius does not extend beyond the extension of the property line. In general, all construction must occur only on the property owner's frontage.

4. Minimum acute angle (A) is measured from the edge of pavement and is generally based on one-way operation. For two-way driveways, and in high pedestrian activity areas, the minimum angle should be 70 degrees. Entrances should be placed at 90 degrees whenever possible.
5. The entrance pavement thickness (T) is based on the following:

PCC - Class "A" or "C" - 4,000 psi

HMA - Greater than or equal to 100K ESAL (optional for rural area).

For those entrances not paved, 6 inches (min.) of Class "A" gravel should be required.

D. Sight Distance

1. Sight distance is based upon AASHTO stopping sight distance criteria. However, the height of an object is increased from 2.0 feet to 3.5 feet to acknowledge an approaching vehicle as the "object" of concern. Therefore, sight distance at an access location is measured from the driver's height of eye (3.5 feet) to the height of approaching vehicle (3.5 feet).
2. An access location should be established where desirable sight distance is available, as shown below.

Table 5L-4.03: Desirable Sight Distances

Design Speed (mph)	Intersection Sight Distance (feet)	
	<i>Left Turn from Stop</i>	<i>Right Turn from Stop and Crossing Maneuver</i>
55	610	530
50	555	480
45	500	430
40	445	385
35	390	335
30	335	290
25	280	240

Note: the sight distances shown above are for a stopped passenger car to turn onto or cross a two lane roadway with no median and grades of 3% or less. For conditions other than those stated, refer to the 2004 AASHTO "Green Book" for additional information.

Source: Based on Exhibit 9-55 and Exhibit 9-58 of the 2004 AASHTO "Green Book."

3. On a four lane divided primary highway where access is proposed at a location not to be served by a median crossover, sight distance is required only in the direction of the flow of traffic.

E. Driveway Grades

1. **Slopes vs. Speed Differential:** Driveway slope is important due to speed differential. Turning vehicles must slow appreciably to enter a driveway. The steeper the driveway, the more vehicles must slow in order to prevent "bottoming out", increasing the speed differential with through traffic and increasing the possibility of rear-end collisions.

Table 5L-4.04: Driveway Slope and Entry Speed

Driveway Slope	Typical Driveway Entry Speed
Greater than 15%	Less than 8 mph
14 to 15%	8 mph
12 to 13%	9 mph
10 to 11%	10 mph
8 to 9%	11 mph
6 to 7%	12 mph
4 to 5%	13 mph
2 to 3%	14 mph
0 to 2%	About 15 mph

Source: Oregon State University, 1998

A speed differential much above 20 miles per hour begins to present safety concerns. When the speed differential becomes very large (say, 30 to 35 miles per hour), the likelihood of traffic crashes involving fast-moving through vehicles colliding with turning vehicles increases very quickly. Rear-end collisions are very common on roads and streets when large speed differentials exist and the density of commercial driveways is high. When the speed differential is high, it is also more likely that when crashes do occur they will be more severe, causing greater property damage and a greater chance of injury or fatalities. Keeping the speed differential low is very important for safety reasons, as the table below indicates.

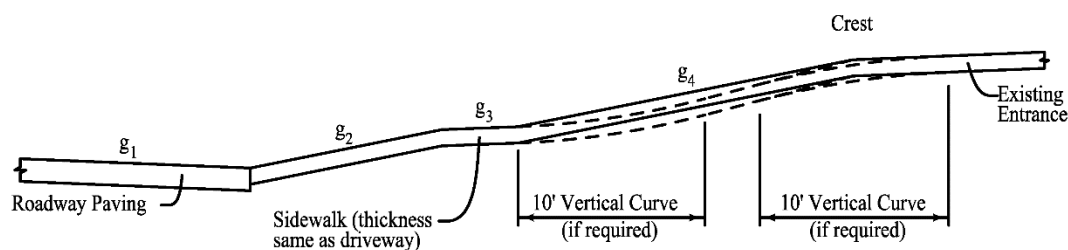
Table 5L-4.05: Speed Differential and Crashes

When the Speed Differential Between Turning and Through Traffic Is:	The Likelihood of Crashes Is:
10 mph	Low
20 mph	3 times greater than at 10 mph
30 mph	23 times greater than at 10 mph
35 mph	90 times greater than at 10 mph

Source: Oregon State University, 1998

2. **Vertical Profile:** A driveway's vertical profile should allow a smooth transition to and from the roadway. The National Highway Institute's course workbook on Access Management recommends the following maximum driveway slopes for urban/suburban streets:
 - Arterial 3 to 4%
 - Collector 5 to 6%
 - Local Less than 8% (may use 9% in special areas)

These slopes were chosen to keep the speed differential at or below 20 miles per hour. See Figure 5L-4.02.

Figure 5L-4.02: Typical Section - Commercial/Industrial and Residential Entrance

1. Algebraic Difference Between g_1 and g_2 :
 - a. Commercial/Industrial: Not to exceed 9%
 - b. Residential: Not to exceed 12%
2. Algebraic Difference Between g_2 and g_3 :
 - a. Commercial/Industrial: Not to exceed 6%
 - b. Residential: Not to exceed 8%
3. Maximum Slope of $g_3 = 2\%$ (ADA compliance)
4. Algebraic Difference g_3 to g_4 :
 - a. Commercial/Industrial: Not to exceed 5%
 - b. Residential: Not to exceed 8%
 - c. 10 foot vertical curve required for change in grade exceeding 5%
5. Maximum Slope of g_4 :
 - a. Commercial/Industrial: 7%
 - b. Residential: 10%
6. 10 foot vertical curve required for change in grade from g_4 to existing exceeding 5%
7. If the above grade restrictions require a depressed sidewalk through the driveway, a transition section should be provided between the normal sidewalk grade and the depressed section. As a general rule, use the following transition lengths:

Elevation Difference from Normal Sidewalk Grade (inches)	Transition Distance (feet)
1 to 2	8
2 to 4	12
4 to 6	16
Greater than 6	Desirable max. slope is 16:1 Absolute max. slope is 12:1

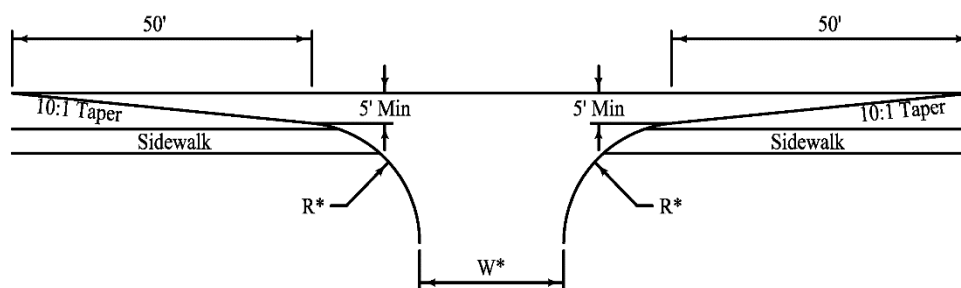
3. Non-curb and Gutter Roadways:

- a. Private drive access to local, collector, or arterial streets that have no curb and/or gutter improvements should be constructed with grades and dimensions as shown in Figure 5L-4.03. Heavily used driveways connected to existing gravel roadways may require an 8 inch deep compacted Class "A" crushed stone base material. The driveway pavement should be extended to the proposed roadway pavement width, if known, or 15.5 feet from the centerline, if not known. A culvert properly sized for the ditch flow should be installed at the established roadside ditch flowline beneath the private drive access. Culvert should be 15 inches minimum and 18 inches desirable. The culvert should be either corrugated metal or reinforced concrete pipe with minimum of 1 foot of cover over the pipe per the Jurisdiction's requirements.
- b. For Farm to Market (FM) roads, when grading on new construction, or complete reconstruction projects on paved (or to be paved) FM roads, the following will apply:
 - 1) When a culvert is not required, the following slopes will apply.
 - 10:1 slope or flatter from shoulder line to ditch bottom in clear zone area.
 - 6:1 slope or flatter from clear zone area to the right-of-way line.
 - 10:1 to 6:1 transition zone.
 - 2) When a culvert is required, the following slopes will apply.
 - 8:1 slope or flatter from shoulder line to normal placement of a culvert.
 - 6:1 slope or flatter from culvert area to the right-of-way line.
 - 8:1 to 6:1 transition zone.

For remaining open ditch roadways (paved or non-paved), the sideslopes will be 6:1 for posted speeds of 40 mph or greater, and 4:1 for posted speeds of less than 40 mph.

F. Other Criteria

1. **Utility Conflicts:** Any adjustments made to utility poles, street light standards, fire hydrants, catch basins or intakes, traffic signs and signals, or other public improvements or installations, which are necessary as the result of the curb openings or driveways, should be accomplished with no additional cost to the Jurisdiction.
2. **Access Signs:** Driveway approaches, whereby the driveway is to serve as an entrance only or as an exit only, should be appropriately signed by, and at the expense of, the property owner subject to approval of the Jurisdiction Engineer.
3. **Abandoned Driveways:** Any curb opening or driveway that has been abandoned should be restored by the property owner.
4. **Offset Radius and Driveway Tapers:** For driveways without a right turn lane on the street approach, providing an offset radius and driveway taper can help reduce speed differential between turning and through traffic, reducing the possibility of rear-end crashes. Figure 5L-4.03 shows a typical taper system that can be effectively used. The downstream taper for right turns from the driveway may be considered optional. Right-of-way restrictions may limit the use of this method.

Figure 5L-4.03: Offset Radius and Driveway Tapers

*Driveway radii and widths vary depending on entrance type, street classification, and zoning.

- 5. Sidewalks:** For driveways that intersect pedestrian circulation paths and pedestrian access routes (sidewalks and shared use paths), all ADA requirements must be met. See [Chapter 12 - Sidewalks and Bicycle Facilities](#).

G. References

Institute of Traffic Engineers. *Transportation and Land Development*. 1988.

Oregon Department of Transportation. *Driveway Profile Study - Summary of Results*. 1998.

Transportation Research Board - National Cooperative Highway Research Program (NCHRP). *NCHRP Report 659: Guide for the Geometric Design of Driveways for Supplemental Information*. National Academy Press. Washington, DC. 2010.

the uppermost layer of the soil, providing an adequate growing bed for the seed; however, the soil below this level may remain severely compacted. This compacted layer acts as an impermeable barrier, slowing or preventing the infiltration of water into the ground. Infiltration of precipitation reduces runoff, and recharges groundwater supplies. Techniques for reducing ground compaction, such as deep tillage, should be investigated.

- b. Topsoil:** In order to provide an adequate growing medium, a minimum of 8 inches of topsoil should be placed over the disturbed area prior to seeding. Deeper topsoil depths (8-12 inches or greater) are desirable as they increase the organic matter available for use by the plants, allow for deeper root penetration and increase the moisture holding ability of the soil. These benefits will increase the drought tolerance and long-term health of the vegetation. Where sufficient topsoil is not available, composted material may be incorporated at the rate of 1 inch of compost for every 3 inches of deficient topsoil. This will increase the organic matter content of the soil, and provide an adequate growing medium for vegetation.
- c. Soil pH:** The soil pH should have a range of 5.5 to 7.5. Where soils are known to be highly acidic (pH 6.0 and lower), lime should be applied at the rate recommended by the soil-testing laboratory.
- d. Soil Fertilization:** Soil fertilization is required for permanent seeding. Fertilizer rates specified in the SUDAS Specifications are recommended for most applications. Sites without sufficient topsoil or low organic matter may require higher fertilizer rates, or fertilizer with a higher nitrogen concentration.

5. Seeding Properties:

- a. General Mixtures:** The SUDAS Specifications provide a number of seed mixes that are acceptable for most general applications. These mixes and a description of their intended usage are shown in Table 7E-24.01.

Table 7E-24.01: SUDAS Seeding Mixtures

Description	Typical Uses	Allowable Seeding Dates
Type 1 - Permanent Lawn Mixture	Used for residential and commercial turf sites. Fertilized; typically mowed.	March 1 - May 31 August 10 - September 30
Type 2 - Permanent Cool - Season Mixture for Slopes and Ditches	Not typically mowed. Reaches maximum heights of 2 to 3 feet; low fertility requirements; grows in spring and fall; can go dormant in summer.	March 1 - May 31 August 10 - September 30
Type 3 - Permanent Warm-Season Slope and Ditch Mixture	Not typically mowed. Reaches heights of 5 to 6 feet; stays green throughout summer; responds well to being burned in spring; do not apply fertilizer.	March 1 - June 30
Type 4 - Temporary Erosion Control Mixture	Short-lived (6 to 8 months) mix for erosion control.	March 1 - September 30 (seeding dates vary by seasonal mix)
Wetland Seeding	Used in areas designated for wetland grass seeding.	April 1 - June 30 August 1 - August 31
Native Grass and Wildflower Seeding	Used in areas designated for native grass and wildflower seeding.	April 1 - June 30

- b. Special Mixtures:** Some sites require specifically designed or selected mixtures to address individual site characteristics. Site characteristics that require special consideration include very shady areas, detention ponds, wet areas, streambanks, severe slopes, and areas with poor soils.
- 6. Weather:** When seeding, be aware of the weather. Do not seed when heavy rainfall is predicted, during windy weather or on wet/frozen ground (hydroseeding and pneumatic seeding may be an exception to seeding on wet/frozen ground).
- 7. Matting:** A rolled erosion control product is recommended for slopes steeper than 3:1. RECPs may also be required for flatter slopes greater than 100 feet in length, to hold the seed in place and protect new vegetation from runoff until it becomes established. [Refer to Section 7E-5 - Temporary Rolled Erosion Control Products.](#)
- 8. Mulching:** Mulching is recommended for most permanent seeding applications. Mulch aids in stabilizing the surface until vegetation is established. Mulch also helps retain soil moisture and maintains temperature conditions favorable to germination. Refer to [Section 7E-17 - Erosion Control Mulching.](#)
- 9. Moisture:** If normal rainfall is insufficient to ensure vegetation establishment, mulching, matting, or controlled watering should be completed to keep seeded areas adequately moist.

C. Application

In order to achieve a dense, healthy stand of vegetation that will provide long-term surface stabilization, seed mixtures and fertilizer should be applied at the rates specified in the SUDAS Specifications.

D. Maintenance

Once the area is seeded, it should not be disturbed and should be protected from traffic. Newly seeded areas should be inspected weekly as part of the overall erosion control inspection, to ensure that grass is growing satisfactorily. Areas that have bare spots, or where erosion has occurred should be re-seeded.

E. Time of Year

The seed mixtures within the SUDAS Specifications should be placed within the dates specified, or as weather conditions allow and if approved by the Jurisdictional Engineer.

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General Information

A. General

Darkness brings increased hazards to users of urban streets because it reduces the distance they can see. The nighttime fatal accident rate on unlighted roadways is about three times the daytime rate, based on proportional vehicular miles of travel. This ratio can be reduced when proper fixed street lighting systems are installed.

Good visibility under night conditions is one of the fundamental requirements enabling motorists to move on roadways in a safe and coordinated manner during the nighttime hours. Properly designed and maintained street lighting will produce quick, accurate, and comfortable visibility at night, which will safeguard, facilitate, and encourage both vehicular and pedestrian traffic. Other objectives of street lighting include:

- Improvement of traffic flow at night by providing light, beyond that provided by vehicle lights, which aids drivers in orienting themselves, delineating roadway geometries and obstructions, and determining relationship to other motorists.
- Aid in police protection and enhanced sense of personal security.
- Promotion of business commerce and the use of public facilities during the nighttime hours.

Street lighting design is concerned with the selection and location of lighting equipment to provide improved visibility and increased safety while making the most efficient use of energy with minimum expenditure. This chapter focuses on the street lighting design approach of urban local, collector, and arterial streets. This chapter does not include guidelines for rural or freeway roadway types.

This chapter makes use of state-of-the-art lighting science and internationally and nationally recommended street lighting design practices to facilitate the quality and energy efficient design of street lighting on Iowa's urban roadways. This design guidance relies on roadway lighting guidelines issued by the Illuminating Engineering Society (IES). IES is considered the nation's technical authority on illumination. The independent, member-based professional organization synthesizes research, investigations, and discussions to develop lighting design recommendations intended to promote good lighting practice. Many of the items in this chapter are references from ANSI IES RP-8-14, *Roadway Lighting*, (RP-8) publication.

B. Iowa Code

Although there are many options for the type of luminaire to be used for street lighting projects, Iowa Code states all new or replaced luminaires shall be replaced with high pressure sodium (HPS) lighting or lighting with equivalent or better energy efficiency. Following are excerpts from the current Iowa Code that pertain to publicly owned exterior lighting. Many of the lighting terms used in the following cited Iowa Code sections will be defined in the definition list and detailed further in this chapter.

1. **Facilities Owned By Cities:** Iowa Code Section 364.23 below pertains to facilities owned by cities. It is understood the reference to "era or period lighting" is in relation to architectural or ornamental lighting of historical significance, often found in downtown locations.

“364.23 Energy-efficient Lighting Required: All city-owned exterior flood lighting, including but not limited to street and security lighting but not including era or period lighting which has a minimum efficiency rating of fifty-eight lumens per watt and not including stadium or ball park lighting, shall be replaced, when worn-out, exclusively with high pressure sodium lighting or lighting with equivalent or better energy efficiency as approved in rules adopted by the utilities board within the utilities division of the department of commerce. In lieu of the requirements established for replacement lighting under this section, stadium or ball park lighting shall be replaced, when worn-out, with the most energy-efficient lighting available at the time of replacement which may include metal halide, high-pressure sodium, or other light sources which may be developed.”

2. **Facilities Owned By Public Utilities:** Iowa Code Section 476.62 below pertains to facilities owned by public utilities.

“476.62 Energy-efficient Lighting Required: All public utility-owned exterior flood lighting, including but not limited to street and security lighting, shall be replaced when worn-out exclusively with high pressure sodium lighting or lighting with equivalent or better energy efficiency as approved in rules adopted by the board.”

3. **Utilities Board Rules:** Iowa Administrative Code (IAC) 199-35.15 (476) contains the rules adopted by the Utilities Board within the Utilities Division of the Department of Commerce that are referenced in the two Iowa Code sections stated above and pertain to exterior lighting energy efficiency. It is understood one of the five conditions of IAC 199-35.14(476) must be met in order to use a light source other than high-pressure sodium for exterior lighting applications.

“199-35.15(476) - Exterior Flood Lighting

35.15(1) - Newly Installed Lighting: All newly installed public utility-owned exterior flood lighting shall be high-pressure sodium lighting or lighting with equivalent or better energy efficiency.

35.15(2) - In-service Lighting Replacement Schedule: In-service lighting shall be replaced with high-pressure sodium lighting or lighting with equivalent or better energy efficiency when worn out due to ballast or fixture failure for any other reason, such as vandalism or storm damage. A utility shall file with the board as part of its annual report required in 199-Chapter 23 a report stating progress to date in converting to high-pressure sodium lighting or lighting with equivalent or higher energy efficiency.

35.15(3) - Efficiency Standards: Lighting other than high-pressure sodium has equivalent or better energy efficiency if one or more of the following can be established:

- a. For lamps less than 120 watts, the lumens-per-watt lamp rating is greater than 77.1, or
- b. For lamps between 120 and 500 watts, the lumens-per-watt lamp rating is greater than 96, or
- c. For lamps greater than 500 watts, the lumens-per-watt lamp rating is greater than 126, or
- d. The new lighting uses no more energy per installation than comparable, suitably sized high-pressure sodium lighting, or
- e. The new lighting consists of solid-state lighting (SSL) luminaries that have an efficacy rating equal to or greater than 66 lumens per watt according to a Department of Energy (DOE) Lighting Facts label, testing under the DOE Commercially Available LED Product Evaluation and Reporting Program (CALiPER), or any other test that follows Illuminating Engineering Society of North America LM-79-08 test procedures.”

Prior to the fall of 2010, the language in IAC 199-35.15(3) was different and used strictly the bare lamp efficacy rating of HPS lamps as the basis of comparison to qualify other lighting source types as

energy efficient. Because of the way light emitting diode (LED) lighting is constructed and produces light, the IAC excluded the use of LED lighting even though it could be demonstrated that in many street lighting applications, current LED lighting was more energy efficient. Therefore, the IAC was revised in the fall of 2010 to the language shown above. The IAC still sets HPS lighting as the energy efficient standard; however, other lighting source types can be used if they pass one of the five stated conditions. The first three conditions (a, b, and c) are a modification from the IAC prior to 2010 and generally apply to high intensity discharge (HID) or other single-lamp type luminaires.

Condition 'd' is intended to apply to lighting replacement or retrofit applications. Again, the IAC uses HPS as the comparison standard. Bear in mind the condition says "suitably sized" HPS lighting. For a defined project area, this requires the designer to compare the energy consumption of the proposed lighting system type (other than HPS) to the energy consumption of HPS lighting if it is properly applied meeting the same illumination criteria. The designer should be forewarned to not necessarily use the existing lighting system, particularly if it is HPS, as the basis of energy consumption for the replacement project because the project area may be over lit by the existing lighting. It is generally understood that the illumination criteria published in RP-8 for roadway lighting is to be used in the comparison process.

Condition 'e' is intended to apply strictly to LED lighting when installed in new lighting project applications. This requires the luminaires to have a luminaire efficacy rating of at least 66 lumens per watt as established by a proper industry testing procedure.

C. Industry Outlook

At this time, LED lighting technology has replaced HPS as the predominant type of light source used for street lighting. LEDs have surpassed HPS in energy efficiency and total fixture efficacy, exceeding those outlined in the Iowa Code, for most typical uses. At this time of this revision, LED technology may not exceed the requirements for the 500 watt fixtures except from limited manufacturers.

LED technology continually evolves. From the previous edition of the SUDAS Street Lighting guide (2013), LEDs have evolved in light output from around 60 lumens per watt to 150 lumens per watt (2019). LED technology is the exterior lighting of today, being used from decorative housing/building landscaping to parking lot/street lighting to major sports stadiums. This is due to the previously stated energy efficiency and color recognition.

As will be discussed in [Section 11C-1](#), there are two basic concepts of lighting design, the illumination concept and the luminance concept. The current edition of RP-8 discusses and supports both design concepts, depending on site criteria. For straight road segments, RP-8-14 recommends utilizing the luminance method. However, for curved roadways, intersections, and walkways, illumination method is recommended. Since the majority of local ordinances are based on the illumination method, both methods will be discussed in this chapter.

D. Definitions

Average Maintained Illuminance: The average level of horizontal illuminance on the roadway pavement when the output of the lamp and luminaire is diminished by the maintenance factors; expressed in average footcandles for the pavement area.

Ballast: A device used with an electric-discharge lamp to obtain the necessary circuit conditions (voltage, current, and wave form) for starting and operating the lamp.

Bracket or Mast Arm: An attachment to a lighting standard or other structure used for the support of a luminaire.

Candela (cd): The unit of luminous intensity. Formerly the term "candle" was used. Refer to Figure 11A-1.01.

Coefficient of Utilization Curve (CU): This curve shows the percentage of the total light output that will fall on the roadway. Mounting height and horizontal dimensions transverse to the roadway relative to the luminaire position must be known to apply the curve. Refer to [Figure 11C-1.02](#).

Efficacy (Luminous Efficacy): The quotient of the total luminous flux delivered from a light source divided by the total power input to the light source. It is expressed in lumens per watt (l/w).

Footcandle (fc): One footcandle is the illumination incident on a surface one square foot in area on which there is uniformly distributed a luminous flux of one lumen. Footcandle is the English unit for illumination. The metric or SI unit is lux. One footcandle equals 10.76 lux. Refer to Figure 11A-1.01.

Foot-lambert (fl): The unit of photometric brightness (luminance). It is equal to $1/\pi$ candela per square foot. One foot-lambert equals 3.426 candelas per square meter.

High Intensity Discharge (HID): A term applied to a category of electric lamps that produce light by means of an electric arc sustained between tungsten electrodes housed inside a translucent or transparent fused quartz or fused alumina arc tube filled with gas and metal salts. The gas facilitates the arc's initial strike. Once the arc is started, it heats and evaporates the metal salts forming a plasma, which greatly increases the intensity of light produced by the arc and reduces its power consumption. High intensity discharge lamps are a type of arc lamp.

Horizontal Footcandle: One lumen distributed uniformly over a horizontal surface one square foot in area. Thus, horizontal footcandle is a measure of illumination from light that strikes a horizontal surface such as the pavement.

Illuminance: The density of the luminous flux incident on a surface. It is the quotient of luminous flux by area of the surface when the latter is uniformly illuminated (measured in footcandles). Refer to Figure 11A-1.01

Initial Lamp Lumens: Manufacturer's published initial bare lamp lumen output of a new lamp.

Isocandela Diagram: A series of lines plotted in appropriate coordinates to show directions in space at which the candlepower is the same.

Isofootcandle Diagram: This diagram is available from the manufacturer of the light source and shows the horizontal footcandles on the pavement surface at various points away from the source. Mounting height must be known to properly use the diagram. Refer to [Figure 11C-1.02](#).

Lamp Lumen Depreciation Curve (LLD): This curve gives information on the relationship between length of service and light output. All lamps deteriorate with time, and total light output becomes less. Refer to [Figure 11B-1.01](#).

Lamp: A generic term for a man-made source of light that is produced either by incandescence or luminescence.

Lighting Standard: The pole with or without bracket or mast arm used to support one or more luminaires.

Lighting Unit: The assembly of pole or standard with bracket and luminaire.

Longitudinal Roadway Lines (LRL): A set of horizontal lines running parallel to the curb line or edge of pavement that establish a coordinate system for roadway lighting analysis. Refer to [Figure 11B-1.03](#).

Lumen (lm): A unit of measure of luminous flux or flow of light from a light source. One lumen is the luminous flux emitted within a unit solid angle (one steradian) by a point source having a uniform luminous intensity of one candela. Refer to Figure 11A-1.01.

Luminaire: A complete lighting assembly consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

Luminaire Dirt Depreciation Curves (LDD): These curves give information on the relationship of light output depreciation due to accumulated dirt on the luminaire and lamp optical surfaces. An estimate of the dirt level present in the environment is needed to apply the curves. Refer to [Figure 11B-1.02](#).

Luminance (L): The luminous intensity of a surface in a given direction per unit of projected area of the surface as viewed from that direction (measured in foot-lamberts).

Lux (lx): The International System (SI) unit of illumination. One lux is the illumination incident on a surface one square meter in area on which there is uniformly distributed a luminous flux of one lumen. One lux equals .0929 footcandle.

Maintenance Factor (MF): A depreciation factor that is the product of the Lamp Lumen Depreciation Factor (LLD) and the Luminaire Dirt Depreciation Factor (LDD). This factor is applied to the initial average footcandles to account for dirt accumulation and lamp depreciation at some predetermined point after installation.

Mean Lamp Lumens: Average quantity of light output (lumens) over the life of the lamp. High pressure sodium, LED, and incandescent lamps are measured for mean lumens at 50% of lamp life. Fluorescent and metal halide lamps are measured for mean lumens at 40% of rated lamp life.

Mounting Height (MH): The vertical distance between the roadway surface and the center of the apparent light source of the luminaire (fixture elevation relative to the roadway surface).

Nadir: A point directly below an observer or object. In lighting, the point vertically below a luminaire's lamp source center with the luminaire mounted in standard position with zero tilt or roll. Refer to [Figure 11B-1.05](#).

Overhang: The transverse horizontal dimension of the position of the luminaire relative to the edge of the roadway or back of curb of the street. Positive overhang is in the direction toward the street center. Negative overhang is in the direction away from the street center.

Roadway Width: The curb to curb width for urban roadway sections and edge to edge pavement width for rural roadway sections.

Steradian: The unit measure of solid angle defined as the conical or pyramid shape that subtends an area on a sphere surface equal to the radius squared. Refer to Figure 11A-1.01.

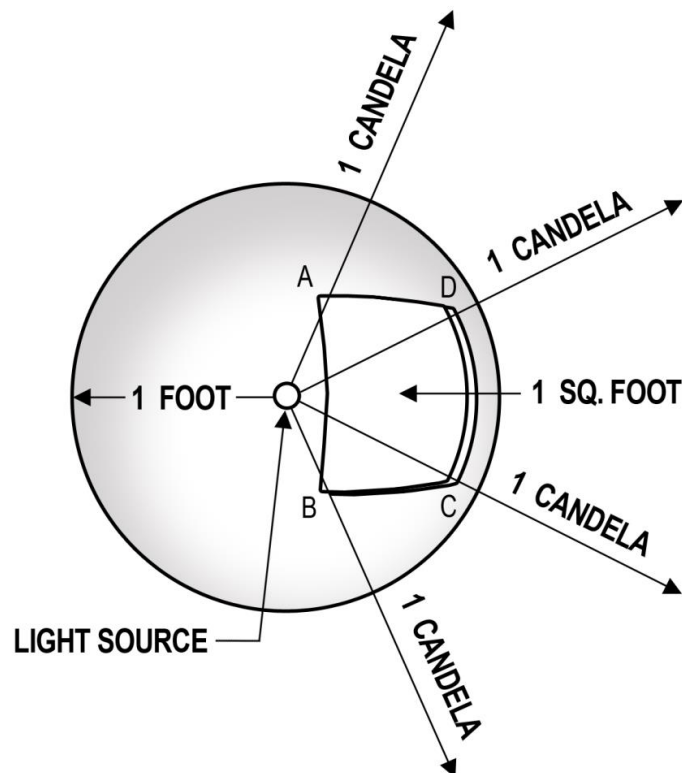
Spacing: The distance between successive lighting units measured longitudinally along the centerline of the roadway.

Transverse Roadway Lines (TRL): A set of horizontal lines running perpendicular to the curb line or edge of pavement that establish a coordinate system for roadway lighting analysis. Refer to [Figure 11B-1.03](#).

Vertical Footcandle: One lumen distributed uniformly over a vertical surface one square foot in area. Thus, vertical footcandle is a measure of illumination from light that strikes a vertical surface such as curbs, piers, retaining walls, or other objects with a vertical surface.

Watt: The measure of power or the rate of flow of energy per time. One watt equals the flow of one joule of energy per second. Watts are also equivalent to volts multiplied by amps.

Figure 11A-1.01: Lighting Units Definition Diagram



Relationship between candelas, lumens, and footcandles: A uniform point source (luminous intensity or candlepower equal to one candela) is shown at the center of a sphere of unit radius whose interior surface has a reflectance of zero. The illuminance at any point on the sphere is one footcandle (one lumen per square foot) when the radius is one foot. The solid angle subtended by the area A,B,C,D is one steradian. The flux density is therefore one lumen per steradian, which corresponds to a luminous intensity of one candela as originally assumed. The sphere has a total area of 4π (or 12.57) square feet and there is a luminous flux of one lumen falling on each unit area. Thus, the source provides a total of 12.57 lumens.

Source: Adapted from ANSI / IES RP-8-00 (R2005)

E. References

Illuminating Engineering Society *Roadway Lighting*. ANSI / IES RP-8-14.

Iowa Administrative Codes, 2018.

Luminaires

A. Lighting Sources

Since the development of street lighting, there have been many electrical lighting source types used to illuminate public streets, the first being the incandescent lamp. Other lamp types developed over time were fluorescent, and high intensity discharge (HID) types such as mercury vapor, metal halide (MH), low pressure sodium, and high pressure sodium (HPS). Most recently, the solid state light emitting diode (LED) has become the choice because of its efficiency to create and apply light in street applications. Because of the enactment of the Iowa Code in 1989 mandating outdoor lighting efficiency, the Code revisions in 2010, and other application considerations, the most practical choices today are LED, HPS, and MH. For a comparison of these source types, refer to Table 11B-1.01.

Table 11B-1.01: Typical Street Lighting Performance Values

Lamp Type and Wattage	Initial Lamp Lumens	Lamp Efficacy (l/w)	Lamp and Ballast Watts	Lamp and Ballast Efficacy (l/w)	Luminaire Optical Efficiency (%)	Overall System Efficacy (l/w)	Average Life (hrs)
133W Light Emitting Diode (LED)	16,400	123	133	123	--	123	>100,000
250W High Pressure Sodium (HPS)	28,000	112	295	95	85	80.7	24,000
250W Metal Halide (MH)	21,500	86	285	75.5	85	64.2	20,000

For HPS and MH, the performance of the light source will vary with wattage size. Typically, the larger the size, the better the efficacy or lumens per watt of the lamp. This is not the case for LED luminaires. Since an LED light assembly is comprised of multiple small LED lamps each having the same efficacy and larger LED luminaires just contain more of the same individual lamps, the efficacy ratio tends to remain the same over the luminaire size range.

For comparison purposes, the table contains a 133 watt LED, a 250 watt HPS lamp, and a 250 watt MH lamp luminaire. The 133 watt LED size was chosen based on application experience. This LED luminaire puts out less total lumens than either of the other two, but because of superior optical efficiency and control, this size luminaire will produce similar street illumination results as a 250W HPS luminaire.

The efficacy ratio suffers as all of the luminaire losses are considered. For the HPS and MH cases, the initial efficacy is based on the lamp input wattage. The efficacy ratio drops when the ballast wattage is included in the calculation. The efficacy ratio drops again when the inherent lumen losses of the luminaire optics are considered. LEDs are rated differently. The initial lumen output is that measured from the entire luminaire assembly at the outset. Therefore, this value has already considered the lamp intensity and any luminaire optical losses. Only the driver wattage needs to be included to arrive at the overall system efficacy.

Another comparison is that LEDs are projected to last significantly longer than HPS or MH. The >100,000 hour life equates to over 22 years for a street light averaging 12 hours of burn time per night. At this time, LED lighting has not been in practical application for this long. Manufacturers base the rated life on projections from laboratory testing. Due to longer life, LED lighting has the potential for significant maintenance savings.

LED luminaires offer the ability to select the color emanating. Typical LED street lighting is using a white light of around 4,000 degrees Kelvin (3,500 to 4,500 degrees). LED luminaires have the option of providing a light similar to those of HPS luminaires (orange tone, around 3,000 degrees Kelvin) or more of a bluish tone (around 5,000 to 6,000 degrees Kelvin).

When replacing existing HPS luminaires with LED, Table 11B-1.02 shows approximate comparable LED luminaire lumen output to HPS wattages.

Table 11B-1.02: LED Lumen Equivalency to HPS Wattage

HPS Wattage	LED Lumen Equivalent	
	Low	High
70	2,500	3,500
100	3,500	6,000
150	6,000	9,000
250	13,000	18,000
400	23,000	28,000

B. Light System Depreciation

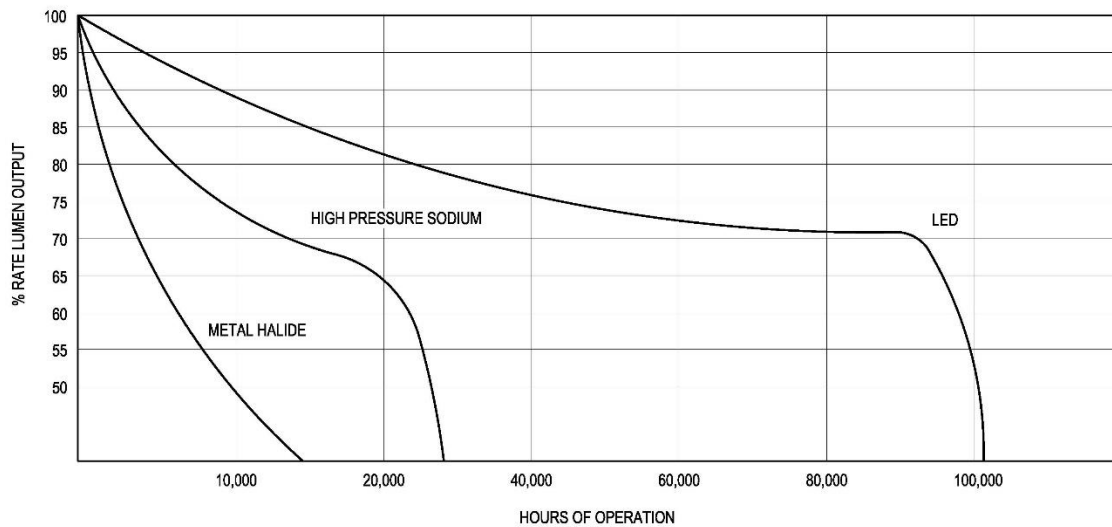
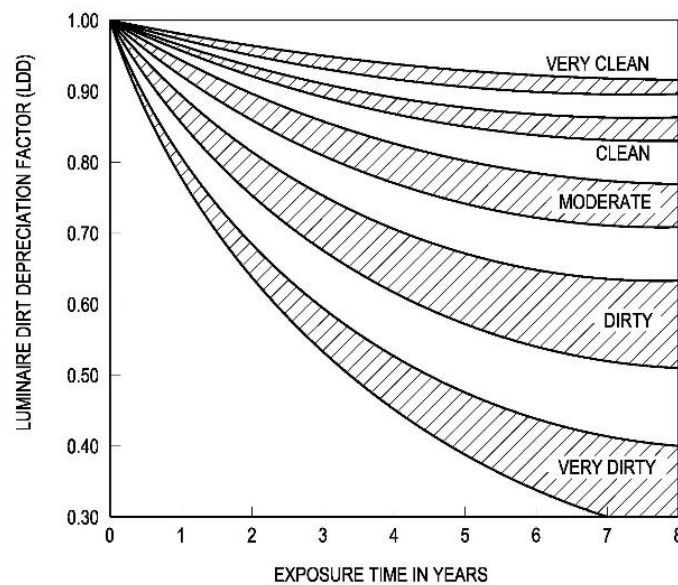
Lighting system depreciation is the loss or degradation of the light output of a luminaire over time with the same power input. The primary factors of lighting system depreciation are lamp lumen depreciation (LLD) and luminaire dirt depreciation (LDD). The light source types considered in this chapter suffer degradation of their light output over their lifetime. A typical range for LLD is from 0.9 to 0.78.

All luminaire assemblies are susceptible to dirt ingress, which absorbs/blocks/disperses light produced by the lamp and prevents it from reaching the intended destination. Some judgment is required to evaluate the luminaire enclosure for contamination protection and the environment to which the luminaire will be exposed. A typical range for LDD is 0.95 to 0.78.

The product of these two factors is referred to as the Maintenance Factor (MF). This factor multiplied by the initial light source lumen output gives the maintained lumen output value, which is the expected performance of the lighting system near the end of its rated life. The maintained lumens value is what is used in lighting design photometric calculations. Typical maintenance factors used are:

High Pressure Sodium:	0.70 to 0.80
Metal Halide:	0.70 to 0.78
LED:	0.80 to 0.85

Figures 11B-1.01 and 11B-1.02 depict lamp lumen and dirt depreciation curves.

Figure 11B-1.01: Typical Lamp Lumen Depreciation**Figure 11B-1.02: Typical Luminaire Dirt Depreciation**

Select the appropriate curve according to the type of ambient conditions as described by the following examples:

- Very Clean - No nearby smoke or dust generating activities and a low ambient contaminant level. Light traffic. Generally limited to residential or rural areas. The ambient particulate level is no more than 150 micrograms per cubic meter.
- Clean - No nearby smoke or dust generating activities. Moderate to heavy traffic. The ambient particulate level is no more than 300 micrograms per cubic meter.
- Moderate - Moderate smoke or dust generating activities nearby. The ambient particulate level is no more than 600 micrograms per cubic meter.
- Dirty - Smoke or dust plumes generated by nearby activities may occasionally envelope the luminaires.
- Very Dirty - As above but the luminaires are commonly enveloped by smoke or dust plumes.

Source: Adapted from *Roadway Lighting Handbook*

C. Luminaire Light Distribution Classifications

The Illuminating Engineering Society (IES) has developed classification categories and parameters to describe the photometric properties of luminaires. The classifications assist lighting designers in choosing the proper luminaires to accomplish the street lighting task. The categories are lateral light distribution, vertical light distribution, and cutoff rating.

- 1. Lateral Light Distribution:** The lateral light distribution classification describes where the light from a luminaire falls into the street surface in relation to the street width, or in other words, how far the light reaches or lands across the street. The classification rating depends on the lateral distance, measured in multiples of luminaire mounting height (mh), where the half-maximum candela trace lands in relation to the location of the luminaire. Refer to Figure 11B-1.03. Following are the IES lateral distribution types and their definitions:

Type I: Half-maximum candela trace falls between 1 mh on the house side and 1mh on the street side of the luminaire position.

Type II: Trace falls between 1 mh and 1.75 mh on the street side of the luminaire position.

Type III: Trace falls between 1.75 mh and 2.75 mh on the street side of the luminaire position.

Type IV: Trace falls beyond 2.75 mh on the street side of the luminaire position.

Type V: Has distribution that is circularly symmetrical around the luminaire position.

The most popular types used for public streets and roads are Types II, III, and IV. Type V distribution is more popularly used in parking or area lighting applications. Type I distribution is used when the luminaire is positioned in the center median of a narrow roadway such as a boulevard driveway.

- 2. Vertical Light Distribution:** The vertical light distribution describes where the maximum light intensity (maximum candela) falls longitudinally up and down the street measured in multiples of mounting height in relation to the location of the luminaire (refer to Figure 11B-1.03). Following are the IES vertical distribution types and their definitions:

Very Short: The maximum intensity point lands 0 to 1.0 mh each way longitudinally from the luminaire position.

Short: The maximum intensity point lands between 1.0 mh and 2.25 mh each way longitudinally from the luminaire position.

Medium: The maximum intensity point lands between 2.25 mh and 3.75 mh each way longitudinally from the luminaire position.

Long: The maximum intensity point lands between 3.75 mh and 6.0 mh each way longitudinally from the luminaire position.

Very Long: The maximum intensity point lands beyond 6.0 mh each way longitudinally from the luminaire position.

On the basis of vertical light distribution, the theoretical maximum spacing for a vertical distribution type is such that the maximum candlepower beams from adjacent luminaires are joined on the roadway surface. With this assumption, the maximum luminaire spacing for each distribution type is:

Very Short: 2.0 mounting heights

Short: 4.5 mounting heights

Medium: 7.5 mounting heights

Long: 12.0 mounting heights

Very Long: Beyond 12.0 mounting heights

From a practical standpoint, the medium distribution is predominantly used in practice, and the spacing of luminaires normally does not exceed five to six mounting heights. Short distributions are not used extensively for reasons of economy, because extremely short spacing and more lighting assemblies are required. At the other extreme, the long distributions are not used to any great extent because the high beam angle of maximum candlepower often produces excessive glare, as further described by the cutoff or backlight, uplight, and glare (BUG) rating of a luminaire.

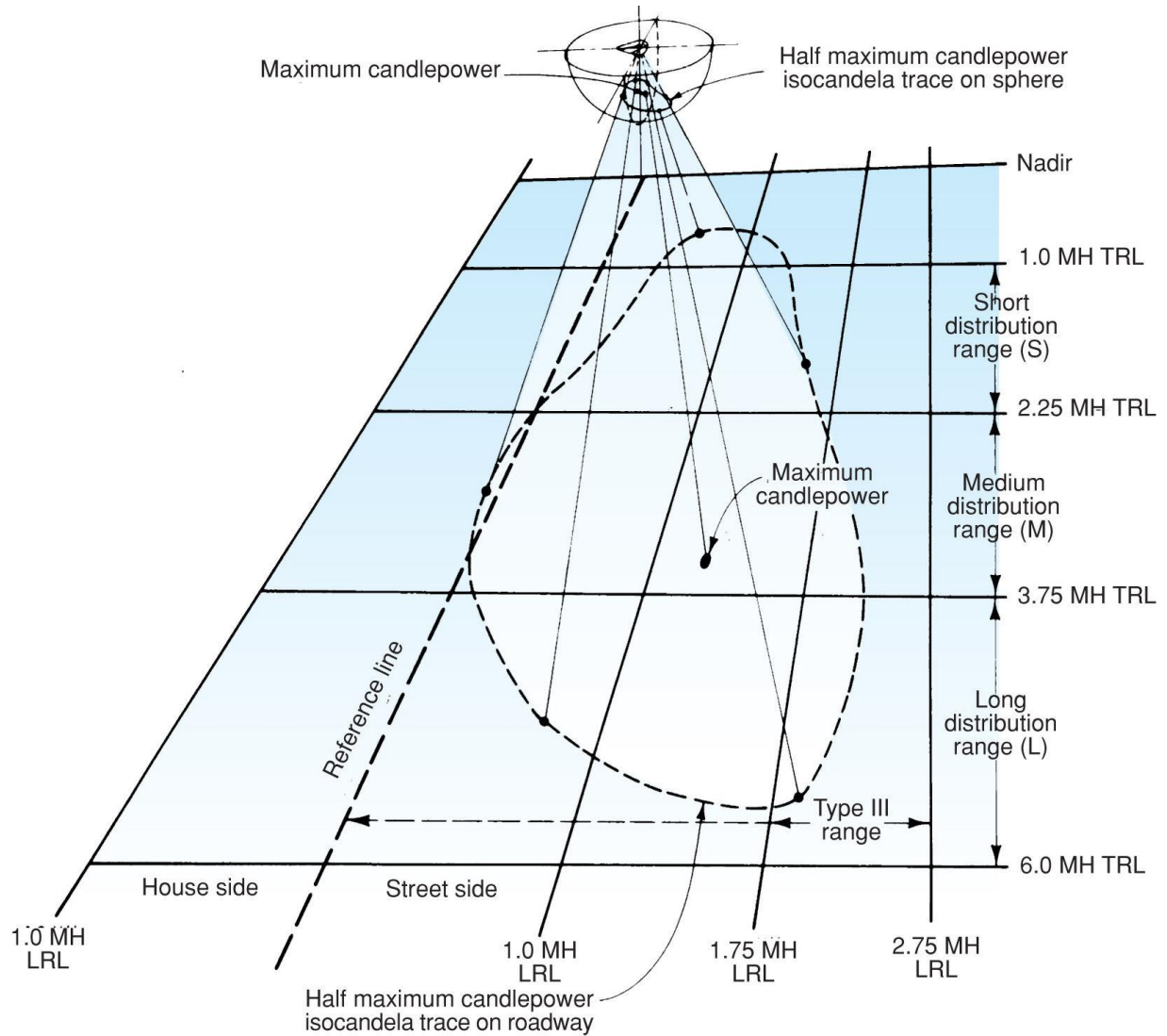
Figure 11B-1.03: IES Light Distribution - Illumination Zone GridSource: *IES Lighting Handbook*

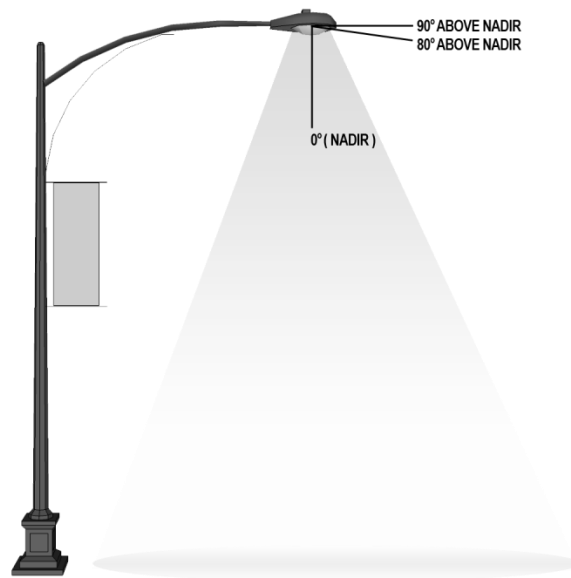
Table 11B-1.02: IES Distribution Summary Diagrams

IES Distribution Type	Longitudinal Classification		
	Short "S"	Medium "M"	Long "L"
	Maximum Spacing Is 4.5 Times Mounting Height	Maximum Spacing Is 7.5 Times Mounting Height	Maximum Spacing Is 12.0 Times Mounting Height
Type I For Streets Up to 2.0 Times Mounting Height in Width			
Type II For Streets Up To 1.75 Times Mounting Height in Width			
Type III For Streets Up To 2.75 Times Mounting Height in Width			
Type IV For Streets Up to 2.75 Times Mounting Height in Width			
Type V For General Area Lighting			

3. **Cutoff Rating:** Disability and discomfort glare are largely a result of light emission into the driver's eye. This is largely caused by high-angle light (zone between 80 degrees to 90 degrees above nadir) emanating from a luminaire. Refer to Figure 11B-1.04. Also a concern is the amount of light emanating from the luminaire above 90 degrees from nadir (horizontal plane at the luminaire). This light contributes to sky glow. If BUG ratings are not available, it is necessary that luminaires be classified according to their relative glare effects. Thus, luminaires are classified by IES as follows:

Full Cutoff: A luminaire light distribution is classified as full cutoff when the luminous intensity (candela) at or above 90 degrees from nadir is zero, and the candela per 1,000 bare lamp lumens does not exceed 100 (10%) at or above a vertical angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Cutoff: A luminaire light distribution is classified as cutoff when the luminous intensity (candela) per 1,000 bare lamp lumens does not exceed 25 (2.5%) at or above 90 degrees from nadir, and does not exceed 100 (10%) at or above a vertical angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Figure 11B-1.04: Luminaire Cutoff Diagram

Semicutoff: A luminaire light distribution is classified as semicutoff when the luminous intensity (candela) per 1,000 bare lamp lumens does not exceed 50 (5%) at or above 90 degrees from nadir, and does not exceed 200 (10%) at or above a vertical angle of 80 degrees above nadir. This applies to all lateral angles around the luminaire.

Noncutoff: A luminaire light distribution where there is no candela limitation in the zone above maximum candela.

As noted above, the metrics related to cutoff classifications for High Intensity Discharge (HID) products are based on candela (intensity) values at specific vertical angles of 80 and 90 degrees when expressed as a percentage of “rated lamp lumens”. If LED fixtures are to be evaluated, a problem is developed because LED fixtures are rated in absolute format where there is no lumen rating. This difference can lead to problems if LED luminaires are compared to HID luminaires.

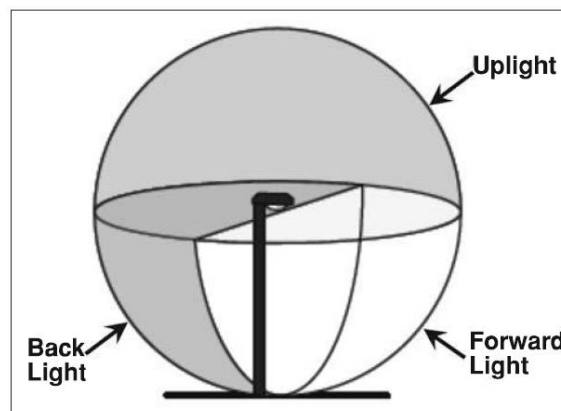
In order to address this difference, the IESNA has published TM-15-11, which uses the parameters of BUG to determine the lumen distributions in specific areas. Design software programs are available that use the BUG rating system. Designers should consult the updated Appendix A of the TM-15-11 document if their design evaluation includes both HID and LED fixtures so the proper comparisons can be made.

- 4. Backlight, Uplight, and Glare (BUG) Rating:** Previous editions of the IES RP-8 included cutoff classifications that have become well known. However, those classifications did not fully describe the light emanating from a fixture. In 2011, IES published TM-15-11, Luminaire Classification for Outdoor Luminaires, which describes the Luminaire Classification System (LCS). This system evaluates fixtures for the amount of light emanating in all directions to include potential nuisance lighting, including backlight, uplight, and forward light (see Figure 11B-1.04). LCS describes the amount of light in each of these three primary angles to classify each fixture by the BUG rating. The lumen output from each fixture is measured at various angles from the fixture to describe overall light distribution. The number of lumens at the various angles are compared to the maximum number of lumens allowable on tables established within the TM-15-11. The following describes the BUG rating in more detail:

- Backlight:** Backlight describes the lumen distribution away from the street (house side). A B0 rating requires less than 110 or 220 lumens directed behind the luminaire/pole depending on the angle. A B0 or B1 rating may require a shield or optic limiter to block light emanating towards private property for typical street light fixtures. Typical rating for a LED luminaire equivalent to a 250 watt HPS fixture would be B3.
- Uplight:** Uplight describes the lumen distribution emanating above the horizontal plane at a luminaire. U0 rating requires zero lumens directed above the luminaire. Most typical LED street luminaires achieve this U0 rating independent of the number of total lumens from the luminaire. Decorative fixtures could emit lumens above horizontal and have a U rating higher than zero.
- Glare:** Glare describes the lumen distribution emanating at a high angle below the horizontal plane of the luminaire. This is the visual light that will cause discomfort to drivers. Typical rating for a LED luminaire equivalent to a 250 watt HPS fixture would be G3.

Use caution when specifying the use of dark-sky or night-sky compliant LED luminaires. The International Dark-Sky Association (IDA) has recommendations and has approved luminaires as dark-sky friendly. Those luminaires do include no uplight (U0), but also include an orange tone (similar to HPS, 3,000 degree Kelvin) to minimize reflected blue light from pavement surface.

Figure 11B-1.05: Three primary angles of LCS



Source: IES TM-15-11

D. References

Federal Highway Administration. *Roadway Lighting Handbook*. 1978.

Illuminating Engineering Society (IES). *IES Lighting Handbook*. 9th Edition.

Illuminating Engineering Society (IES). *Luminaire Classification System for Outdoor Luminaires*. TM-15-11.

Facility Design

A. General

The basic goal of street lighting is to provide patterns and levels of pavement luminance to provide a safer night driving environment and reduce conflict between motorists and pedestrians. A driver's eye discerns an object on or near the street due to contrast between the brightness of the object and the brightness of the background or pavement, or by means of surface detail, glint, shadows, or detection of motion.

LED lighting provides “smart” capabilities such as the ability to monitor power consumption, remote ability to turn fixtures on/off, pre-programming and remote control of dimming, among others. Another term for those capabilities is “adaptive lighting.” That is the term used in IES-RP-8-14. Although the new technology is available, designers should be aware that problems can result as is the case with all new applications. The technology could be pre-programmed by the manufacturer or set locally through “smart” controls.

Consideration for dimming of LED street lights is the primary adaptive lighting application. If there are significant reductions in vehicle or pedestrian volumes consistently overnight, the agency may consider dimming of the street lights for that period to save additional dollars. In order to minimize potential liability related to dimming the street lights, it is important for an agency to ensure they establish a formal policy allowing the dimming process. An example might be that the base design for a section of street is to meet the criteria for Arterial (major) street with high pedestrian volumes until midnight and then meet the Collector level with low pedestrian volumes until sunrise or at a designated time. One of the challenges for pre-programmed dimming is the ever moving sunrise time and other elements, such as daylight savings time, since there is not a way to set fixed start/stop times. Fixtures with “smart” controls, depending on the supplier, may have the ability to set fixed times for dimming or at least have more control related to dimming. If an agency contracts with a utility to supply and maintain the street lighting network, performance standards related to a dimming program must be very specifically stated in the contract.

Lighting design is concerned with the selection and location of lighting equipment so as to provide improved visibility and increased safety while making the most efficient use of energy with minimum expenditure for the lighting equipment. There are two basic concepts of lighting design - the luminance concept and the illumination concept.

The luminance concept is based on the premise that visibility is related to the luminance of the pavement compared to the luminance of the objects on the pavement. Calculations to determine the luminance of pavement or objects require the estimation of the reflectivity of varying pavement surfaces and objects within the driver's field of vision. These reflectivity values can be difficult to estimate and can vary widely. The illuminance concept, which is almost universally used in the United States, is based on the premise that by providing a given level of illumination and uniformity of distribution, satisfactory visibility can be achieved.

The luminance concept is fairly popular in parts of Europe and is being promoted by lighting professionals in the United States. The ANSI/IES RP-8-14 (RP-8) recommends luminance method for relatively straight roads and streets and illuminance method for curved streets and intersections.

The IES DG-21-15, *Design Guide for Residential Street Lighting*, references RP-8-14 and the use of the luminance method. However, most agencies that have lighting codes/requirements utilize illuminance criteria and therefore both methods will be discussed.

B. Design Process

By definition, lighting design according to the luminance method determines how “bright” or amount of light reflected from the pavement towards the driver (quantity) and the uniformity of that luminance the driver sees (quality). The steps in the design process are as follows:

- Determination of the design illumination and uniformity criteria by assessing the facility to be lighted.
- Selecting the type of light source.
- Selecting light source size and mounting height.
- Selecting luminaire light distribution type.
- Determining luminaire spacing and location.
- Checking for design adequacy.

These steps are arranged in the order in which they are usually encountered in the design process.

- 1. Design Criteria:** The first task of the lighting designer is to research and determine if any requirements (such as ordinances, resolutions, or policies) pertaining to street lighting are in effect in the jurisdiction. Many municipalities have no requirements at all. Some may have adopted a published standard in its entirety or have adopted it with some variations. Others may have developed prescriptive guidelines that, for a given street type, specifically describe the luminaire size and type, specific mounting height, and pole spacing. Still others may have developed a combination of these depending on the street type. Finally, a municipality may have requirements that do not deal directly with the amount of light on the street. Rather, they may simply be lighting limitations such as maximum footcandle levels at property or right-of-way lines to control light trespass, or restrict luminaires that emit light above horizontal to control sky glow or excessive glare.

Some communities may provide specific standards such as street lights at intersections only with the potential of mid-block lighting if the block length exceeds a specific distance, such as 500 feet. In rural areas intersection lighting serves more of a way-finding function so more dispersion of the light is important. Most installations of this type remain high pressure sodium light installations.

The designer’s first obligation is to conform to state codes and jurisdictional requirements, but in the absence of such requirements, it is recommended that the designer follow a nationally recognized written street lighting design standard such as RP-8.

To perform street lighting design, two parameters need to be considered - luminance/illuminance level and uniformity. The amount of luminance at a given point on a street is expressed in candela per square meter (cd/m^2). The amount of illuminance at any given point on a street surface is expressed in footcandles (fc). Since the street lighting is typically not distributed evenly over the pavement surface, both methods are expressed in averages when describing the lighting level over a defined area. This parameter describes the “quantity” of light provided.

While the average amount of luminance/illuminance on the street surface may be satisfactory, the lighting distribution may consist of very high (bright) and very low (dim) localized areas. A driver traveling down a street illuminated in this manner will experience difficulty seeing the street and other objects due to the inability of the eye to rapidly adjust to the varying light

conditions. Therefore, another parameter is needed to describe the evenness or uniformity of the applied lighting. This parameter is known as the uniformity ratio of the lighting distribution and is defined as either the ratio of maximum-to-minimum values or the ratio of the average-to-minimum values over the project area. The most popular choice is the average-to-minimum ratio. This parameter describes the “quality” of the lighting distribution. A ratio of 1:1 represents perfectly uniform distribution. A real-life example of this is moonlight at night from a full moon overhead. The illuminance level of moonlight is approximately 0.5 fc but it is almost perfectly uniform.

The Illuminating Engineering Society (IES) has established acceptable luminance levels and uniformity ratios for various public street types (source ANSI/IES RP-8-14). See Table 11C-1.01. To obtain the recommended average luminance and uniformity ratio for a given street, there are two classifications that need to be determined - the street use and the level of pedestrian conflict associated with the street.

Table 11C-1.01: Luminance Method - Recommended Values

Street Classification ¹	Pedestrian Area Classification ²	Average Luminance L_{avg} (cd/m ²)	Average Uniformity Ratio L_{avg}/L_{min}	Max. Veiling Luminance Ratio L_{vmax}/L_{avg}
Arterial	High	1.2	3	0.3
	Medium	0.9	3	0.3
	Low	0.6	3.5	0.3
Collector	High	0.8	3	0.4
	Medium	0.6	3.5	0.4
	Low	0.4	4	0.4
Local	High	0.6	6	0.4
	Medium	0.5	6	0.4
	Low	0.3	6	0.4

¹ See Table 11C-1.02

² See Table 11C-1.03

Table 11C-1.02: Street Surface Classifications

Class	Q_o^*	Description	Mode of Reflectance
R1	0.10	PCC street surface. Asphalt street surface with a minimum of 12% of the aggregates composed of artificial brightener (e.g., Synopal) aggregates (e.g., labradorite, quartzite).	Mostly diffuse
R2	0.07	Asphalt street surface with an aggregate composed of minimum 60 percent gravel [size greater than 1 cm (0.4 in.)]. Asphalt street surface with 10% to 15% artificial brightener in aggregate mix. (Not normally used in North America).	Mixed (diffuse and specular)
R3	0.07	Asphalt street surface (regular and carpet seal) with dark aggregates (e.g., trap rock, blast furnace slag); rough texture after some months of use (typical highways).	Slightly specular

* Q_o = representative mean luminance coefficient

Source: ANSI / IES RP-8-00 (R2014)

Table 11C-1.03: Pedestrian Conflict Area Classifications

High	Areas with significant numbers of pedestrians expected to be on the sidewalks or crossing the streets during darkness. Examples are downtown retail areas, near theaters, concert halls, stadiums, and transit terminals.
Medium	Areas where lesser numbers of pedestrians utilize the streets at night. Typical are downtown office areas, blocks with libraries, apartments, neighborhood shopping, industrial, older city areas, and streets with transit lines.
Low	Areas with very low volumes of night pedestrian usage. These can occur in any of the cited street classifications but may be typified by suburban single family streets, very low density residential developments, and rural or semi-rural areas.

Table 11C-1.04: Illuminance Method - Recommended Values

Street and Pedestrian Conflict Area		Pavement Classification (Minimum Maintained Average Values)		Uniformity Ratio E_{ave}/E_{min}	Veiling Luminance Ratio L_{max}/L_{avg}
Street	Pedestrian Conflict Area	R1 fc	R2 and R3 fc		
Major (Arterial)	High	1.2	1.8	3.0	0.3
	Medium	0.9	1.3	3.0	0.3
	Low	0.6	0.9	3.5	0.3
Collector	High	0.8	1.2	3.0	0.4
	Medium	0.6	0.9	3.5	0.4
	Low	0.4	0.6	4.0	0.4
Local	High	0.6	0.9	6.0	0.4
	Medium	0.5	0.7	6.0	0.4
	Low	0.3	0.4	6.0	0.4

¹ See Table 11C-1.02² See Table 11C-1.03

Source: Adapted from ANSI / IES RP-8-14

IES removed the recommended average illuminance and uniformity ratio for various public street types in the latest RP-8. However RP-8 states that for curved roadways and streets, the illuminance method should be used. An equivalent amount of luminance should be generated by incorporating a ratio of $1 \text{ cd/m}^2 \approx 15 \text{ lux}$ (1.5 fc) for an R3 pavement and $1 \text{ cd/m}^2 \approx 10 \text{ lux}$ (1.0 fc) for an R1 pavement. These equivalent illuminance values are in Table 11C-1.04. To obtain the recommended average illuminance and uniformity ratio for a given street, there are three classifications that need to be determined - the street use, the pavement type, and the level of pedestrian conflict associated with the street.

- a. **Street Use:** Some jurisdictions have already classified their streets and it is recommended to follow these classifications first. If the jurisdiction has not established classifications, refer to the descriptions in [Chapter 5 - Roadway Design](#) to determine the classification of the subject street.
- b. **Pavement Type:** Illuminance method only - pavement types are classified into three categories, R1 through R3. For the purposes of determining lighting criteria, two of the pavement classifications, R2 and R3, are combined, forming two illumination classifications. Refer to Table 11C-1.02 to determine the pavement type classification of the subject street.

- c. Pedestrian Conflict:** Pedestrian conflict is categorized into three classifications - high, medium, and low. The level of pedestrian conflict is almost entirely driven by the land use adjoining the street and the potential of the land use to cause pedestrian traffic during nighttime hours. For example, pedestrian conflict would be low for a local residential street as compared to a high pedestrian conflict level for a local street next to a movie theater. Refer to Table 11C-1.03 to determine the potential pedestrian conflict for the subject street.

Using the defined classifications, determine the recommended luminance/illuminance and uniformity ratio for the subject street. Both luminance (cd/m^2) and illuminance (fc) values listed represent average maintained values over the street surface. The uniformity ratio is average value divided by the minimum value. The designer may consider more illumination and/or better uniformity for the street if it would better serve expected activity along the route.

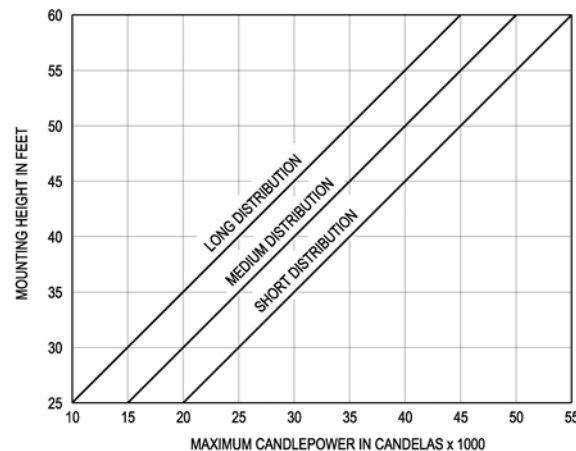
- 2. Selecting the Type of Light Source:** The vast majority of street lighting in municipalities is owned, operated, and maintained by the local electric utility. The cost for the installation, energy, and maintenance is paid for by the municipality in monthly installments based on established utility tariff rates for the type of lighting units installed. These rates are regulated and set by the utility with approval from the Iowa Utilities Board. If the street lighting to be installed on a particular project will be utility owned, the lighting equipment will need to be selected from that available from the utility.

If the street lighting will be owned and operated by the municipality, the installation needs to meet Iowa Code. LED technology has become the standard technology for street lighting over HPS lighting, including in the decorative/historical luminaires.

If initial cost is an important parameter, HPS will have lower installation cost. If life-cycle cost is the deciding factor, then LED will win out, but the designer will have to develop layouts for each type to make the comparison. If the color of the light and color rendering of objects are important, LED will be the choice.

- 3. Selecting Light Source Size and Mounting Height:** The distance the lamp/luminaire is mounted above the street will affect the lighting intensity, uniformity, area covered, and relative glare of the unit. Higher mounted units will provide greater coverage, more uniformity, and reduction of glare, but a lower lighting level. The illumination of an object from a light source varies inversely to the square of the distance from the light source, so doubling the distance will reduce the illumination on the object to one fourth of the original value. Therefore, greater mounting heights will require larger lumen/wattage luminaires. It is necessary to weigh the effects of larger lumen/wattage luminaires against a greater number of smaller units at lower mounting heights with an increase in glare potential.

Mounting heights of street luminaires vary from 15 feet to more than 100 feet above the street surface. Conventional municipal street lighting utilizes mounting heights of 25 to 50 feet. Generally, the greater the target uniformity ratio, the shorter the mounting height and vice versa. Local street lighting uses 25 to 30 feet mounting heights while collector and major streets will use 30 to 40 feet mounting heights. Figure 11C-1.01 shows minimum mounting heights for various maximum candela levels and vertical light distributions.

Figure 11C-1.01: Minimum Mounting Height vs. Maximum Candela

Source: Adapted from *Roadway Lighting Handbook*

4. **Selecting Luminaire Light Distribution Type:** Selection of the luminaire light distribution type (lateral, vertical, and BUG rating) for a given street lighting application depends on several elements, the mounting height, the pole placement pattern, the cross sectional geometry of the street, and any jurisdictional ordinances that control or limit light trespass, glare, or sky glow. Again, the options may be limited by the local electrical utility.

Table 11B-1.02 is a guide to selecting which lateral light distribution(s) are best suited for the street width and pole placement pattern. This is only a guide. While lighting distribution types are defined, luminaires that fit into a type still vary between manufacturers. A Type II from one manufacturer may provide better illumination than a Type III from another for a wider street. For the given street width, pole pattern, and mounting height, the distribution pattern from the Type II may “fit” together better and provide more uniform light.

The designer may select the first luminaire that meets the lighting criteria. However this may not be optimum selection based on defined goals of the project. Street lighting design is an iterative process if optimization is to be achieved.

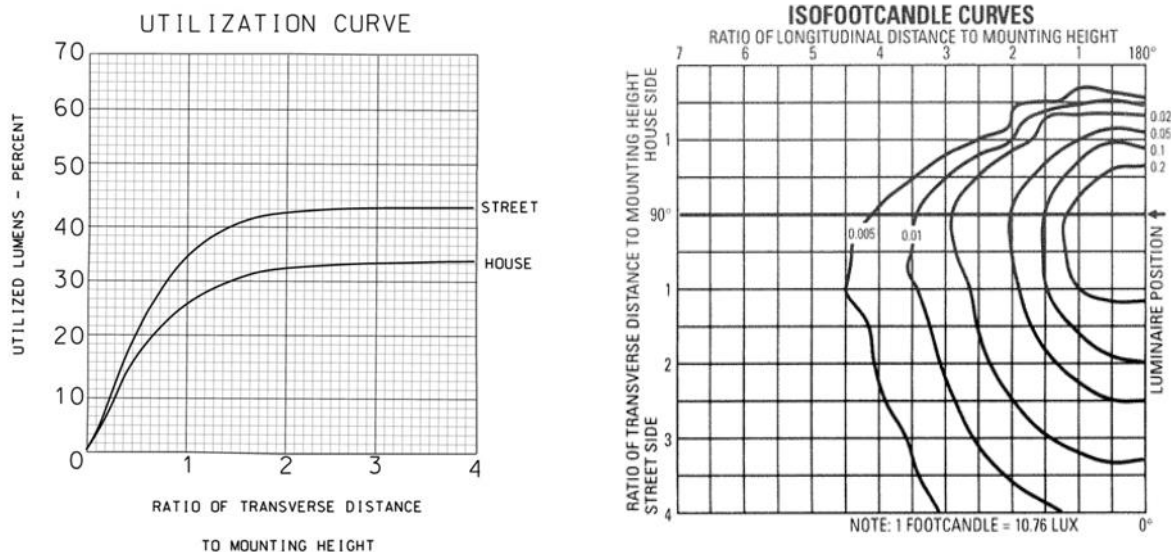
5. **Determining Luminaire Spacing and Location:** The most common lateral location of street lighting luminaires is positioned over the curb line or edge of pavement (zero overhang). This is also the base line for luminaire design. Since it would be impractical to place light poles directly at the edge of the street, lighting support structures typically consist of a poles fitted with mast arms to set the poles back away from and provide clearance for traffic and pedestrians. Streets typically have defined clear zones behind the curb or pavement edge, the width of which depends on the street characteristics. The designer needs to consider setback to determine if a mastarm of sufficient length is available to place the luminaire at the street edge. Luminaires positioned with excessive negative overhang will likely require shorter longitudinal luminaire spacing to compensate.

[Section 11B-1](#) discusses theoretical maximum longitudinal luminaire/pole spacing for a given vertical light distribution. However, this spacing may not be practical to fit the site. The designer needs to consider how the street interfaces with the adjoining property features. These factors include location of sidewalks, bike trails, driveways, alleys, and cross streets. Many times, particularly in residential areas, it is desirable to place the light poles in line with the side property lines.

6. Checking for Design Adequacy: All of the above selected elements are formed into a design concept or model. The next step is to perform calculations to verify the chosen equipment and layout to meet the design criteria. For many years, manual calculations were the only methods used to determine the resulting design illumination and uniformity. Numerous software programs have been developed and are available to automate the calculation process.

a. Manual Calculation Method: The most popular manual calculation method is the coefficient of utilization and isofootcandle plot method. As the name implies, two pieces of graphical information are required, a coefficient of utilization curve and an isofootcandle plot. These are developed by luminaire manufacturers and are required for the calculation process. Examples of such are shown in Figure 11C-1.02. The coefficient curve is a quantitative description of the percentage of total lumens emitted from the fixture that will land on or be utilized to illuminate the street below based on the street width and relative position of the luminaire to the street.

Figure 11C-1.02: Typical Luminaire Utilization and Isofootcandle Plots



Rather than repeat the process here, the designer is recommended to visit and access [Minnesota DOT Street Lighting Design Manual](#), Chapter 4. The discussion in this document provides a good step-by-step description of the manual calculation process.

b. Computer Modeling Method: There are numerous programs available, both purchased and free to model lighting installations and perform photometric calculations. Some software packages can be very sophisticated with the ability to create such things as shade plots and shade and shadow renderings to closely represent what the human eye would see. For the design purposes described herein, all that is required of the software is to take luminaire photometric data and perform point-by-point calculations on a defined plane and be able to export the numerical results.

The first requirement is to create a computer model of the street to be lit. For most situations, this involves defining the width and length of the street. Most of the lighting programs have drawing tools to create the model directly in the program. If an electronic representation of the street is available from a computer-aided design file such as that created by AutoCAD or Microstation, this can be imported into the lighting program to form the model. Once this is done, the designer will “place” luminaires spatially above the model surface locating them with the desired mounting height and overhang from the street edge.

For each luminaire type to be considered, the designer needs to acquire a photometric file that describes the photometry or lighting distribution characteristics of the luminaire. These files are generated by the manufacturer through laboratory testing. They are text files containing a defined array of light intensity values (candela) in standardly defined spatial directions emanating from the luminaire. The files are commonly referred to as IES photometric files (or IES files) since the standard was developed by the Illuminating Engineering Society (IES). The files are readily available from the manufacturer's website at no cost.

The files are imported into the program to model the performance of the selected luminaires. The candela values in the file are typically based on a default lamp lumen value of 1,000 lumens. The designer will be required to input the proper initial lamp lumen value, which will scale the intensity values accordingly. For LED luminaires however, the file usually contains the actual initial lumen value of the luminaire assembly since the LEDs are not necessarily a removable modular element of the luminaire. In any case, the designer is cautioned to verify the proper lumen value is used. Also, the designer will need to enter the lumen maintenance factor for each luminaire model.

The final task is to define a calculation area by drawing a region on the street model surface. Confirm with the municipality to determine any potential requirements for defining the calculation area. The width of the area could be back of curb to back of curb for example, or it could be right-of-way to right-of-way to calculate the illumination from building face to building face in a downtown business district. Within this area, the designer will create a calculation grid that is a defined set of points on the surface, at which the lighting level will be calculated. Typical calculation point grids are a 10 feet by 10 feet or a 5 feet by 5 feet rectangular array. More points in the calculating area will usually yield more accurate results but require more computer processing time. For a small area, this is not a problem, but if the designer has created a large area, the time may be significant. The RP-8-14 recommends locating two grid lines per lane, one-quarter of the distance from each lane line. It continues to indicate that points along the gridlines should not be placed further than 5 meters (16 feet) apart and have at least 10 calculation points located between each luminaire. This applies for both luminance and illuminance methods.

The program utilizes the superposition principal to perform the calculation. The program will step through each point and calculate the luminance/illuminance contribution at that point on the model surface from each luminaire defined in the model. Each of these contribution values are simply added together to get the overall illumination at that point. Once all of the points are calculated, the program determines the average value of all of the points in the grid, giving the average luminance or illuminance of the entire surface. The program then uses the point with the lowest value to calculate the average-to-minimum uniformity ratio.

A clear advantage of using computer modeling is the ease in which the designer can make changes to the luminaire layout model and obtain the luminance or illuminance results for different scenarios. For example, the designer could change luminaire, type, wattage, mounting height, or position; or any combination of these to optimize the lighting design and minimize the energy consumption.

Most available lighting design software packages contain pre-defined street models or "wizards" for quick luminaire spacing optimization. This allows a designer to simply input a luminaire at a mounting height, a street width, a mounting pattern (one-side, each side staggered, etc.), and target design criteria, and have the program calculate the optimum longitudinal luminaire spacing.

C. References

Federal Highway Administration. *Roadway Lighting Handbook*. 1978.

Illuminating Engineering Society. *Roadway Lighting*. ANSI / IES RP-8-14.

Illuminating Engineering Society. *Design Guide for Residential Street Lighting*. IES DG-21-15.

Minnesota Department of Transportation. *Roadway Lighting Design Manual*. 2010.

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Traffic Signal General Information

A. Introduction

The purpose of this chapter is to supplement [SUDAS Specifications Section 8010](#) and to provide general guidance for traffic signal designs on roadways within Iowa. The information is provided as an overview for traffic signals design consideration.

B. Scope

There is no legal requirement to use the information within this chapter by local agencies. This document refers to a number of other resources available for the designer to be considered when designing a traffic control signal. The document loosely follows the format of the MUTCD, as published by The U.S. DOT, FHWA and as adopted or modified by the Iowa DOT. However, no attempt is made to re-print the content of the MUTCD herein. A variety of other technical resources are also noted for consideration by the designer.

By MUTCD definition, a traffic control signal is “any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed” with highway traffic signal being defined as “a power-operated traffic control device by which traffic is warned or directed to take some specific action. These devices do not include power-operated signs, illuminated pavement markers, barricade warning lights, or steady-burning electric lamps.” From an application standpoint traffic control signals are used to assign vehicular or pedestrian right-of-way.

The design for traffic control signals shall be in conformance with the current edition of the MUTCD as adopted or modified by the Iowa DOT. The following should be used as design standards as applicable to a project (all accessed October 2012):

- [MUTCD Part 4 Highway Traffic Signals](#)
- Jurisdiction Design Standards and Construction Standards
- Iowa DOT and FHWA regarding the design of traffic control signals
- Institute of Transportation Engineers - “Manual of Traffic Signal Design,” “Traffic Engineering Handbook,” “Traffic Signal Timing Manual,” “Manual of Traffic Engineering Studies”
Robertson, H.D, Editor, J.E. Hummer, and D.C. Nelson. Institute of Transportation Engineers, Washington, DC, 1994 and “Traffic Control Devices Handbook.”
- Other standard references such as the National Electrical Code by the National Fire Protection Association (NFPA), and the National Electrical Manufacturers Association (NEMA) Standards Publications.

Other resources to consider and that are referenced within this document include:

- [Mn/DOT Traffic Engineering Manual](#)
- [Mn/DOT Signal Design Manual](#)
- [Mn/DOT Lighting and Signal Certification Field Guide](#)
- [Mn/DOT Signals 101 Course Presentation](#)
- [Mn/DOT Signal Justification Reports](#)
- [Arizona DOT Traffic Engineering Policies, Guidelines, and Procedures](#)

C. Definitions

A resource for traffic signal definitions can be found within MUTCD [Section 4A.02](#) “Definitions Relating to Highway Traffic Signals.”

Traffic Control Signal Needs Study

A. General

The MUTCD states that “A traffic control signal should not be installed unless an engineering study indicates that installing a traffic control signal will improve the overall safety and/or operation of the intersection.” The first question that must be answered is whether a traffic control signal is justified or is the most effective treatment option. It is the responsibility of the Engineer or agency to make this determination with serious consideration given to the following MUTCD [Section 4B](#):

[Section 4B.01](#) General

[Section 4B.02](#) Basis of Installation or Removal of Traffic Control Signals

[Section 4B.03](#) Advantages and Disadvantages of Traffic Control Signals

[Section 4B.04](#) Alternatives to Traffic Control Signals

[Section 4B.05](#) Adequate Roadway Capacity

B. Data Collection

The engineering study should be based upon a complete collection of site and traffic data (vehicle, pedestrian, etc) pertaining to the candidate location. [Section 9-4.01](#) of the Mn/DOT Traffic Engineering Manual notes the studies which will be helpful in assessing and demonstrating the need for a signal as follows:

- Volume studies, including approach volumes, turning movements, and peak hour detail counts
- Pedestrian counts, including any unusual numbers of children, handicapped, and elderly
- Traffic gap studies
- Speed studies
- Crash studies
- Intersection delay studies

Procedures for completing various traffic studies are found in the ITE Manual of Traffic Engineering Studies.

MUTCD [Section 4C.01](#) provides a detailed description of engineering study data which may be needed to conduct a warrant analysis. These include:

1. The number of vehicles entering the intersection in each hour from each approach during 12 hours of an average day. It is desirable that the hours selected contain the greatest percentage of the 24 hour traffic volume.
2. Vehicular volumes for each traffic movement from each approach, classified by vehicle type (heavy trucks, passenger cars and light trucks, public-transit vehicles, and, in some locations, bicycles), during each 15 minute period of the 2 hours in the morning and 2 hours in the afternoon during which total traffic entering the intersection is greatest.
3. Pedestrian volume counts on each crosswalk during the same periods as the vehicular counts in Item B above and during hours of highest pedestrian volume. Where young, elderly, and/or

persons with physical or visual disabilities need special consideration, the pedestrians and their crossing times may be classified by general observation.

4. Information about nearby facilities and activity centers that serve the young, elderly, and/or persons with disabilities, including requests from persons with disabilities for accessible crossing improvements at the location under study. These persons might not be adequately reflected in the pedestrian volume count if the absence of a signal restrains their mobility.
5. The posted or statutory speed limit or the 85th-percentile speed on the uncontrolled approaches to the location.
6. A condition diagram showing details of the physical layout, including such features as intersection geometrics, channelization, grades, sight-distance restrictions, transit stops and routes, parking conditions, pavement markings, roadway lighting, driveways, nearby railroad crossings, distance to nearest traffic control signals, utility poles and fixtures, and adjacent land use.
7. A collision diagram showing crash experience by type, location, direction of movement, severity, weather, time of day, date, and day of week for at least 1 year.

The following data, which are desirable for a more precise understanding of the operation of the intersection, may be obtained during the periods specified in item 2 of the preceding paragraph:

1. Vehicle-hours of stopped time delay determined separately for each approach.
2. The number and distribution of acceptable gaps in vehicular traffic on the major street for entrance from the minor street.
3. The posted or statutory speed limit or the 85th-percentile speed on controlled approaches at a point near to the intersection but unaffected by the control.
4. Pedestrian delay time for at least two 30 minute peak pedestrian delay periods of an average weekday or like periods of a Saturday or Sunday.
5. Queue length on stop-controlled approaches.

It is critical to present the above information in an organized fashion. Mn/DOT makes use of a [Signal Justification Report](#), which contains the following information:

1. Intersection Location: Trunk highway cross-street name and county road numbers, municipality, and county. A map should be included that identifies the site.
2. Type of Work: Type of signal or beacon proposed, whether temporary or permanent.
3. Character of Site: Function and importance of roads, number of lanes, existing and proposed geometrics, channelization, grades, presence or absence of parking, bus stops and routes, posted speed limit, 85th percentile speed if markedly different, and sight distance restrictions.
4. Land Use: Present land use at the intersection, presence of any special traffic generators, proposed or likely future development.
5. Traffic Control: Existing traffic control, present and planned adjacent signals, and proposed or existing coordinated systems.

6. Actual Traffic Volumes at the Intersection: Volumes must include at least 16 hours of counts on all approaches, turning movement counts for at least a.m. and p.m. peak hours. Unusual numbers of heavy vehicles and unusual percentages of turning movements must be noted. Volumes shall have been counted within two years of the date of submission of the report.
7. Iowa DOT generated or approved volume estimates for a proposed intersection, such as found in an official TAM or SPAR report, and for which warrant estimation methods are acceptable.
8. Pedestrian counts, particularly if the intersection is a school crossing or is used by large numbers of elderly or handicapped pedestrians.
9. Crash Data: Number and general types of crashes which have occurred for a minimum of 12 months before the date of the report. If Warrant 7 for crash experience is addressed, a collision diagram must be included, showing crashes by type, location in the intersection, directions of movement, severity, date, time of day, weather, light, and roadway conditions.
10. Any special site conditions adding to the Engineer's judgment that signals are necessary.

The above information can be presented in either checklist or narrative form, so long as it is clearly and logically presented. Volumes can be presented in graph or tabular form.

Mn/DOT's [Section 9-4.02.04](#) signal justification also provides a section on "Signal Removal Justification Criteria."

C. Warrants

MUTCD [Section 4C.01](#) "Studies and Factors for Justifying Traffic Control Signals" states, "An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location.

The investigation of the need for a traffic control signal shall include an analysis of the applicable factors contained in the following traffic signal warrants and other factors related to existing operation and safety at the study location:

[Section 4C.01](#) Studies and Factors for Justifying Traffic Control Signals

[Section 4C.02](#) Warrant 1, Eight-Hour Vehicular Volume

[Section 4C.03](#) Warrant 2, Four-Hour Vehicular Volume

[Section 4C.04](#) Warrant 3, Peak Hour

[Section 4C.05](#) Warrant 4, Pedestrian Volume

[Section 4C.06](#) Warrant 5, School Crossing

[Section 4C.07](#) Warrant 6, Coordinated Signal System

[Section 4C.08](#) Warrant 7, Crash Experience

[Section 4C.09](#) Warrant 8, Roadway Network

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal."

Accompanying MUTCD figures and tables for the above warrants include:

[Table 4C-1](#) Warrant 1, Eight-Hour Vehicular Volume

[Figure 4C-1](#) Warrant 2, Four-Hour Vehicular Volume

[Figure 4C-2](#) Warrant 2, Four-Hour Vehicular Volume (70% Factor)

[Figure 4C-3](#) Warrant 3, Peak Hour

[Figure 4C-4](#) Warrant 3, Peak Hour (70% Factor)

Mn/DOT's Traffic Signal Design Manual [Section 9-4.02](#) provides additional guidance for the following:

- Section 9-4.02.02 Warrants for Flashing Beacons at Intersections
- Section 9-4.02.03 Advance Warning Flashers Consideration

Traffic Signal Features

A. Traffic Control Signal Features

The MUTCD [Chapter 4D](#) Traffic Control Signal Features establishes traffic signal uniformity and serves as a critical resource for checking each traffic signal design. The features of traffic control signals of interest to road users are the location, design, and meaning of the signal indications. Uniformity in the design features that affect the traffic to be controlled, as set forth in the MUTCD, is especially important for reasonably safe and efficient traffic operations. This chapter includes the following sections:

- [Section 4D.01](#) General
- [Section 4D.02](#) Responsibility for Operation and Maintenance
- [Section 4D.03](#) Provisions for Pedestrians
- [Section 4D.04](#) Meaning of Vehicular Signal Indications
- [Section 4D.05](#) Application of Steady Signal Indications
- [Section 4D.06](#) Application of Steady Signal Indications for Left Turns
- [Section 4D.07](#) Application of Steady Signal Indications for Right Turns
- [Section 4D.08](#) Prohibited Steady Signal Indications
- [Section 4D.09](#) Unexpected Conflicts During Green or Yellow Intervals
- [Section 4D.10](#) Yellow Change and Red Clearance Intervals
- [Section 4D.11](#) Application of Flashing Signal Indications
- [Section 4D.12](#) Flashing Operation of Traffic Control Signals
- [Section 4D.13](#) Preemption and Priority Control of Traffic Control Signals
- [Section 4D.14](#) Coordination of Traffic Control Signals
- [Section 4D.15](#) Size, Number, and Location of Signal Faces by Approach
- [Section 4D.16](#) Number and Arrangement of Signal Sections in Vehicular Traffic Control Signal Faces
- [Section 4D.17](#) Visibility, Shielding, and Positioning of Signal Faces
- [Section 4D.18](#) Design, Illumination, and Color of Signal Sections
- [Section 4D.19](#) Lateral Placement of Signal Supports and Cabinets
- [Section 4D.20](#) Temporary Traffic Control Signals
- [Section 4D.21](#) Traffic Signal Signs, Auxiliary

Accompanying MUTCD figures and tables for signal features include:

- [Table 4D-1](#) Minimum Sight Distance
- [Figure 4D-1](#) Maximum Mounting Height of Signal Faces Located Between 40 Feet and 53 Feet from Stop Line
- [Figure 4D-2](#) Horizontal Location of Signal Faces
- [Figure 4D-3](#) Typical Arrangements of Signal Lenses in Signal Faces

B. Pedestrian Control Features

The MUTCD [Chapter 4E](#) Pedestrian Control Features establishes pedestrian control uniformity and serves as a critical resource for checking each traffic signal design. Pedestrian signal heads provide special types of traffic signal indications exclusively intended for controlling pedestrian traffic. These signal indications consist of the illuminated symbols of a WALKING PERSON (symbolizing WALK) and an UPRaised HAND (symbolizing DONT WALK). This Chapter includes the following sections:

[Section 4E.01](#) Pedestrian Signal Heads

[Section 4E.02](#) Meaning of Pedestrian Signal Head Indications

[Section 4E.03](#) Application of Pedestrian Signal Heads

[Section 4E.04](#) Size, Design, and Illumination of Pedestrian Signal Head Indications

[Section 4E.05](#) Location and Height of Pedestrian Signal Heads

[Section 4E.06](#) Accessible Pedestrian Signals

[Section 4E.07](#) Countdown Pedestrian Signals

[Section 4E.08](#) Pedestrian Detectors

[Section 4E.09](#) Accessible Pedestrian Signal Detectors

[Section 4E.10](#) Pedestrian Intervals and Signal Phases

Accompanying MUTCD figures and tables for pedestrian control features include:

[Figure 4E-1](#) Typical Pedestrian Signal Indications

[Figure 4E-2](#) Recommended Pushbutton Locations for Accessible Pedestrian Signals

C. Agency Specific Information

Agencies often have design requirements that differ or are in addition to those found in the MUTCD. Therefore, one of the first steps in the traffic signal design process is to learn the design requirements by meeting with agency staff, studying agency specific design manuals, and/or studying the MUTCD. Field observations of existing traffic signals within an agency's jurisdiction can also provide insight to specific design requirements.

Determining agency specific design requirements prior to design can be challenging. It can be difficult to ask all the right questions, give all the necessary answers, and not overlook any details. More challenges can arise when staff is less experienced or a new working relationship is being established. Most design requirements that are overlooked will be caught during the design process or review process. However, taking steps to prevent design requirements from being overlooked will accelerate the design process and minimize costs by eliminating or reducing change orders. The following are some examples of design requirements that can vary between agencies.

- The 2003 edition of the MUTCD requires a maximum distance of 180 feet from the stop line to the 12 inch signal faces unless a near side supplemental signal face is used. The previous version required a maximum distance of 150 feet and some agencies continue to follow the old requirement.
- Some agencies center mast arm mounted signal heads over the lane line and others center them over the center of the lane.
- Certain agencies elect to install supplemental signal heads on the vertical shaft of the mast arm pole and others elect not to.
- Doghouse style five section heads are used for protected / permissive left turns by some agencies but not others.

- Protected / permissive left turn lane operation can vary. Some agencies configure left turn lane loop detectors to call the protected phase only when all loop detectors are covered by vehicles while other agencies always call the protected phase.
- Detector types, sizes, and layouts vary between agencies.
- The size and number of conduits, handholes, and wiring varies greatly among agencies.
- Some agencies share conduit between signal cable, street light power, and/or interconnect while others keep these cables in separate conduits.
- Some agencies choose to install emergency preemption.
- Signal wiring details vary among agencies.
- Some agencies use the “astro” type brackets to mount all signal heads and others do not use this on side of pole mounted heads. Bracketing and banding of all hardware (typically to the poles) varies greatly among agencies.
- Traffic signal cabinets, cabinet risers, and controller types and preferences vary greatly among agencies.
- Mounting heights for signal heads, street light luminaires, detection cameras, monitoring cameras, etc. vary greatly among agencies.

D. Preliminary Signal Design Discussion List

Signal designers should meet and confer to agree on preliminary signal design details. Having a list of the basic criteria to be discussed at a preliminary stage can be of significant benefit to both the engineer and agency. The following list is based on Mn/DOT's [Signal Design Manual](#) “Pencil Sketch” review list.

1. General nature of the signal project - new installation, minor or major revisions.
2. Phasing of the intersection, relation of proposed phasing to the traffic volumes and turning movements; use of protected-permissive left-turn phasing rather than protected-only; use of overlaps.
3. Determine design standards based on who will operate the system.
4. Use of four and five section heads and non standard bracketing.
5. Head type (LED, optically programmed, etc.).
6. Appropriateness of poles and pedestals for the site.
7. Placement of signal standards to ensure legal placement of all vehicle and pedestrian signal indications.
8. Placement of pedestrian pushbuttons relative to signal standards and in place sidewalks and crosswalks.
9. Need for emergency vehicle pre-emption (EVP) and police door with auto/flash switch, manual/stop time switch, and on/off power switch for signal heads only, including placement of components.
10. Detector placement and functions. See the Signal Design Manual for loop detector placement diagrams.

11. Placement and type of handholes.
12. Design of equipment pad.
13. Type of service equipment.
14. Discuss needs for combined pad with lighting and/or TMC.
15. Need for intersection geometric improvements.
16. For revised systems, the wording of the signal pole notes for the revision.
17. Need for AWF's, supplemental heads, etc.
18. House moving route needs (Mn/DOT uses a mast-arm mount that can swivel).
19. Painting of signal.
20. Luminaires metered or unmetered.
21. Source of power (to determine cabinet location).
22. Interconnect (determine need and type, location of master).

E. Additional Information

The MUTCD [Chapter 4E](#) Pedestrian Control Features establishes pedestrian control uniformity and serves as a critical resource for checking each traffic signal design. Pedestrian signal heads provide:

- [Chapter 4F](#) Traffic Control Signals for Emergency Vehicle Access
- [Chapter 4G](#) Traffic Control Signals for One-Lane, Two-Way Facilities
- [Chapter 4H](#) Traffic Control Signals for Freeway Entrance Ramps
- [Chapter 4I](#) Traffic Control Signals for Movable Bridges
- [Chapter 4J](#) Lane-Use Control Signals
- [Chapter 4K](#) Flashing Beacons
- [Chapter 4L](#) In-Roadway Lights

Traffic Signal Design Considerations

In addition to basic MUTCD requirements, the safe and efficient operation of a signalized intersection requires careful attention and balance of a number of design parameters. This section provides some reference resources for the traffic signal designer in consideration of these features.

A. Geometrics

The geometrics of an intersection are a critical consideration given the potential impact on intersection safety and performance. Geometrics directly impact sight distance, vehicle separation, operations, and capacity. As a result, intersection geometrics should always be considered whether dealing with existing, reconstructed, or new signalized intersections.

References are made to [Signalized Intersections: Informational Guide](#), FHWA-HRT-04-091, August 2004, which provides a single, comprehensive document with methods for evaluating the safety and operations of signalized intersections and tools to remedy deficiencies. The treatments in this guide range from low-cost measures such as improvements to signal timing and signage, to high-cost measures such as intersection reconstruction or grade separation. While some treatments apply only to higher volume intersections, much of this guide is applicable to signalized intersections of all volume levels.

1. **Basic Geometric Considerations:** The geometric design section of the [Signalized Intersections: Informational Guide](#) provides the following comments:

Geometric design of a signalized intersection involves the functional layout of travel lanes, curb ramps, crosswalks, bike lanes, and transit stops in both the horizontal and vertical dimensions. Geometric design has a profound influence on roadway safety; it shapes road user expectations and defines how to proceed through an intersection where many conflicts exist.

In addition to safety, geometric design influences the operational performance for all road users. Minimizing impedances, eliminating the need for lane changes and merge maneuvers, and minimizing the required distance to traverse an intersection all help improve the operational efficiency of an intersection.

The needs of all possible road users must be considered to achieve optimal safety and operational levels at an intersection. At times, design objectives may conflict between road user groups; the practitioner must carefully examine the needs of each user, identify the tradeoffs associated with each element of geometric design, and make decisions with all road user groups in mind.

The [Geometric Design](#) section addresses the following design topics to be considered when designing traffic signal controlled intersections:

- [3.1 Channelization](#)
- [3.2 Number of Intersection Legs](#)
- [3.3 Intersection Angle](#)
- [3.4 Horizontal and Vertical Alignment](#)
- [3.5 Corner Radius and Curb Ramp Design](#)
- [3.6 Sight Distance](#)

- [3.7 Pedestrian Facilities](#)
- [3.8 Bicycle Facilities](#)

2. Additional Sight-distance Considerations:

- a. Sight distance is a safety requirement that impacts intersection geometrics as fundamental as horizontal and vertical alignments. It is a design requirement that is discussed in detail as it relates to the visibility of traffic signal indications in the MUTCD. In addition to the sight distance requirements of the MUTCD, the AASHTO “Policy on Geometric Design of Highways and Streets 2001” states that drivers of the first stopped vehicles on all approaches should have adequate sight distance to view one another. It also states that left turning vehicles should have adequate sight distance to select gaps in oncoming traffic and complete turning maneuvers. This requires consideration of offset left turn lanes to provide adequate left turn sight distance. If right turns are allowed on a red signal indication, the appropriate departure sight triangle should be provided. Finally, the policy states that the appropriate departure sight triangles should be provided for left and right turning vehicles on the minor approach for two-way flashing operations. Two-way flashing operations are flashing yellow for the major street and flashing red for the minor street. See Chapter 9 - Intersections in the AASHTO “Policy on Geometric Design of Highways and Streets 2001” for additional sight distance information.
- b. One sight distance issue that deserves additional consideration is the sight triangle and the sight obstructions found within it. Certain obstructions are obvious like structures near the street. Other obstructions are not always obvious or are installed after the traffic signal is designed and constructed. These obstructions seem to blend into the background. They are obstructions like entrance monuments, special street name signs, business signs, and landscape vegetation that may not be a problem initially but become a problem as the plants reach maturity. Finally, be aware of the signal cabinet size and location including the height of the footing or cabinet riser so it does not become a sight obstruction.
- c. Sight distance requirements are less restrictive at signalized intersections as drivers are required by law to obey the signal indications; however, there are instances when drivers do not obey traffic signals. A traffic signal should be designed to exceed minimum sight distance requirements when possible. Drivers are taught to drive defensively and providing additional sight distance will only aid drivers in collision avoidance.

3. Turn Lanes:

- a. Traffic volumes, turning movement counts, and crash history are used to complete intersection capacity and accident analyses. The results of the analyses determine the need for turn lanes, the number of turn lanes, and the length of the turn lanes. The turn lane information is used to properly design the geometrics of signalized intersection approaches.
- b. Turn lane capacity issues often create safety problems. Left or right turning vehicle queues blocking through traffic create increased potential for rear-end accidents. Sideswipe potential also increases as traffic attempts to maneuver out of defacto turn lanes or around left turn queues blocking through lanes. High volumes of turning vehicles combined with high volumes of opposing vehicles significantly reduce the number and size of available gaps needed to complete turning maneuvers increasing the potential for right angle collisions. As a result, properly designed turn lanes improve safety as well as capacity.

- c. Determining turn lane design details when upgrading existing signalized intersections in largely developed areas is relatively straight forward. Capacity problems are recognized through evidence obtained from capacity analyses, visual inspections, and/or citizen comments. Capacity analyses and visual inspections of peak hour traffic often reveal long queues that do not clear after multiple signal cycles. Heavy turning volumes and a lack of turn lanes on multilane facilities often result in shared lanes acting as defacto turn lanes. If turn lanes exist, traffic volumes may exceed the capacity of the turn lanes resulting in vehicle queues spilling out of the turn lanes and into the through lanes.
- d. Determining turn lane design details when constructing new signalized intersections in undeveloped or under developed areas experiencing significant growth is a challenge. In many cases, there is no visual evidence of existing capacity or safety problems. The challenge is judging future traffic patterns and the extent of the traffic growth over a given time period, usually twenty years, with no guarantees as to the type, extent, and rate of development. Judgment is improved with information and the information is obtained from capacity analyses that examine existing and proposed development, existing traffic volume data, and future traffic volume data derived from land use maps and the ITE Trip Generation Manuals. This information combined with traffic growth rates obtained from developed areas with similar land use characteristics and engineering judgment are used to arrive at an intersection design that will support existing traffic volumes as well as future growth.
- e. Past experience has helped to formulate several design guidelines used to initially determine the number of lanes needed at an intersection. These guidelines are planning level guidelines and should be confirmed with the results of the operational analysis methods discussed in the Operations section of this chapter. The guidelines can be found in Chapter 10 of the Highway Capacity Manual 2000 (HCM 2000) and are summarized as follows:
 - 1) Exclusive Left Turn Lanes:
 - A single exclusive left turn lane should be considered when the minimum left turn volume is 100 veh/hr.
 - Dual exclusive left turn lanes should be considered when the minimum left turn volume is 300 veh/hr.
 - 2) Exclusive Right Turn Lanes:
 - An exclusive right turn lane should be considered when the right turn volume exceeds 300 veh/hr and the adjacent mainline volume exceeds 300 veh/hr/ln.
 - 3) Number of Lanes:
 - Enough lanes should be provided to prevent the total volume of the approach from exceeding 450 veh/h/ln.
- f. Past experience has also helped to formulate several design guidelines used to initially determine turn lane lengths needed at intersections. Like the guidelines used to determine the number of lanes, the guidelines used to determine turn lane lengths are planning level guidelines and should be confirmed with the results of an operational analysis. Also remember that the lengths discussed here are the actual storage lengths and do not include taper lengths. Taper requirements are discussed in several sources including [Chapter 5 - Roadway Design](#), the Iowa DOT Design Manual, and the AASHTO Policy on Geometric Design of Highways and Streets. The guidelines are as follows:
 - Enough storage length should be provided to equal one foot for each vehicle per hour (vph) turning during the peak hour in the horizon year. For example, 250 vph turning during the peak hour in the horizon year would require a 250 foot turn lane.

- Storage length can also be computed using the following equation:

$$\text{Storage Length} = (h / s) (v + g) (p)$$

h = horizon year peak hour volume (vph)

s = number of signal cycles per hour

A signal cycle is typically 60 to 120 seconds. Engineering judgment is used to select the cycle length or lengths to use in the equation.

v = average vehicle length

The average vehicle length often used is 20 feet.

g = average gap between vehicles

The average vehicle gap often used is 5 feet.

p = probability factor

The probability factor is based on the Poisson distribution and associated with the probability that enough length is provided to store all vehicles.

Probability Factor (p)	Probability of Storing All Vehicles
1.50	0.90
1.75	0.95
1.85	0.98
2.00	> 0.98

A paper written by the Transportation Research Institute at Oregon State University suggests modifying the average vehicle length plus gap ($v + g$) based on the percentage of trucks using the turn lane. The paper suggests modifying $v + g$ as follows:

Percent Trucks	$v + g$
< 2%	25'
5 %	27'
10 %	29'

The initial storage length for dual left turn lanes can be found by dividing the storage length found from one of the two methods discussed above by 1.8.

Example:

$h = 250$ vph

$s = 100$ s/cycle

$3600 \text{ s/hr} / 100 \text{ s/cycle} = 36$ cycles/hr

5% trucks

$v + g = 27'$

$p = 1.85$ (95% probability)

Single lane storage length = $(250 / 36) (27) (1.75)$

Single lane storage length = 328': Say 325'

Determining turn lane length also requires some additional considerations. One consideration is the length of the queues in the through lanes. If the turn lanes are not long enough, through

lane queues may prevent turning vehicles from entering the turn lanes leaving the turn lanes nearly empty until the through lane queues begin clearing. This issue could be addressed with lagging lefts but lagging lefts require additional considerations to prevent left turn traps and an operational analysis to determine optimal signal phasing and timing. If through lane queues block the turn lanes, the turn lanes could be lengthened beyond the through lane queues. However, the additional length needed may not be practical.

Another consideration is maximum turn lane length. Once a turn lane becomes too long, the signal cycle cannot serve all the traffic waiting in the turn lane reducing, if not eliminating, the benefits of the extra length. At this point, it may be more practical to add turn lanes or look at other solutions to relieve congestion. When is a turn lane too long? It is difficult to point to an exact number but in the neighborhood of 350 to 400 feet. An operational analysis will provide better evidence regarding the maximum length.

The final consideration that can impact the length of a turn lane is visibility. A turn lane that starts just beyond the crest of a vertical curve may not be visible until a vehicle is at the start of the lane. It may be practical to extend the turn lane to increase its visibility giving drivers more time to react to the lane.

- g. Lane balance should be considered when addressing lane geometrics. Left turn lanes should be opposing or offset to one another. If dual left turn lanes are required on one approach, dual left turn lanes or a wide median should be installed on the opposing approach to promote lane balance. Through lanes should be located so they align with one another as the intersection is traversed. Creating a lane shift through an intersection creates driver confusion.

4. **Agency Geometric Considerations:** The Mn/DOT [Traffic Engineering Manual](#) (Section 9-6.00 Traffic Signal Design) provides a good identification of major issues for design consideration and serves as an example of agency specific criteria. Since this is a PDF document, Sections 9-6.02 through 9-6.05 are provided below:

Intersection geometry is an important element of traffic signal design. The design of traffic signal system hardware and operation of the traffic signal system should be preceded by a thorough evaluation and, if necessary, geometric improvement of the existing intersection. Mn/DOT Section 9-6.03 notes the following geometric elements should be considered:

- a. Pavement width should be adequate for anticipated traffic movements and future capacity requirements. Highway capacity analysis should be performed to get a better understanding of the capacity of the intersection.
- b. If appropriate islands should be designed and constructed so that the driver has adequate reaction distance to them and they are large enough to install a standard signal foundation. Existing shoulders should always be carried through the intersection; this will usually provide enough reaction distance to the island. However, turning radii should be checked to ensure enough setback for comfortable turns.
- c. Turn lanes must provide adequate storage in order to prevent turning traffic from interfering with other traffic movements and thus causing capacity breakdown.
- d. When a median width is more than 30 feet between opposing through lanes, special signal design considerations are necessary (See MN MUTCD, Section 4H). Extremely wide medians confuse drivers on the crossing street, prevent them from being comfortable with opposing traffic, and cause them to lose track of their path. Wide medians also cause

- capacity restrictions because more time is needed for vehicle movements and clearances through the intersection.
- e. Sidewalks should be constructed as close to the center of the corner as possible. Pedestrian crosswalks should be in line with the sidewalk and as close to the intersection as practical.
 - f. Alignment changes within the intersection should be avoided. Vehicles approaching the intersection should be directed through the intersection. Vertical alignments approaching signals must allow for proper signal visibility.
 - g. Driveways within an intersection should be signalized and accommodated by the intersection geometrics. Whenever feasible, the driveways should be located or relocated outside the limits of the intersection.
 - h. The size of corner radii is an important consideration. Excessively large corner radii may obscure intersection limits and create a hazard for bicycles and pedestrians, while very small radii may create a hazard for motorists. Corner radii at signalized intersections should not be less than 20 feet nor more than 60 feet. A turning radius guide for 58 foot vehicles should be used to determine proper corner radii. At intersections where bus routes are located, corner radii should be analyzed giving due consideration to bus maneuvers.
 - i. It may be necessary to relocate utilities such as manholes, catch basins, fire hydrants, overhead power and telephone lines and power poles, to obtain adequate geometrics for signalization. The existence of these utilities must not get in the way of adequate geometrics.
 - j. Pedestrian curb ramps should be considered in accordance with [Chapter 12 - Sidewalks and Bicycle Facilities](#) if sidewalks are present.
 - k. Handhole spacing should be based on the following factors:
 - Location of junction points within the signal system
 - Physical features, such as driveways, utilities, etc.
 - Cable pull length based on size of cable and diameter of conduit

B. Operational Characteristics

The behavior of the traffic at an intersection is another highly important element of signal design. Mn/DOT Section 9-6.03 notes the following elements should be considered:

1. Existing 15 minute vehicle volumes, by vehicle class, and pedestrian volumes, are the most basic operational consideration. Data used should represent intersection operation in peak periods. Saturated approaches should have an upstream count taken to determine the demand volume rather than the service volume at the intersection.
2. Intersection capacity should be determined based on the Highway Capacity Manual and other sources.
3. The vehicle approach posted speeds should be determined for the location of advance detection.
4. Adjacent land uses should be evaluated to identify activities which may conflict with intersection operation. Items that should be considered include entrances, advertising devices, and areas of high pedestrian activity (schools, manufacturing plants, shopping centers, etc.).

5. Crashes within the intersection should be studied to determine causes and possible design solutions.
6. Pedestrian volumes and school-crossing activities should be studied to determine pedestrian routes and necessary design treatments. Pedestrian movements in and around signals should be routed into the intersection crosswalks in front of vehicles stopped for the signal. Provide pedestrian refuges in medians 6 feet and wider.

C. System (Arterial) Considerations

In many cases, an individual traffic control signal must be considered as part of a system, either as one of a series of signals along a linear route, or as one signal in a grid network. Mn/DOT Section 9-6.04 notes the following elements should be considered.

System considerations in signal design should include but are not limited to the following:

1. Adjacent signals should be interconnected whenever they are less than one-half mile apart, when the travel time between adjacent signals is less than the cycle length at each signal, or when platoons leaving one intersection remain intact to the next signal.
2. Properly spaced signalized intersections greatly simplify coordination in planning new signals. Minimum spacing of one-quarter mile is recommended. Irregular signal spacing reduces the overall operational efficiency of the mainline movements and greatly complicates signal coordination.
3. Whenever possible, platoons should be kept intact to allow easier mainline coordination and minimize cross-street delay.
4. New street or roadway construction should anticipate the need for future signals and the need for handholes and conduit, particularly under the roadway.
5. Pretimed controllers are used in built-up urban environments, particularly central business districts. The streets are not excessively wide and the traffic patterns are quite predictable. In this environment, a signal cycle should contain pedestrian movements. Actuated controllers are used in suburban and rural environments. In the rural environment, the actuated controller tends to reduce the number of stops and does not cut off platoons of vehicles. In the suburban environment, the arterial streets tend to be very wide, and the volumes are usually quite high on these arterials. There are not usually many pedestrians crossing such an arterial, so an actuated controller tends to operate much more efficiently, as it is not necessary to time pedestrian intervals except when an actual demand exists.
6. Splits and offsets should be carefully estimated to determine their impact on arterial flow. A split is the relative percentage of green time allocated to each of the various phases at a single intersection. An offset is the travel time between signals, usually expressed in percent of cycle length.
7. Minimum pedestrian walk and clearance timings should be anticipated when designing coordinated signal systems.

D. Signal Design Elements

Mn/DOT Section 9-6.05 notes the following elements should be considered:

1. The most efficient operation of a signal system is attained with the fewest phases that are enough to move traffic without hazardous conflicts. Procedures exist to determine the optimum number of phases for an intersection.
2. The primary consideration in signal head placement is clear visibility. Drivers approaching an intersection shall be given a clear and unmistakable indication of their right-of-way assignment. The number and placement of signal faces shall conform to the requirements of the MUTCD. Overheads should be located as near as practicable to the line of the driver's normal view. When an overhead is to control two lanes, it should be installed over the lane line dividing the two lanes. An overhead should be used over each lane when speeds are above 40 mph. The size of lenses shall be as stated in the MUTCD. See the signal head placement charts in the Signal Design Manual. In general, vehicle signal faces should be placed and aimed to have maximum effectiveness for an approaching driver located a distance from the stop line equal to the distance traveled while reacting to the signal and bringing the vehicle to a stop at an average approach speed. Visors, shields, or visual delimiting should be used to help in directing the signal indication to the approaching traffic, and to reduce sun phantom resulting from external light entering a signal lens.
3. Vehicle detectors should be placed according to the detector spacing chart and the loop placement diagrams.
4. At locations where pedestrians are expected, provisions must be made to control pedestrian activity in and around the signalized intersection. At locations where pedestrians are expected, pedestrian indications shall be provided if minimum pedestrian crossing time exceeds minimum vehicular green time, or if any of the conditions set out in section 4E.3 of the MN MUTCD are met. Pedestrian push buttons should be installed at locations with pedestrian activity where it is not operationally efficient to provide pedestrian timing on every cycle. Pedestrian signal indications shall be mounted, positioned, and aimed so as to be in the line of pedestrians' vision, and to provide maximum visibility at the beginning of the controlled crossing.
5. If it is determined to prohibit pedestrian movement across any approach, that prohibition must be clearly visible to pedestrians by use of Standard Sign R9-3a on each side of the prohibited crosswalk. See part 4 of the MN MUTCD for further information.
6. Street lighting should normally be installed with traffic signals and flashing beacons. The luminaires are generally 250-watt high-pressure sodium vapor luminaires, mounted in the far-right quadrants of the major street. Larger intersections may require additional luminaires. Forty foot mounting heights provide even light distribution. Street lights installed on Type A signal mast-arm poles should be mounted at approximately 350 degrees clockwise from the mast arm in order to provide frontal illumination of any signs mounted on the mast arm.

Signal design must take into account the existing adjacent lighting systems and the equipment available to provide access to the luminaires for relamping and maintenance. The presence of overhead power lines must also be taken into account. These must be designed around or moved.

E. Traffic Signal Operations

The Mn/DOT [Traffic Engineering Manual](#) provides an exceptional discussion on basic traffic signal operations and design considerations. These are not reprinted within this document but these references are noted below.

- [Mn/DOT Traffic Signal Timing and Coordination Manual](#)
- [Traffic Engineering Manual](#)
 - Chapter 2. Traffic Signal Phasing and Operations
 - Chapter 3. Head Placement Charts
 - Chapter 4. Detection
- [Mn/DOT Signal & Lighting Certification Manual](#)

F. Pedestrian Considerations

1. Geometrics:

- a. Geometrics have a significant impact on pedestrian operations and safety at signalized intersections as alluded to in the previous section. Intersection skew, number of lanes, lane width, medians, islands, and curb returns all impact the distance pedestrians must travel to cross an intersection. As the distance to traverse an intersection approach increases, so does the signal timing that must be allocated to the pedestrian clearance interval. Long pedestrian clearance intervals have a negative impact on traffic capacity and operations. A pedestrian actuation will disrupt traffic signal coordination and require several cycles to bring a corridor back into coordination. However, large pedestrian volumes may dictate signal timing resulting in less than optimal conditions for vehicles. A traffic engineer must balance the priorities of vehicles and pedestrians with no calculations or answers that clearly define a solution but do provide guidance.
- b. Right turns present challenges for pedestrians. A driver of a vehicle turning right on red will be looking left for a gap in traffic. A pedestrian approaching from the right may have a walk indication. If the driver sees a gap but does not look back to the right, the pedestrian may not be seen by the driver resulting in a collision. As a result, a traffic engineer must decide whether to allow right turns on red.
- c. Right turn lanes can present additional challenges for pedestrians, especially if the returns are large and channelize traffic with an island. The islands can channelize right turning vehicles away from the traffic signal indications creating difficulties signalizing the right turn movement. Using a stop sign instead of a supplemental signal indication for the channelized right turning movement is not an option. It creates a confusing message when all movements on the approach see green indications, including right turning vehicles, until they are partially through the turning maneuver and see a stop sign. Some agencies assign the right turning vehicles a yield sign but it creates an issue protecting pedestrians. If a pedestrian push button is used at the back-of-curb and pedestrians must cross a right turn lane controlled by a yield sign, it may give pedestrians a false sense of security when crossing in front of right turning vehicles. Drivers of right turning vehicles see a yield sign and look left, away from the pedestrians stepping off the curb, for a gap in traffic. In fact, drivers of right turning vehicles would be looking even farther left due to the channelization and orientation of the vehicles making it even more difficult for drivers to see pedestrians approaching from the right. Consequently, pedestrian volume and safety are important considerations when considering and designing right turn lanes.

- d. The final geometric consideration as it relates to pedestrians is the pedestrian refuge. Right turn islands and medians often double as pedestrian refuges. If islands and medians are intended to be used as pedestrian refuges, they must be large enough to hold pedestrians and be ADA compliant. A traffic engineer must consider the likelihood that pedestrians will stop and get stranded in an island or median. On large approaches, it may be intended that pedestrians only cross a portion of the approach and stop in a median or island. As a result, a traffic engineer must decide whether to install supplemental push buttons in the right turn island or median. If islands and medians are not intended to function as pedestrian refuges, they must be located so they do not obstruct the path of pedestrians.
2. **Visibility:** Visibility is important to the safe operation of the pedestrian indications. Pedestrian indications as well as the push buttons should be easily located by pedestrians. Consider where vehicles, especially large trucks, may stop so they do not obstruct the view of the pedestrian indications. This will require careful location of median noses, stop bars, crosswalks, and the pedestrian heads. Finally, make sure there are no obstructions in the returns that may prevent drivers and pedestrians from seeing one another such as the signal cabinet or vegetation.
3. **Special Considerations:** Circumstances often arise that require special considerations. For example, children may have difficulty understanding the meaning of pedestrian indications. Count down pedestrian heads may be easier for children to understand; therefore, have increased value in school zones. Count down pedestrian heads may also have added value on wide approaches. The flashing numbers can attract a person's eye and the numbers tell a pedestrian how much time they have to cross which has added value on very wide approaches. There may be a particular area within a city that has a high concentration of visually impaired. In this case, audible pedestrian indications may have added benefit. In many cases, some extra thought and minimal dollars can change a design from adequate to desirable.
4. **Americans with Disabilities Act:** The Americans with Disabilities Act (ADA) addresses several design requirements relating to pedestrians. ADA addresses design requirements for items such as sidewalk ramps, truncated domes, and pedestrian push buttons. These topics are addressed in detail in [Chapter 12 - Sidewalks and Bicycle Facilities](#) and other design manuals such as the MUTCD and the AASHTO Policy on Geometric Design of Highways and Streets.
 - a. **Accessible Pedestrian Signals (APS):** Each traffic signal project location should be evaluated to determine the need for accessible pedestrian signals, especially if the project location presents difficulties for individuals with visual disabilities. An engineering study should be completed that determines the needs for pedestrians with visual disabilities to safely cross the street. The study should consider the following factors:
 - Potential demand for accessible pedestrian signals
 - Requests for accessible pedestrian signals by individuals with visual disabilities
 - Traffic volumes when pedestrians are present, including low volumes or high right turn on red volumes
 - The complexity of the signal phasing, such as split phasing, protected turn phases, leading pedestrian intervals, and exclusive pedestrian phases
 - The complexity of the intersection geometry

One tool that is available for evaluation of the need for APS and also prioritizing the order for installing APS equipment on crosswalks can be found at www.apsguide.org developed by the National Cooperative Highway Research Program (NCHRP).

If APS are warranted, it is necessary to provide information to the pedestrian in non-visual formats. This will include audible tones and vibrotactile surfaces. Pedestrian push buttons should have locator tones for the visually impaired individual to be able to access the signal. Consistency throughout the pedestrian system is very important. Contact the Jurisdictional Engineer regarding the standards and equipment types that should be incorporated into the design of the accessible pedestrian signal system. New tones such as clicks, ticks, and other electronic sounds have replaced the cuckoos and chirping tones of past systems.

b. APS Design Elements: Refer to MUTCD Sections 4E.08 through 4E.13 and the following information.

- 1) Push Button Stations:** An APS push button station is a weather-tight housing with a 2 inch diameter push button, a speaker, and a pedestrian sign. Braille signing, raised print or a tactile map of the crosswalk may also be provided. The push button has a vibrotactile arrow pointing in the direction of the crossing.
- 2) Location of Pedestrian Push Buttons:** Push buttons should be located adjacent to the sidewalk, between 1.5 and 6 feet from the edge of curb, shoulder, or pavement and no more than 5 feet from the outside crosswalk line. Where physical constraints make the 6 feet maximum impractical, push buttons should be located no more than 10 feet from the edge of curb, shoulder, or pavement. Where two push buttons are provided on the same corner of the intersection, they should be separated by at least 10 feet. If the 10 feet separation is not feasible, audible speech walk messages are required. Supplemental push button poles or posts will typically be needed to meet the above criteria. Push buttons should be mounted at a height of approximately 3.5 feet, but no more than 4 feet above the adjacent sidewalk. The push button should be located so pedestrians using the audible or vibrotactile indication can align themselves and prepare for the crossing while waiting close to the push button station and the crossing departure point.
- 3) Locator Tone:** APS push buttons have a locator tone to allow visually impaired individuals to access the signal. The locator tone should be audible 6 to 12 feet from the push button. The locator tone is active during the pedestrian clearance and “DON’T WALK” intervals.
- 4) Walk Indications:**
 - In addition to visual indications, APS include audible and vibrotactile walk indications. When at least 10 feet separation is provided between pedestrian push button stations, the audible walk indication is a percussive tone. If 10 feet separation is not provided, speech messages are required. The speech message should name the street to be crossed and indicate that the walk sign is on. For example: “Main. Walk sign is on to cross Main.” Other audible messages may be developed, including counting down the pedestrian clearance time, depending on the needs of the particular crosswalk or intersection. Designations such as “Street” or “Avenue” should not be used unless necessary to avoid ambiguity at a particular location. If the traffic signal rests in WALK, the tone/message should be limited to 7 seconds and be repeated with each actuation.
 - The vibrotactile walk indication is provided by a high visual contrast tactile arrow on the push button that vibrates during the walk interval. The vibrotactile indication is particularly useful to individuals who have both visual and hearing impairments. The pedestrian must be able to stand with a hand on the device while being aligned and waiting to begin the crossing. The arrow should be aligned parallel to the direction of travel on the associated crosswalk.

c. APS System Options:

- Products currently in the marketplace involve use of 2-wire or 4-wire systems, indicating the number of wires between the push button station and the control unit (CU). The 2-wire system uses a central CU mounted in the controller cabinet, and may provide Ethernet connectivity. Advantages of this system include minimal field wiring required on retrofit applications and central control of multiple crossings.
- The 4-wire system requires a separate CU mounted in the applicable pedestrian signal head for each push button station. In addition to the typical two wires between the push button and the controller cabinet, a 4-wire cable must be provided between the push button station and the CU. This system may be more cost effective for installations with only one or two crossings.

d. APS Compliant Equipment: The following equipment currently meets 2009 MUTCD and 2011 proposed public right-of-way accessibility guidelines (PROWAG) for accessible pedestrian signals. Other compliant equipment may also be available.

- Advisor Guide and Advisor Advanced Pedestrian Stations (AGPS and AAPS) manufactured by Campbell Company.
- EZ Communicator Navigator APS manufactured by Polara.

e. Location of Pedestrian Push Buttons: It is common to see a narrow grass strip between the sidewalk and pole used to mount the push buttons or to only see sidewalk on one side of a pole containing multiple push buttons. It is difficult to impossible for a person in a wheelchair to reach the push button in cases like these since it often requires the person to struggle with one wheel in the grass and one on the sidewalk. As a result, sidewalks must be paved up to the pole used to mount the push buttons and be at a reasonable slope. There should also be sidewalk on each side of a pole that has a push button. The MUTCD requires a pedestrian push button mounting height of approximately 3.5 feet above the sidewalk; keep in mind that the 3.5 feet is above the grade where the pedestrian would be when accessing the button. Often times pole foundation elevations end up above grade and installing a push button based on the foundation elevation and not the ground elevation where the pedestrian accesses the button results in a mounting height that is too high. Finally, consider the proximity of the push buttons to the street. If the poles used to mount the push buttons are too far from the street, pedestrians will not use the push buttons. Consider installing supplemental poles closer to the street for mounting the push buttons.

G. Driver and Pedestrian Expectations

Other traffic signal design considerations involve driver and pedestrian expectancy. A traffic engineer must look beyond the traffic signal being designed and consider the characteristics of the corridor and the attributes of the existing traffic signals along the corridor. For example, left turn phasing should be applied consistently and not switch between protected only and protected/permissive without legitimate reasons. If pedestrian signal heads are used, they should be used consistently and not sporadically where one intersection uses the heads and the next intersection relies on vehicular signal heads to guide pedestrians. Traffic signal head style, placement, and orientation should be consistent along a corridor as well as sign type, size, and location. Intersections should not randomly switch between doghouse and vertical five section heads, center of lane and lane line placement, or vertical and horizontal signal head orientation. Consistently applied design criteria improve driver and pedestrian expectations which typically promote safety and operations. However, circumstances exist that may, at times, require changes to design criteria to increase vehicle and pedestrian safety and operations.

H. Future Development and Improvements

One of the biggest traffic signal design challenges is designing a traffic signal in an area that is under developed or being redeveloped. Under these circumstances, much of the data needed for design is either unknown or unstable. Land uses are often modified and business prospects continually change often having significant impacts on existing and future traffic volumes. In addition, the rate at which traffic volumes will increase is difficult to determine. In such cases, the traffic signal designer must work closely with adjacent area land use planning agencies to work towards reasonable expectations for future travel demands and overall operations. Future phases can be accommodated for within the design to significantly reduce the need to replace foundation locations, adjust mast-arm lengths, or add additional functionality to the traffic signal. These simple steps can build credibility with the public and add considerable efficiency to the traffic signal design and overall engineering process.

Traffic Signal Specifications Information

This section provides design information that complements and is organized similar to [SUDAS Specifications Section 8010](#), which includes:

Part 1 - General

Part 1 provides direction on general items such as submittals; substitutions; delivery, storage, and handling; scheduling and conflicts; and measurement and payment.

Part 2 - Products

Part 2 describes the products to be provided and is arranged as follows:

- 2.01 Underground
- 2.02 Detection
- 2.03 Communications
- 2.04 Cabinet and Controller
- 2.05 Poles, Heads, and Signs

Part 3 - Execution

Part 3 describes how these products should be installed and matches the arrangement described in Part 2, with the following additions:

- 3.06 Temporary Traffic Signal
- 3.07 Surface Restoration
- 3.08 Testing
- 3.09 Documentation

The information below provides selective guidance on the specifications.

A. Part 1 - General

1. **Submittals:** There are several key submittals required of the contractor following award of the project. These are described below.
 - a. **Schedule of Unit Prices:**
 - 1) **Document:** Prepared by the traffic signal designer and included within the contract documents (generally attached to the back of the traffic signal specifications).
 - 2) **Purpose:** Contracting authority approval of the unit pricing for all major traffic signal items. Establish unit pricing for change order work if needed. Used to estimate partial payments.
 - 3) **Includes:** Identification of major traffic signal items along with an estimate of quantity and units of measurement. Two additional blank columns are provided (unit price, and unit extension).
 - 4) **Contractor Action:** Within 30 days after award, the contractor is required to submit a completed schedule of unit prices to the contracting authority for engineer approval.

- 5) **Engineer Action:** Review the schedule in a timely manner. Check the appropriateness of each unit price, the accuracy of each unit extension calculation, and ensure that the grand total for all unit extensions matches the lump sum bid item for traffic signalization. Upon acceptance, sign and date the document and provide a copy to the contractor.
- b. Material and Equipment List:**
- 1) **Document:** Prepared by the traffic signal designer and included within the contract documents (generally attached to the back of the traffic signal specifications).
 - 2) **Purpose:** Contracting authority approval of the make and model numbers for all major traffic signal items.
 - 3) **Includes:** Identification of major traffic signal items along with an estimate of quantity and units of measurement. Two additional blank columns are provided (manufacturers name and each items model number).
 - 4) **Contractor Action:** Within 30 days after award, the contractor is required to submit a completed list of materials and equipment to the contracting authority for engineer approval.
 - 5) **Engineer Action:** Review the schedule in a timely manner. Check the appropriateness of each identified manufacturer and model number. Upon acceptance, sign and date the schedule and provide a copy to the contractor.
- c. Contractor Certification:**
- 1) **Document:** Prepared by the contractor on company letterhead.
 - 2) **Purpose:** Contracting authority approval of key project personnel.
 - 3) **Includes:** Name, contact information, and certification of the Level II International Municipal Signal Association (IMSA) Certified Traffic Signal Technician(s) working on the project.
 - 4) **Contractor Action:** Within 30 days after award, the contractor is required to submit the contractor certification to the contracting authority for engineer approval.
 - 5) **Engineer Action:** Review the appropriateness of the information and on acceptance, sign and date the document, and provide a copy to the contractor.
- d. Shop Drawings:**
- 1) **Document:** Prepared by the traffic signal pole supplier for the contractor.
 - 2) **Purpose:** Contracting authority approval of traffic signal poles, supports, and related hardware.
 - 3) **Includes:** Shop drawing information detailing each traffic signal pole, accompanying parts, and necessary hardware.
 - 4) **Contractor Action:** Within 30 days after award, submit shop drawings to the contracting authority for engineer approval.
 - 5) **Engineer Action:** Review the shop drawings in a timely manner. Check the appropriateness of each detail. Upon acceptance, sign and date the shop drawings and provide a copy to the contractor.
- e. Catalog Cuts:**
- 1) **Document:** Prepared by the traffic signal equipment supplier for the contractor.
 - 2) **Purpose:** Contracting authority approval of all items within the equipment and materials list as well as for supporting components.
 - 3) **Includes:** Catalog cut information detailing the make, model number, manufacturer, and specific details for all traffic signal equipment.
 - 4) **Contractor Action:** Within 30 days after award, submit catalog cuts to the contracting authority for engineer approval.

- 5) **Engineer Action:** Review the catalog cuts in a timely manner. Check the appropriateness of each item. Upon acceptance, sign and date the catalog cut documents and provide a copy to the contractor.
2. **Substitutions:** Comply with [SUDAS Specifications Division 1 - General Provisions and Covenants](#).
3. **Delivery, Storage, and Handling:** Comply with [SUDAS Specifications Division 1 - General Provisions and Covenants](#).
4. **Scheduling and Conflicts:** Comply with [SUDAS Specifications Division 1 - General Provisions and Covenants](#).
5. **Special Requirements:** Comply with the current edition of the MUTCD as adopted by the Iowa DOT.
6. **Measurement and Payment:** Traffic signal work is typically bid as a lump sum item of which no measurements are made. However, partial payments to the contractor are established through measuring installed quantities and applying these quantities to the appropriate approved unit price (see Schedule of Unit Prices above).

B. Part 2 - Products

1. Underground:

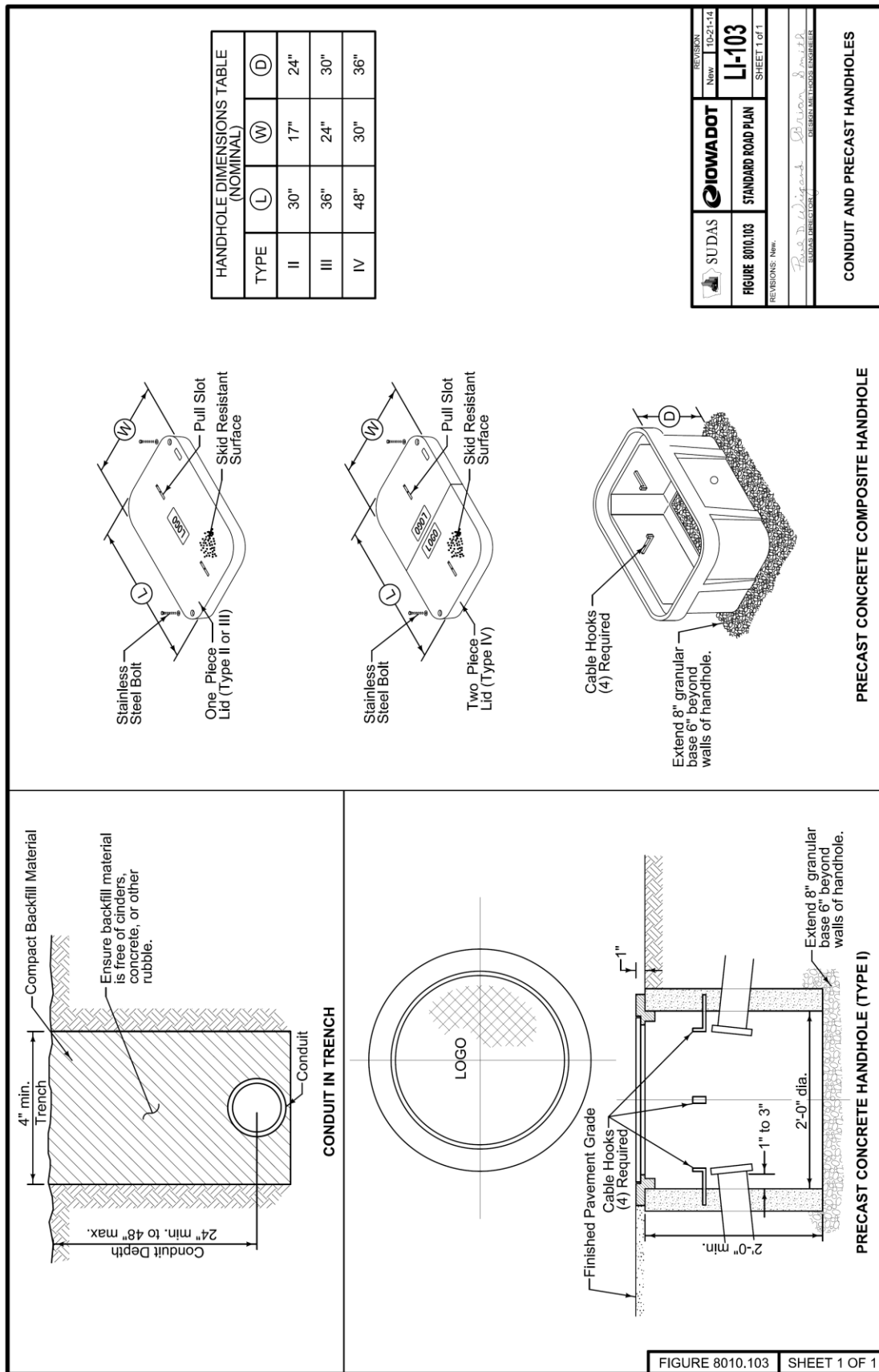
- a. **Handhole:** Handholes are a critical component to traffic signal design. The standard precast concrete handhole shown in Figure 13A-5.01 is typically used at all locations except where fiber optic cables are used and adjacent to the controller cabinet.

Composite handholes can come in all shapes and sizes (see [Quazite](#) example table) and must be specified by the Engineer. These are typically made of a polymer concrete. Polymer concrete is made from selectively-graded aggregates in combination with a polymer resin system. When combined through a process of mixing, molding and curing, an extremely powerful cross-linked bond is formed. Precast polymer concrete is reinforced with fiberglass for strength and rigidity.

The designer should ensure that the contract documents clearly distinguish between handhole types, sizes, and desired locations. Handholes are typically uniquely numbered on the contract documents.

An online resource can be found through Chapter 12 - Handholes, Pulling Vaults, and Junction Boxes from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for considering handhole features and functions along with execution issues such as installation, inspection, and key points to remember.

Figure 13A-5.01: Conduit and Handholes
 (SUDAS Specifications Figure 8010.103)



- b. Conduit:** The SUDAS Specifications allow both steel and PVC plastic conduit. Steel conduit is typically used on all service risers and plastic PVC or HDPE is used at all other locations. A typical signal installation will use a variety of conduit sizes. When connecting HDPE conduit to PVC conduit, the designer should work with the Contractor to clarify the method or materials to be used.

A conduit check list from Mn/DOT [Signal Design Documents, Checklists, and Worksheets](#) is noted below: The designer should ensure the following:

- Conduit size and cables listed.
- Correct symbol for in-place conduit.
- Correct symbol for proposed conduit.
- Check for conflict with in place underground utilities.
- Conduit fill less than 40% (Check).
- 3 inch RSC minimum size conduit under all public traveled roadways.
- Spare 4 inches of conduit out of controller cabinet for future use, threaded and capped.
- Conduit runs for interconnect should be as straight as possible.
- No PVC above ground (for example: bridge crossings and wood pole systems).
- All conduits except those within pads shall drain.
- Primary power shall be in a separate conduit run and separate hand holes.
- Size of bends and elbows in conduit in accordance with National Electrical Code or UL guidelines.
- If conduit is suspended under a bridge, does the distance between supports conform to code, is a hanger detail given in plan, and are expansion fittings called for?
- Conduit placed under in-place pavement does not need to be labeled (bored or pushed).

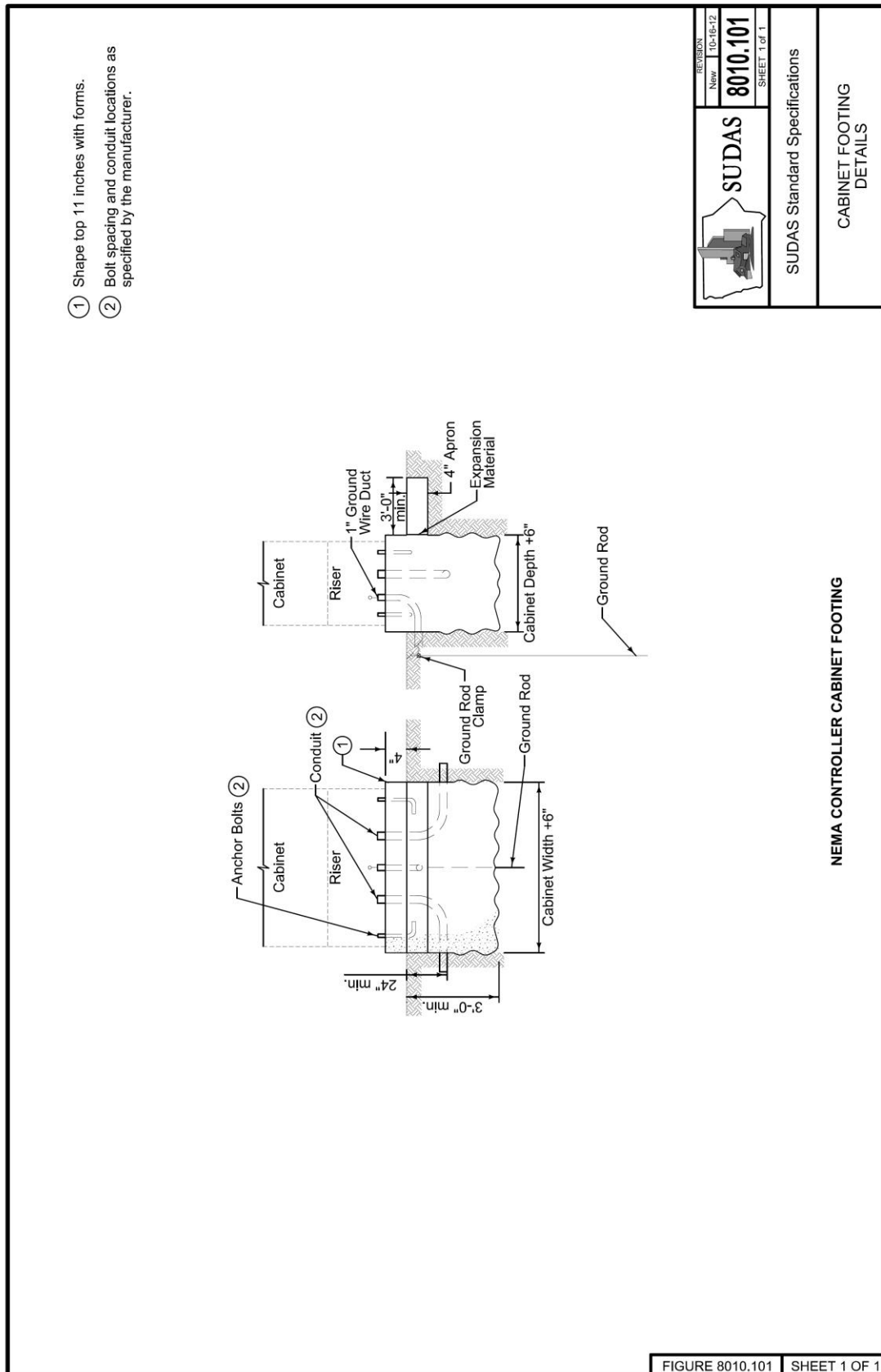
An online resource can be found through Chapter 11 - Conduits and Fittings from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for considering conduit installation and features.

- c. Wiring and Cable:** Signalized intersections require a variety of standard wires and cables; however, the number, size, and quantity of extra conductors pulled can vary by agency. The designer should include sufficient details to ensure the clear identification of cable runs by conduit. The inspector should make sure all wires are terminated neatly and in an organized fashion. With the exception of detector lead-in wires, no splices are allowed within handholes. All plan terminology should be consistent for example:
- Cable symbols correct (3/C #12, 2/C #14, 3/C #20 all different, for example).
 - Ped indications on different phases shall have separate 3/C #12 cables.
 - Separate 2/C #14 for each detector.
 - Provide spares for future expansion of system, if necessary, and label them.

An online resource can be found through Chapter 15 - Wiring from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for labeling and training wires (very Mn/DOT specific though).

- d. Foundations:** Signalized intersections require footings or foundations for all poles, controller pads, and other service cabinets such as fiber optic hubs or electrical service panels. Controller footing details are included for NEMA controller cabinets as shown in Figure 13A-5.02. The designer should ensure that the plans reflect any desired future use spare conduit stubs out of the foundation.

Figure 13A-5.02: Cabinet Footing Details
([SUDAS Specifications Figure 8010.101](#))



Foundation size and depths vary according to pole style, mast-arm length, and pole loadings. The SUDAS Specifications provide figures for both pedestal poles and for mast-arm poles (Figure 13A-5.04). SUDAS standard Type A mast arm pole foundation in soil designs (Table 13A-5.01 and Figure 13A-5.04) are based on the following guidelines, parameters, and assumptions:

- Broms' method for lateral resistance (moment/shear design) per AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals*, 6th Edition, 2013 (AASHTO LTS-6), with a safety factor of 2.86, which accounts for the possible under capacity of the soil strength (0.7) and the overload factor for the loadings (2.0).
- Alpha method for torsion design per FHWA-NHI-10-016 *Drilled Shafts: Construction Procedures and LRFD Design Methods*, May 2010, with a safety factor of 1.0.
- Disturbed soil due to frost: 2.5 feet for moment/shear design, 5.0 feet for torsion design. Broms' method as presented in AASHTO LTS-6 includes an additional 1.5 diameters of foundation length to be added to the minimum foundation length required. The maximum value of 1.5 diameters or 2.5 feet shall be used when determining the disturbed soil for moment/shear design.
- Groundwater is present for moment/shear and torsion designs.
- Pole loadings as shown in Figure 13A-5.03, with poles designed per AASHTO LTS-6 specifications. Basic wind speed equals 90 mph with a 50 year mean recurrence interval and gust effect factor of 1.14 for strength design. Use Category II for fatigue design. Apply only natural wind gust loads (i.e. do not apply galloping loads, vortex shedding loads, or truck-induced gust loads) for fatigue design. Install vibration mitigation devices on all traffic signal pole mast arms over 60 feet in length as shown in the figures.
- Cohesive soils along the length of the foundation with an average blow count (N60) greater than or equal to 8, which equates to an average unconfined compressive strength (Qu) greater than or equal to 2.0 kips per square foot.
- Reinforced concrete design per AASHTO LTS-6 specifications.

For pole loading conditions greater than shown in Figure 13A-5.03, granular soils, or lower strength soils, special foundation designs will be required. Soil boring testing should be performed prior to construction to verify soil types and strengths if non-typical soils are suspected. If rock is anticipated at the project site and the designer intends to utilize the Type C mast arm pole foundation in rock or a Type B foundation (see Figure 13A-5.04), determine rock quality through a subsurface investigation completed by a geotechnical engineer licensed in Iowa. If rock is encountered unexpectedly, the contractor may undertake a subsurface evaluation conducted by a geotechnical engineer licensed in Iowa to determine the quality of the rocks encountered. Based on that investigation, the Engineer may approve the use of a Type B or Type C foundation in rock if requested by the contractor.

Table 13A-5.01: Standard Mast Arm Pole Foundation Designs

Loading Type (Figure 13A-5.03)	Maximum Mast Arm Length (feet)
1	35
2	45
3	55
3	60
4	70
4	80
4	90
4	100

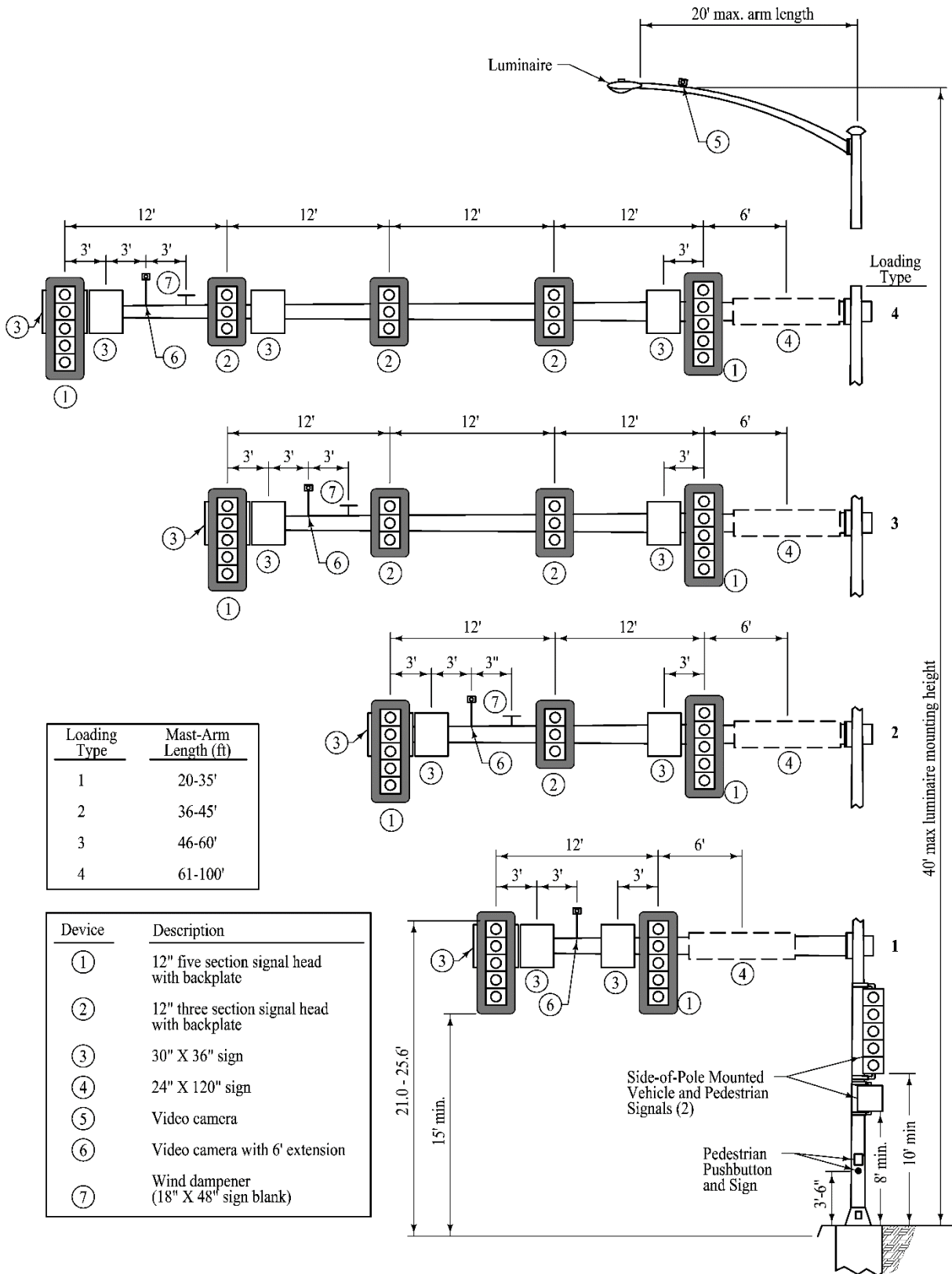
Figure 13A-5.03: Mast Arm Pole Loadings for Standard Foundation Designs

Figure 13A-5.04: Pole Foundation Details
(SUDAS Specifications Figure 8010.102)

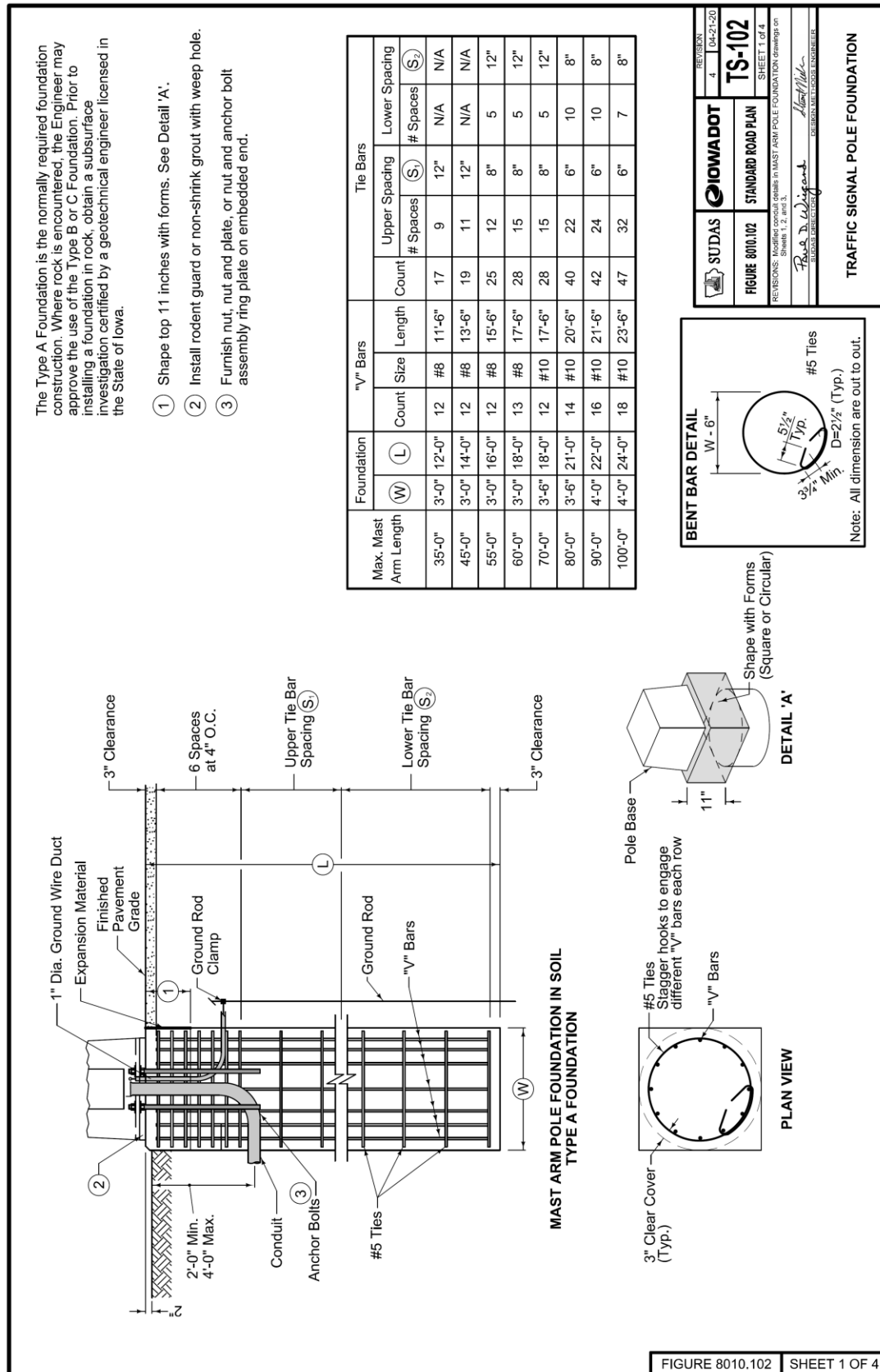


Figure 13A-5.04 (Continued): Pole Foundation Details
(SUDAS Specifications Figure 8010.102)

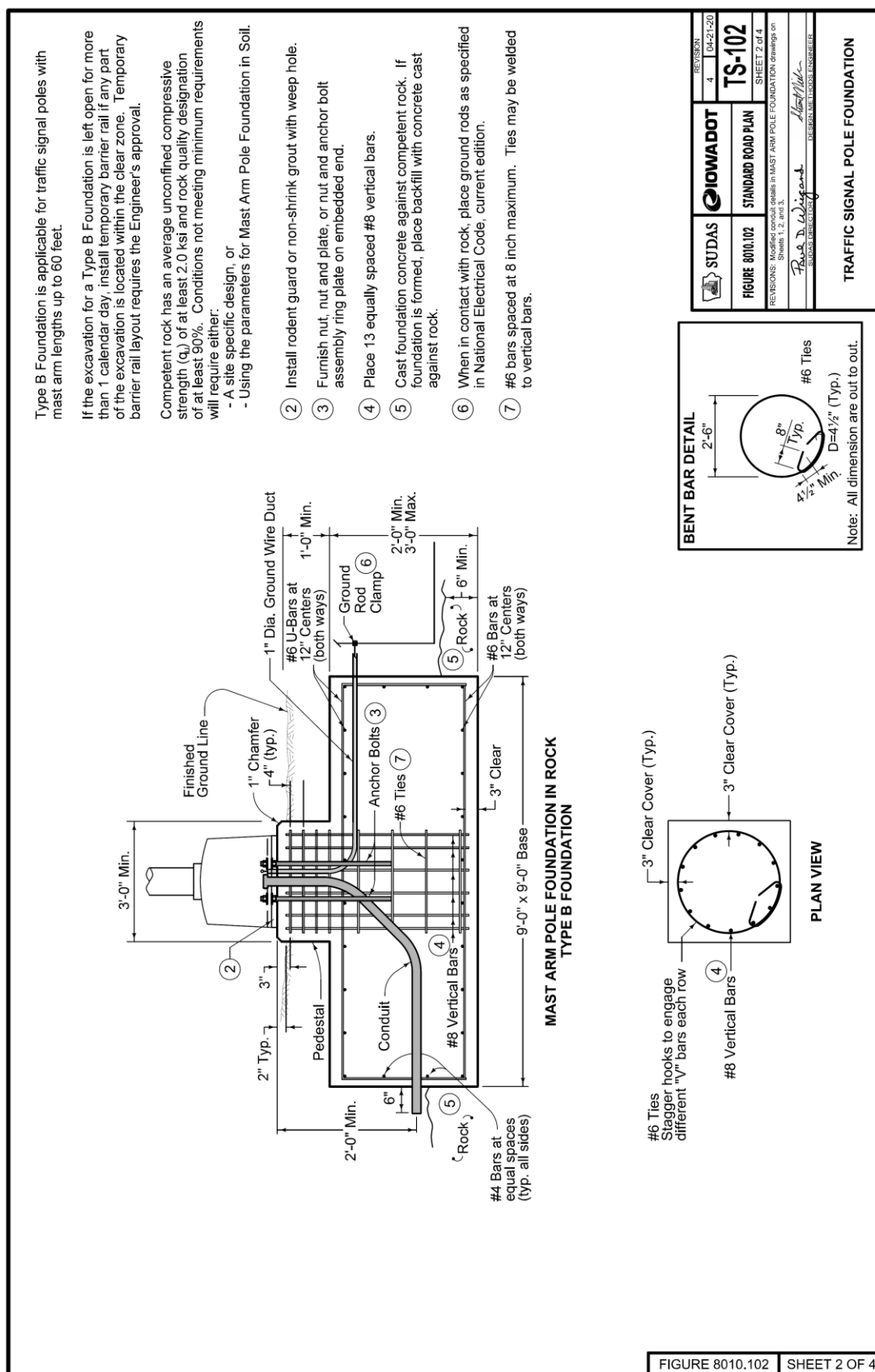


Figure 13A-5.04 (Continued): Pole Foundation Details
 (SUDAS Specifications Figure 8010.102)

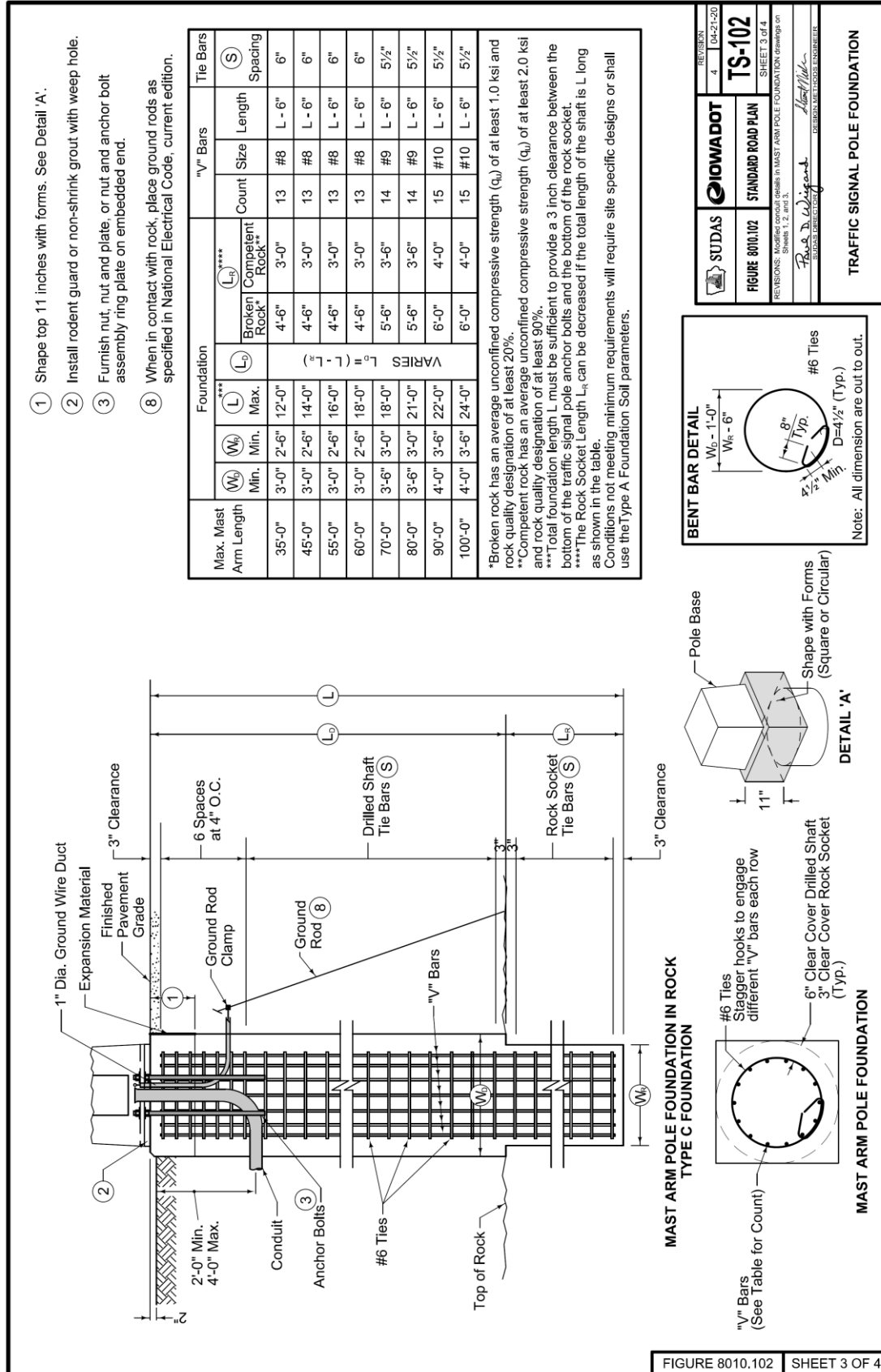
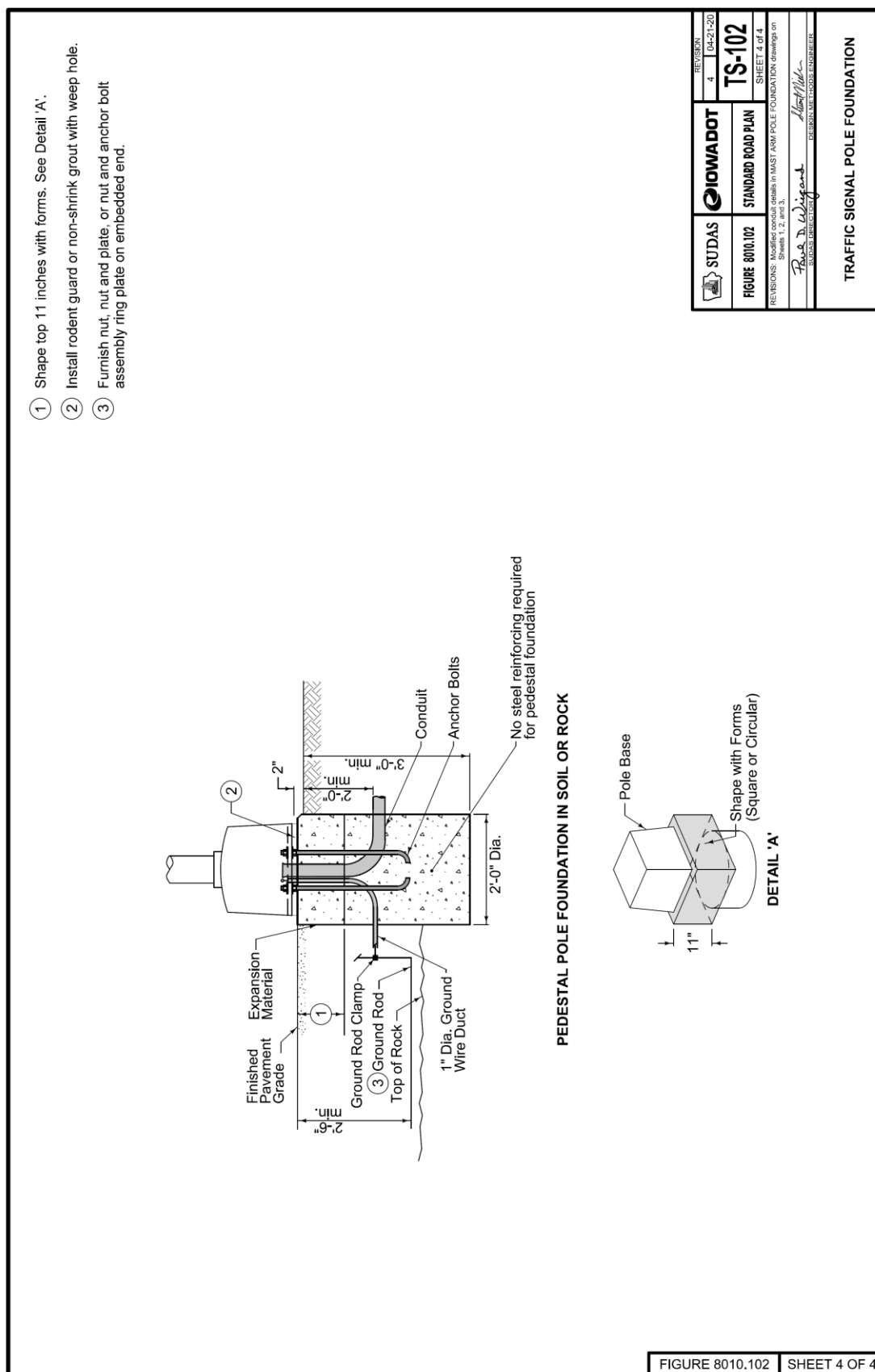


Figure 13A-5.04 (Continued): Pole Foundation Details
(SUDAS Specifications Figure 8010.102)



The designer should ensure that all foundations:

- Are located in compliance with applicable clear zone requirements
- Do not conflict with pedestrian walkways or ramps
- Are at the proper finish grade elevation

An online resource can be found through Chapter 10 - Foundations and Equipment Pads from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for foundation types and installation details.

- e. **Bonding and Grounding:** All traffic signal installations must be bonded and grounded according to the National Electrical Code.

Bonding is defined in the Code Book as the permanent joining of metallic parts required to be electrically connected. In a traffic signal, the term is used to describe the electrical and mechanical connection of conduit, metal poles, cabinets, and service equipment.

Grounding is defined in the Code as a conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conductive body that serves in place of earth.

The designer should ensure that the contract documents include sufficient notation for the traffic signalized intersection to be properly bonded and grounded. This includes placing ground rods at each traffic signal pole and at the controller as well as through use of bonding and grounding jumpers within the handholes.

An online resource can be found through Chapter 13 - Grounding and Bonding from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for bonding and grounding details.

2. **Detection:** Detectors provide vehicle and pedestrian inputs to the traffic signal controller. Proper detector installation, operation, and maintenance is critical to the safe and efficient operation of any signalized intersection. An online resource to learn more about detection styles, modes, and typical layouts can be found within Chapter 9 - Traffic Signals from Mn/DOT's [Traffic Engineering Manual](#). Since this document is a PDF, some of the information from this source is provided below.

Detector sizes and locations vary by agency and by location. SUDAS provides a standard drawing for a typical rectangular detector loop (Figure 13A-5.05).

An online resource can be found through [Chapter 16](#) - Vehicle Detection from [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for installation and mounting details.

- a. **Inductive Loop Vehicle Detector:** The most common type of vehicle detection device in use today is the inductive loop. This is a loop of wire imbedded in the pavement (saw cut in existing concrete or NMC loop in new concrete) carrying a small electrical current. When a large mass of ferrous metal passes over the loop, the magnetic field is disturbed and generates, or induces, a change in resonant frequency in the wire. This change in frequency is then recognized by the detector amplifier and signals the controller that a vehicle is present.

Figure 13A-5.05: Inductive Loop Vehicle Detectors
 (SUDAS Specifications Figure 8010.104)

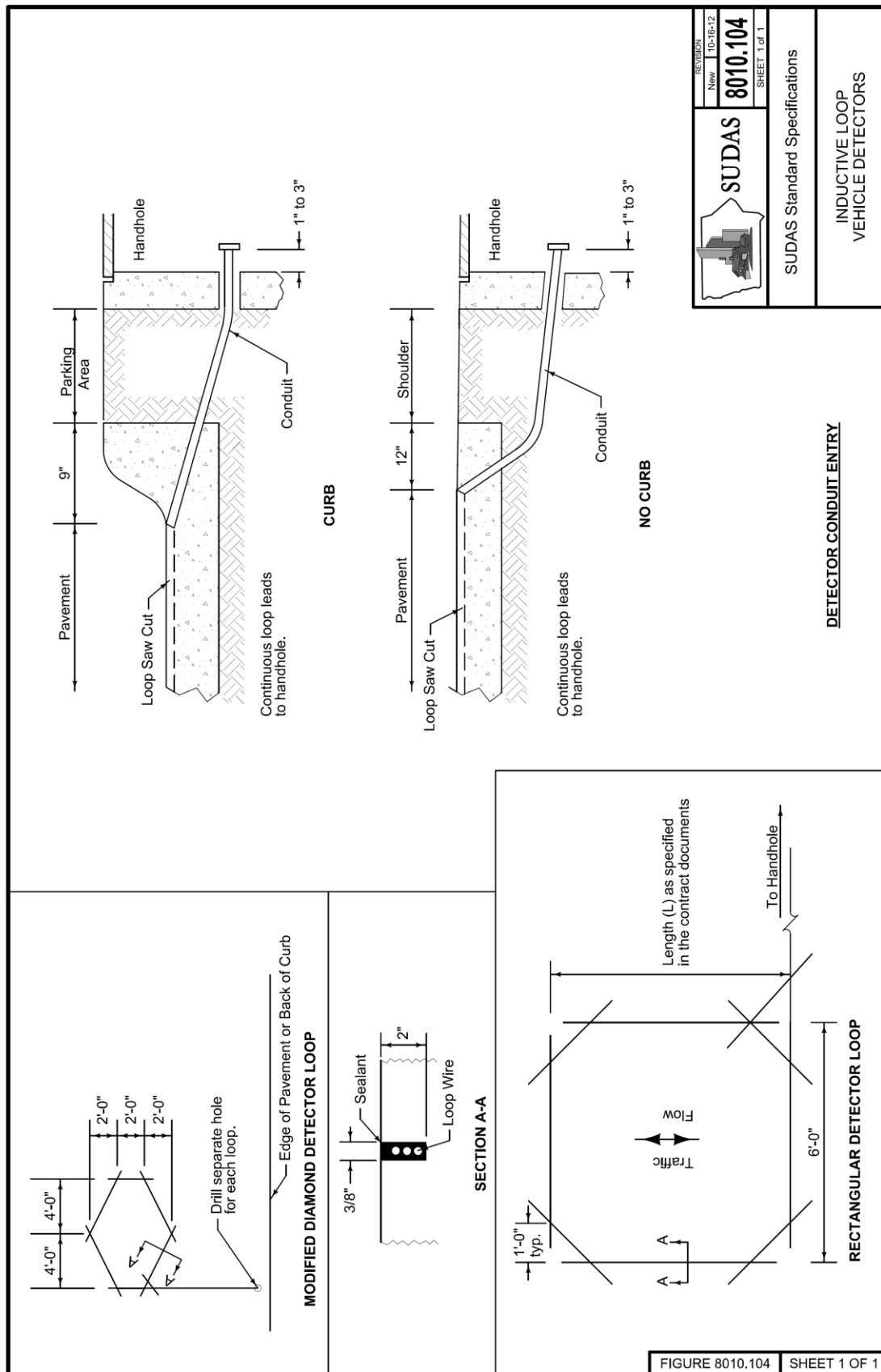


FIGURE 8010.104

SHEET 1 OF 1

- b. Pedestrian Push Button Detector:** There are a number of ways to provide pedestrian actuation at a signalized intersection. The most common equipment used by far is the pedestrian pushbutton detector. Pressing the button provides a contact closure that actuates the call. There are plenty of examples of good and bad pedestrian pushbutton placement; however, part of the problem is getting the pedestrian to use the button. Specific information regarding pedestrian detectors can be found in the MUTCD [Section 4E.08 Pedestrian Detectors](#).

An online resource can be found through Chapter 19 - Accessible Pedestrian Signal Push Buttons from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

- c. Video Detection Camera System:** Vehicle detection by video cameras is a popular form of vehicle detection within Iowa. The rapid processing of video images provides the detection outputs to the controller. The designer should carefully consider the type of equipment necessary to provide video detection, the maintenance needs of this equipment, and the specific installation and mounting requirements necessary.

Designers should consider relevant manufacturer recommendations and other online resources such as the [Guidelines for Using Video Detection at Intersections and Interchanges](#) by Bonneson at Texas Transportation Institute.

- d. Microwave Vehicle Detector:** Microwave detection is often used within Iowa during temporary signal control to provide simple, non-intrusive vehicle detection. A variety of styles and levels of sophistication exist in the market today.
- 3. Communications:** The designer may be required to provide supplemental specifications for these items given the highly proprietary nature of this equipment and the needs of the contracting agency. Generic specifications have been provided in the SUDAS Specifications.
- 4. Cabinet and Controller:** The designer may be required to provide supplemental specifications for the controller, cabinet, and emergency vehicle pre-emption system given the highly proprietary nature of this equipment. Generic specifications have been provided in the SUDAS Specifications. New information was added to the specifications regarding uninterruptable power supply battery back-up system. The designer should carefully consider the cabinet and mounting requirements of the battery back-up system.

An online resource can be found through Chapter 22 - Traffic Signal Cabinets from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

5. Poles, Heads, and Signs:

- a. Vehicle Traffic Signal Head Assembly:** Vehicle signal heads must comply with the following MUTCD sections:

[Section 4D.16](#) Number and Arrangement of Signal Sections in Vehicular Traffic Control Signal Faces

[Section 4D.17](#) Visibility, Shielding, and Positioning of Signal Faces

[Section 4D.18](#) Design, Illumination, and Color of Signal Sections

An online resource can be found through Chapter 18 - Signal Heads from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

- b. Pedestrian Signal Head Assembly:** Pedestrian vehicle signal heads must comply with the following MUTCD sections:

[Section 4E.01](#) Pedestrian Signal Heads

[Section 4E.02](#) Meaning of Pedestrian Signal Head Indications

[Section 4E.03](#) Application of Pedestrian Signal Heads

[Section 4E.04](#) Size, Design, and Illumination of Pedestrian Signal Head Indications

[Section 4E.05](#) Location and Height of Pedestrian Signal Heads

[Section 4E.06](#) Accessible Pedestrian Signals

[Section 4E.07](#) Countdown Pedestrian Signals

- c. Traffic Signal Poles and Mast Arms:** Signalized intersections require poles and mast arms to achieve proper traffic signal and pedestrian head placement. Mast arm details and typical loadings are shown on Figure 13A-5.03; additional mast arm details are shown on Figure 13A-5.06. The designer should ensure that the plan locations comply with all clear zone, sight restriction, and pedestrian flow criteria. Vertical clearance to overhead utility lines is a constant issue that designers should take note of during pre-design field activities. Although the minimum height from the pavement to the bottom of the signal housing is 15 feet, the designer should consider the street classification and the volume of large trucks in establishing the signal height above the pavement. However, the top of the signal housing cannot exceed 25.6 feet above the pavement. If the project being designed has specific requirements relative to the elevation of the end of the mast arm in relation to the connecting point on the vertical pole, include those requirements in the special provisions of the contract documents.

An online resource can be found through Chapter 17 - Mast Arm Poles and Pedestals from Mn/DOT's [Lighting and Signal Certification Field Guide](#), which provides the designer with a photographic resource for style, installation, and mounting details.

- d. Traffic Signal Pedestal Poles:** Pedestal poles provide alternate mounting heights for signal and pedestrian heads and are much easier to locate within a tight right-of-way. Pedestal pole details and typical head mounting information are shown in Figure 13A-5.07.
- e. Traffic Signs:** The designer must ensure that all signs comply with Iowa DOT standards and the MUTCD.

Figure 13A-5.06: Mast Arm Pole Details
[\(SUDAS Specifications Figure 8010.105\)](#)

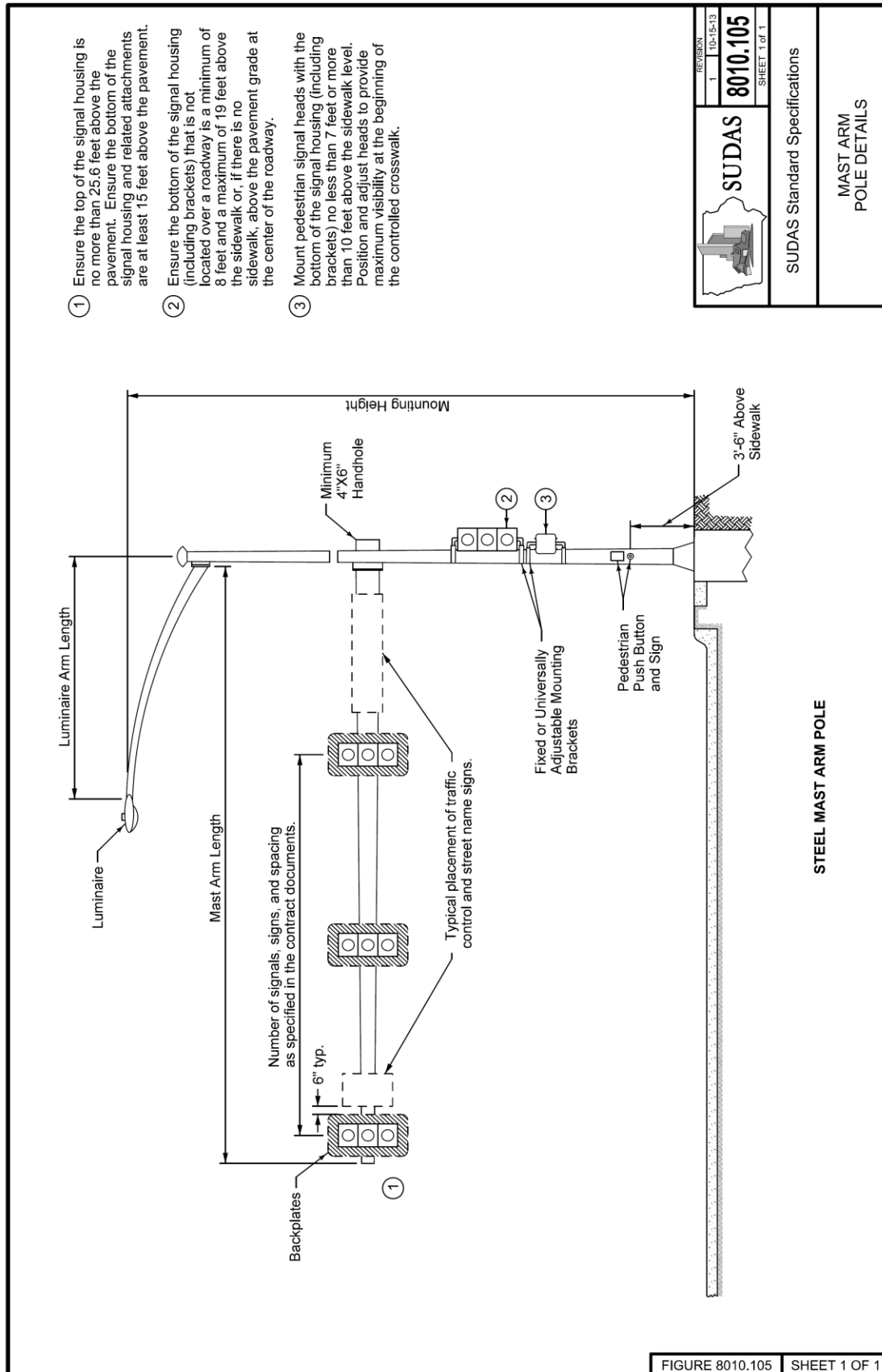
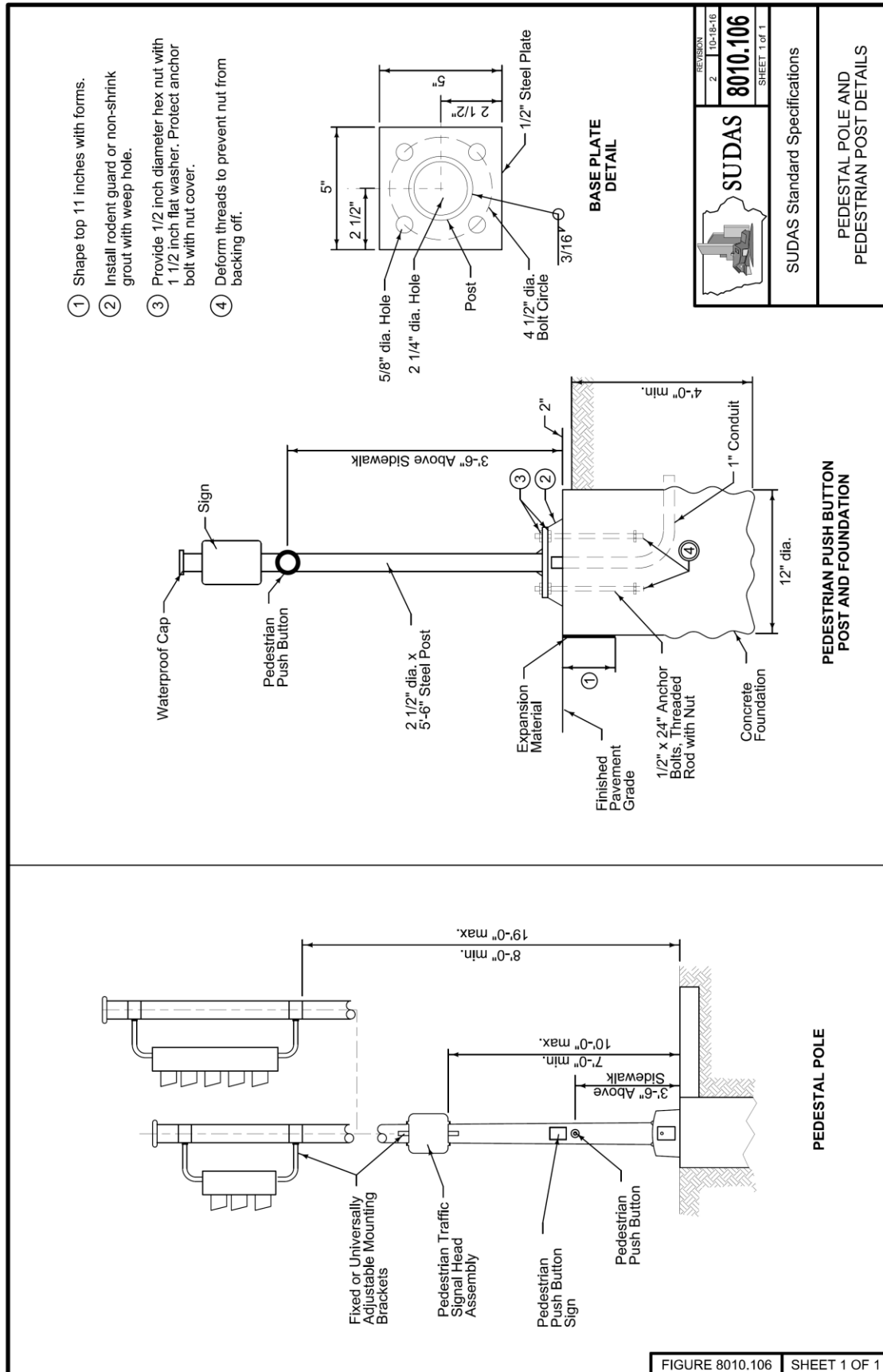


Figure 13A-5.07: Pedestal Pole and Pedestrian Post Details
[\(SUDAS Specifications Figure 8010.106\)](#)



C. Items Requiring Supplemental Specifications

A summary listing of items within [SUDAS Specifications Section 8010](#) requiring supplemental specifications to be provided by the designer includes the following:

- Composite handhole and cover - specify materials and dimensions.
- Foundations - specify dimensions and any conduit stubs needed for future use.
- Communications - specify all traffic monitoring equipment along with any fiber optic equipment and materials.
- Cabinet, controller, and emergency vehicle preemption - specify all relevant equipment.
- Traffic signal poles and mast arms - specify specialty finish for pole if necessary.
- Traffic signs - specify sheeting, sign dimensions, and mounting requirements.

Work Zone General Information

A. Introduction

This section provides information on establishing temporary traffic control in work zones, addressing the safe and efficient accommodation of all road users: motorists, bicyclists, pedestrians, and those with special needs. The information presented is based on standards and guidance in the 2009 Edition of the Manual on Uniform Traffic Control Devices (MUTCD). References to the MUTCD sign designations in this chapter are shown in parentheses, e.g. (W20-1).

Not all the recommendations in this chapter will apply to every circumstance faced by local agencies, and each unique situation may not be addressed. Modifications of the typical applications may be required to adapt to specific field conditions. Therefore, use engineering judgment, seeking the advice of experienced professionals and supervisors in difficult and complex interpretations. This information can be used as a reference for temporary traffic control in work zones on all city or county roadways. However, always check contract documents and local agency requirements for any pertinent modifications.

B. Importance of Quality Traffic Control

The value of proper traffic control through work zones cannot be overemphasized. Three major reasons for providing quality temporary traffic control can be identified:

1. **Safety:** Many crashes occur each year in Iowa work zones, resulting in death and injuries to motorists and workers. Appropriate levels of traffic control will help lessen the occurrence of work zone crashes.
2. **Liability:** Improper use of temporary traffic control, deficiency of devices, or negligence may result in legal claims against a contractor, agency, or even individual workers. Complying with accepted standards and guidance could help avoid and reduce possible legal actions.
3. **Responsibility:** Providing temporary traffic control in compliance with established practices is a requirement of the public trust; it's simply the right thing to do!

The MUTCD is incorporated into the Code of Federal Regulations and is recognized as the national standard for traffic control devices on all roads open to public travel in the nation. In addition, Iowa has adopted the MUTCD as the state standard (Iowa Code section 321.252 and Administrative Rule 761 - Chapter 130). Local agencies are required to adhere to the MUTCD requirements in Iowa Code Section 321.255. Always remember the MUTCD standard statements, "The responsibility for the design, placement, operation, maintenance, and uniformity of traffic control devices shall rest with the public agency or the official having jurisdiction," and "temporary traffic control plans and devices shall be the responsibility of the authority of a public body or official having jurisdiction for guiding road users." Even though the authority for placing temporary traffic control is sometimes granted to others (contractors, utilities, etc.), the responsibility for requiring properly signed work zones remains with the agency that has jurisdiction over that road or street.

C. Applicable Standards and References

The MUTCD presents minimum standards only. Iowa has adopted the MUTCD as the official standard for traffic control, but many applications and practices in Iowa exceed national standards. The user should check for recent revisions of the MUTCD and state and local policies before selecting an appropriate application.

- 1. National Requirements:** Other important federal requirements and guidance are available in Federal Highway Administration's (FHWA) *Standard Highway Signs* manual and the National Committee on Uniform Traffic Laws and Ordinances' *Uniform Vehicle Code*. Worker and flagger apparel recommendations and requirements from the American National Standards Institute (ANSI) have been adopted into the MUTCD. Information about worker and flagger apparel can be found through the International Safety Equipment Association (ISEA). Complying with the *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way*, also known as the Public Right-of-Way Accessibility Guidelines or PROWAG, is especially important when accommodating pedestrians. The US Access Board is an excellent source for background and supplemental accessibility information (www.access-board.gov). The Institute of Transportation Engineers' Traffic Control Devices Handbook also provides valuable supplemental guidance.
- 2. State Requirements:** When working on or near any road or street right-of-way where Iowa Department of Transportation (Iowa DOT) has jurisdiction, Iowa DOT requirements take precedence over this chapter.
- 3. Local Requirements:** Cities and counties may adopt ordinances and policies that apply to temporary traffic control - provided these meet or exceed the standards presented in the MUTCD. Verify local requirements before establishing any temporary traffic control on local roads and streets.

D. Work Duration

Work duration is a major factor in determining the number and types of devices used in TTC zones. The duration of a TTC zone is defined relative to the length of time a work operation occupies a spot location. The five categories of work duration and their time at a location are:

- Long-term stationary is work that occupies a location more than 3 days.
- Intermediate-term stationary is work that occupies a location more than one daylight period up to 3 days, or nighttime work lasting more than 1 hour.
- Short-term stationary is daytime work that occupies a location for more than 1 hour within a single daylight period.
- Short duration is work that occupies a location up to 1 hour.
- Mobile is work that moves intermittently or continuously.

Work Zone Set Up

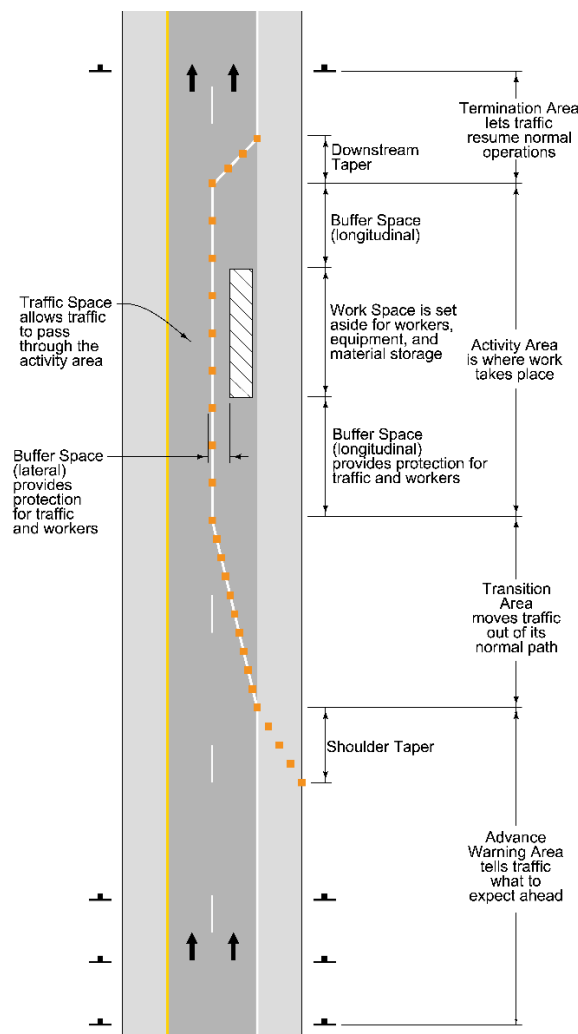
A. Major Elements

A typical work zone, designated with signs and various other traffic control devices, is defined as extending from the first advance warning sign or vehicle with amber, high-intensity, rotating, flashing, oscillating, or strobe light to an END ROAD WORK (G20-2) sign or other device beyond which traffic returns to normal paths.

Most work zones involving major traffic obstructions can be divided into four major areas:

- advance warning
- transition
- activity
- termination

Figure 13B-2.01: Work Zone Temporary Traffic Control - Major Elements



1. **Advance Warning Area:** Advance warning is crucial to safety, and every work zone should include this important feature. Without effective warning, road users cannot be expected to react properly. The advance warning area is that section of roadway where road users are informed about the activity ahead. Depending on the type of road, traffic volumes and speeds, and degree of obstruction, advance warning might consist of a
 - vehicle with amber, high-intensity, rotating, flashing, oscillating, or strobe light,
 - single sign, or
 - series of signs.

Vehicle hazard lights may be used to supplement amber, high-intensity, rotating, flashing, oscillating, or strobe lights (hereinafter called vehicle warning lights), but they shall not be used alone. Flags may be used to call attention to the advanced warning signs

When a series of signs is required, information is presented in this order:

- a. General information, such as ROAD WORK AHEAD (W20-1)
 - b. Description of activity or obstruction, such as RIGHT LANE CLOSED AHEAD (W20-5R) or ONE LANE ROAD AHEAD (W20-4)
 - c. Specific action, such as BE PREPARED TO STOP (W20-7b) or FLAGGER AHEAD (W20-7a)
2. **Transition Area:** In a transition area, traffic is directed from the normal, intended path to a new course, such as from one lane to another. To accomplish this, the MUTCD requires channelizing. Channelization, or redirection of traffic, is usually accomplished with tapers.
 3. **Tapers:** Part 6 of the MUTCD discusses tapers in detail. Several types of tapers are available for work zones, depending on circumstances:
 - Merging tapers are used for lane closures on multi-lane roadways.
 - Shifting tapers divert traffic to alternate paths without closing lanes.
 - Shoulder tapers can be used to delineate shoulder closures.

The recommended minimum length of all these taper types depends on the speed of approaching traffic and the width of the lane being closed. Lengths of merging tapers for various speeds are shown in Table 13B-2.01. Speed limit refers to the legally established and signed speed limit.

Two other taper types do not depend on traffic speed or lane width:

- one lane, two-way taper (used mostly for flagging or self-regulating)
- downstream (termination) taper

One hundred feet is the maximum recommended length for a one-lane, two-way taper, but a length of 50 feet can benefit flagging operations. Refer to the [Iowa DOT's Flagger's Handbook](#) for more details. At least 100 feet for each closed lane is recommended for a termination taper length. For merging taper lengths on multi-lane roadways, see Table 13B-2.01.

Table 13B-2.01: Merging Taper Lengths for Lane Closure*

Speed Limit (mph)	Taper Length (L) (ft)	Number of Devices	Spacing of Devices (ft)
20	80	5	20
25	125	6	25
30	180	7	30
35	245	8	35
40	320	9	40
45	540	13	45
50	600	13	50
55	660	13	55

* This table does not apply to one lane, two-way (flagger) tapers.

4. **Channelizing Devices:** Several channelizing devices are available for use in tapers, including cones, vertical panels, drums, and barricades.
5. **Activity Area:** The activity area of many work zones can be divided into three main parts:
 - a. **Buffer Space:** Buffer spaces are recommended wherever workers are exposed to high-speed moving traffic. Neither work activity nor storage of equipment, vehicles, or material should occur within a buffer space.
 - 1) **Longitudinal buffer spaces** are a safety protection for workers and road users. They give drivers space to recover in emergency situations. Like many other work zone dimensions, longitudinal buffer space is based largely on the traffic speed. Table 13B-2.02 includes buffer lengths for various traffic speeds and are applicable to all temporary traffic control situations. The length of the longitudinal buffer space used may need to be modified based on site conditions.

Table 13B-2.02: Longitudinal Buffer Space

Speed (mph)	Length (ft)
20-35	0-200
40	0-300
45	0-400
50	400
55	600

- 2) **Lateral buffer spaces** are especially effective in high-speed and heavy traffic situations where maximum possible separation of workers from moving vehicles is desired. Flaggers are often beneficial in these circumstances as well.
- b. **Work Space:** The work space is that area closed to traffic where maintenance and construction activities are accomplished. This area can be occupied by equipment, materials, and workers and should be made as secure and safe as possible.
- c. **Traffic Space:** Motor vehicles and other road users occupy the traffic space, also known as the open lane. Workers and equipment should respect this area and not intrude or otherwise hamper free movement of traffic in the open lane.
4. **Termination Area:** The termination area begins at the end of the work space and extends to the END ROAD WORK (G20-2) sign, if posted. This sign is optional, but is recommended by the MUTCD. A downstream or termination taper (50 to 100 feet) may be installed in this area for traffic guidance.

Temporary Traffic Control Devices

Traffic control devices are any signs, signals, markings, or other items used to guide, warn, and regulate traffic. Traffic control devices are the major means of communication for road users; thus it is most important that design, condition, and placement be proper at all times. All devices used in work zones shall comply with the provisions of the MUTCD. In addition, sign design must comply with the *Standard Highway Signs* manual. Do not install temporary traffic control devices until work is ready to begin. The MUTCD requires all temporary traffic control devices to be promptly removed or covered when no longer needed. Signs are the most common type of work zone traffic control device, categorized into three types:

- regulatory
- warning
- guide

The MUTCD requires all signs to be retroreflective or illuminated when used at night. Roadway lights are not sufficient as illumination sources. Supplemental nighttime warning lights may be required in pedestrian or recreational areas.

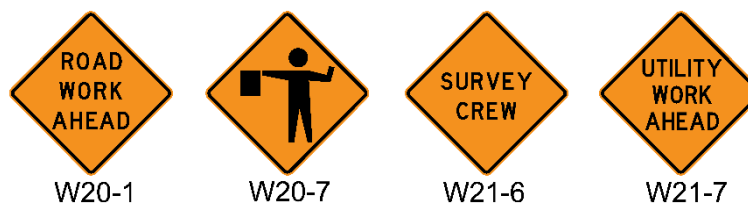
A. Regulatory Signs

Regulatory signs inform users about traffic laws and regulations. Because these signs impose legal obligations, they must be used properly and only with prior official authorization by the local agency. Regulatory signs are generally rectangular with a black legend and border on a white background. Exceptions include the STOP, YIELD, DO NOT ENTER, WRONG WAY, and ONE WAY signs. STOP (R1-1), ROAD CLOSED (R11-2), and SPEED LIMIT (R2-1) are all regulatory signs. Specific requirements for road closures are discussed in detail later in this chapter.



B. Warning Signs

Warning signs draw attention to conditions on or near the roadway that may not be readily apparent. These signs are generally diamond-shaped with an orange background and black lettering or symbols; although other colors are allowed for a few specific signs. Examples of common warning signs are the FLAGGER (W20-7a) and the ROAD WORK AHEAD (W20-1) sign. Advisory speeds on warning plaques are not enforceable; use for guidance only.



C. Guide Signs

Guide signs advise drivers and pedestrians about navigating through the work zone. These signs are normally orange with black lettering. An example of a guide sign is END ROAD WORK (G20-2).



G20-2

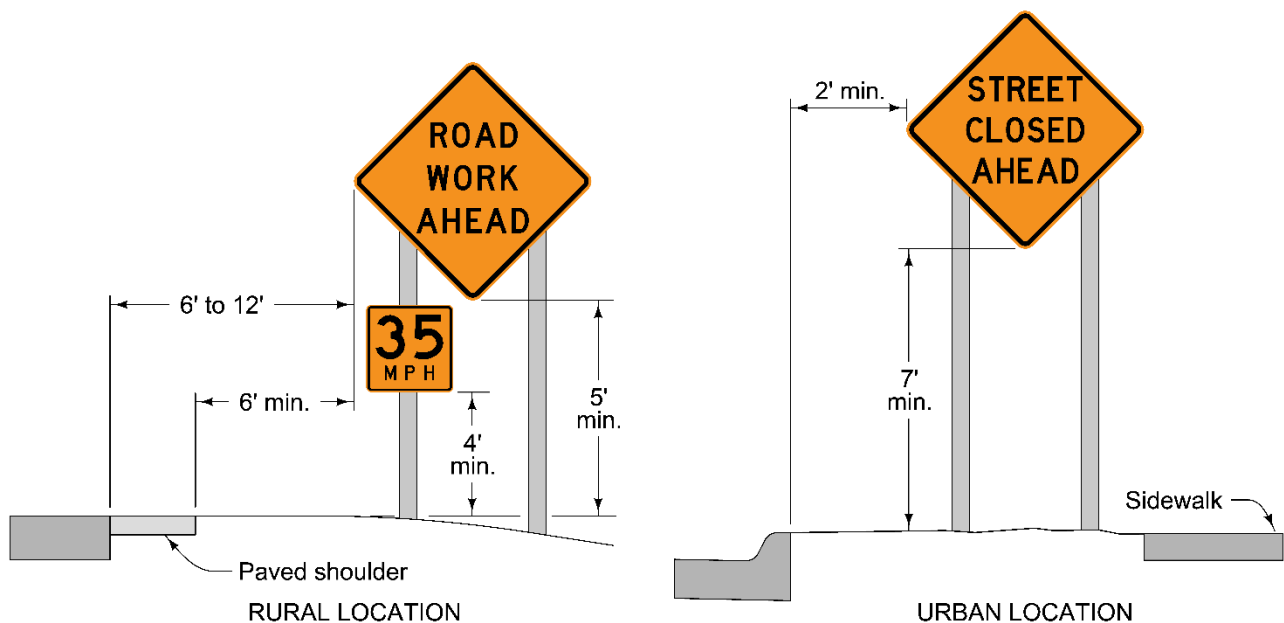
D. Sign Dimensions

Sign size and legend are critical for road user recognition and understanding. Based on traffic speed, use the following guidelines when deciding sign dimensions. For best performance, use larger signs, even in low-speed areas.

- **High speed roadway (35 mph and above):** Advance warning signs shall be at least 48 inches by 48 inches. In general, uppercase lettering should be at least 7 inches high.
- **Moderately low traffic volumes and speeds (25 to 35 mph):** The MUTCD allows 36 inches by 36 inches, with an uppercase lettering size of 5 inches.
- **Low speed local roads and streets (25 mph or below):** Smaller advance warning signs, 30 inches by 30 inches, may be allowed, with sign messages short and symbols clear in meaning.

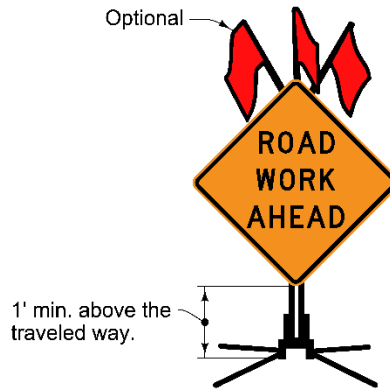
E. Sign Installation

Consider the position of signs relative to the roadway and the spacing between the signs when installing temporary traffic control. The MUTCD requires that long-term stationary work zones (more than three consecutive days in one location) use post-mounted advance warning signs. Minimum dimensions for post-mounted signs are shown on the figure below.



Supplemental plaques may be mounted 1 foot lower than the primary sign. If installed within the clear zone, sign supports shall be crashworthy or shielded. Signs should not be positioned on sidewalks or bicycle facilities in urban areas, and any signs with less than a 7 foot mounting height should not project more than 4 inches into pedestrian facilities.

Portable sign mounting is used for work zone applications lasting less than 3 days. The supports shall be crashworthy.



Several designs have been approved, but any used in the clear zone shall be crashworthy per the test and evaluation criteria of National Cooperative Highway Research Program (NCHRP) Report 350 or Manual on Assessing Safety Hardware (MASH). Fabric, roll-up, portable signs are popular because they are lightweight and easy to install. However, some designs are too flexible in windy conditions, degrading visibility. Flexible base portable signs that do not provide necessary stability in windy situations shall be adequately supported, or work activities must be terminated. Both the requirements for crashworthiness and adequate visibility shall be met with all work zone signs. Other installation methods for work zone signs include vehicle and barricade mounting. Do not allow post-mounted signs to encroach on sidewalks, shared use paths, or bike lanes or place portable signs on them unless those facilities are officially closed.

Vehicle-mounted signs should be high enough for adequate visibility for approaching vehicles, suggested at least 4 feet above the ground surface.



Barricade mounted signs shall be at least 1 foot above the traveled way. In addition, signs on Type III barricades should not cover more than 50% of the top two rails and not more than 33% of all three rails.

F. Spacing of Signs

Appropriate spacing is crucial for road users' reaction to work zone signs. Spacing depends on several factors, including speed of traffic, type of roadway, locations of intersections or major driveways, vertical and horizontal roadway alignment, and physical obstructions in the work area. If road users don't seem to be recognizing the signs, consider increasing the sign spacing and/or size and adding flags or warning lights.

The MUTCD contains guidance for minimum spacing of signs in Section 6C.04. A basic "rule of thumb" for warning sign placement is 4 to 8 times the speed limit in urban areas and 8 to 12 times the speed limit in rural locations. Table 3 illustrates these minimum guidelines. The positions of the signs should be adjusted for available sight distance.

Table 13B-2.01: Distance Between Signs

Speed Limit (mph)	Spacing (ft)
25	100
35	250
45	350
55	500

G. Channelizing Devices

Channelizing devices warn about work zone conditions and guide road users through or around the work area. Several types of channelizing devices are available, including cones, vertical panels, channelizers, tubular markers, drums, and barricades - with new types continually being developed and approved. Promptly repair, clean, or replace any devices that are damaged, dirty, or deficient in retroreflectivity.

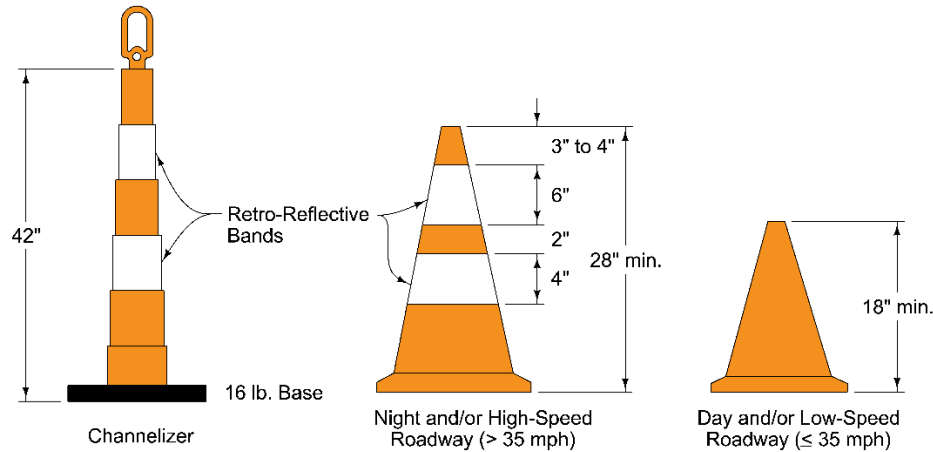
1. **Ballast:** Ballast is often required to maintain position and stability of channelizing devices, and proper placement and type of ballast is important. Follow these guidelines:
 - Never place ballast on top of channelizing devices; keep ballast on the lower part of the device.
 - Use sandbags or weighted bases, and do not use items such as rocks, broken concrete, etc., for ballasting.
2. **Spacing of Devices:** Like signs, spacing of channelizing devices in work zone applications depends primarily on traffic speed. A rule of thumb suggested by the MUTCD for maximum spacing is the speed limit when used in merging or shifting taper applications and twice the speed limit for tangent applications. Closer spacing should be considered where drivers might need more guidance, such as in horizontal curves or in low-speed applications.

Table 13B-2.02: Channelizing Device Spacing

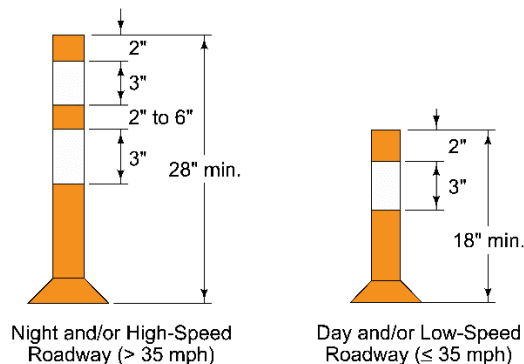
Speed Limit (mph)	Taper (ft)	Buffer (ft)	Work Space (ft)
25	25	50	50
30	30	60	60
35	35	70	70
40	40	80	80
45	45	90	90
50	50	100	100
55	55	110	110

3. Types of Devices:

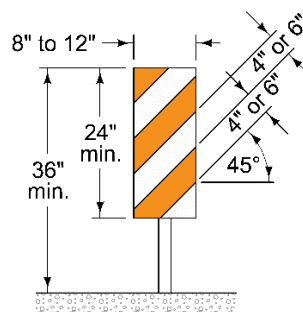
- a. **Cones:** Cones are required to be predominantly orange in color. Retroreflective striping is required for night use. To maintain proper position, ballasting as described earlier may be employed, or cones can be nested to increase weight and stability.



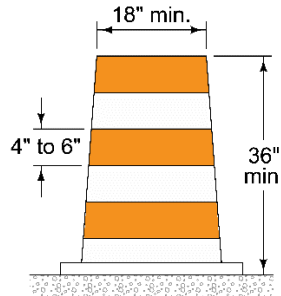
- b. **Tubular Markers:** Tubular markers have similar requirements as cones - predominantly orange, crashworthy, and retroreflective if used at night. Because of the narrow width (2 inch minimum), tubular markers are especially useful in restricted work areas. These devices must be securely ballasted or attached to the road surface to prevent movement.



- c. **Vertical Panels:** Vertical panels provide greater visibility for road users than some other channelizing devices and can still be used in narrow work zone applications. Panels shall also have alternating retroreflective orange and white stripes, 4 or 6 inches wide, sloping downward at an angle of 45 degrees in the direction vehicular traffic is to pass. If warning lights are used with vertical panels, they must be securely fastened to prevent dislodging if struck by an errant vehicle. Proper ballasting should be used to maintain stability.

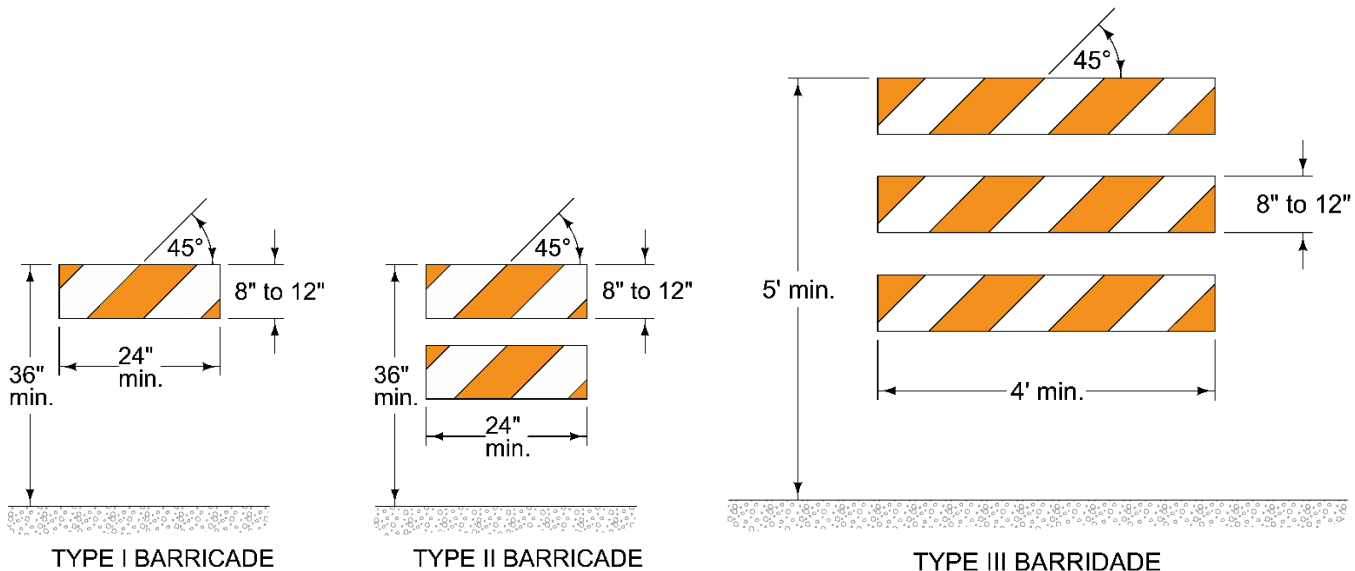


- d. Drums:** Drums are very effective traffic control devices, especially for long-term applications. These devices shall be made with lightweight, deformable materials and alternating 4 to 6 inch wide orange and white retroreflective stripes. Drums made of metal are not allowed, and tops shall be securely fastened to prevent accumulation of debris. Using ballast on top of drums is not acceptable.



- e. Barricades:** Barricades for work zone applications are available in three types: I, II, and III, differentiated primarily by the number of boards used. Barricades may be used individually or in groups to mark a specific condition. They may also be used in a channelization series, in either taper or tangent applications.

Type I barricades are generally used on conventional roads or city streets. Type I or Type II barricades are intended for work areas where traffic flow is maintained. Type II or Type III barricades are recommended on higher volume roadways. Type III barricades should be used to close or partially close a street or road. For complete closures, Type III barricades can be extended across the entire roadway or street or supplemented with fencing.



Using ballast, rocks, or broken concrete on top of barricades for stabilization is not allowed. Barricade rails shall feature alternating retroreflective orange and white stripes, 4 to 6 inches wide, sloping downward at a 45 degree angle in the direction traffic is expected to pass. As with vertical panels, properly placing the barricades is very important. If traffic is allowed to pass Type III barricades, retroreflective striping at the appropriate slope is required on both sides.

f. **Miscellaneous Devices for Channelizing:** The MUTCD describes several other devices that can be used in channelization of vehicular and pedestrian traffic in work zones.

1) **Arrow Boards:** As described in MUTCD Section 6F.61, arrow boards are signs with lighted elements capable of flashing or sequential displays. They are intended to be used with signs or other traffic control devices. The panels are rectangular and non-reflective black with yellow lights. The types of arrow boards used for temporary traffic control are:

- Type A: Suitable for low-speed urban streets
- Type B: Used on intermediate speed roadways or for maintenance and mobile operations
- Type C: Used for high-speed and high-volume applications

Table 13B-2.03: Minimum Requirements by Board Type

Board Type	Board Size	Legibility Distance	Number of Elements
A	48 x 24 inches	1/2 mile	12
B	60 x 30 inches	3/4 mile	13
C	96 x 48 inches	1 mile	15

Arrow boards can be mounted in various ways, but they should be mounted at least 7 feet above the ground, except on vehicle-mounted arrow boards, which should be as high as practical. Amber, high-intensity, rotating, flashing, oscillating, or strobe lights are required when panels are mounted on vehicles. Boards shall be able to dim 50% for night operations.

A caution mode is only allowed for two-lane or shoulder applications. The MUTCD does not allow a single arrow board to close more than one lane at a time.

Examples of the advance warning arrow board displays are below. Note right arrow is shown; left is similar.



Flashing Arrow (Merge Right)



Sequential Arrow (Merge Right)



Sequential Chevron (Merge Right)



Flashing Double Arrow (Merge Right or Left)



Flashing Caution

Flashing Caution

Alternating Diamond Caution

- 2) **Portable Changeable Message Sign (PCMS):** These devices have become more common in work zones on high-volume and high-speed roadways. A PCMS has a message panel, control system, power source, and transporting unit. Requirements and guidance for using these devices is presented in MUTCD Section 6F.60, and these provisions should be closely reviewed before using a PCMS. Effectiveness of a PCMS depends on how well drivers perceive and react to this device. Therefore, message visibility, length, clarity, and location to work activities are all critical for getting the most benefit from these devices. Current PCMS designs are not crashworthy, so place the devices off the roadway or behind a barrier.
- 3) **Shadow Vehicles:** Shadow vehicles, equipped with two amber, high-intensity, rotating, flashing, oscillating, or strobe lights mounted on the rear of the vehicle, can be used to warn traffic of the operation ahead. The distance between the work vehicle and the shadow vehicle may vary according to terrain, type of work, or other factors. Whenever adequate stopping sight distance exists, the shadow vehicle should maintain the minimum distance to the work vehicle and proceed at the same speed. The shadow vehicle should slow down in advance of vertical or horizontal curves that restrict sight distance. The work and shadow vehicle should pull over periodically to allow traffic to pass. When an adequate shoulder is present, the shadow vehicle should use it for travel. If the work and shadow vehicle cannot pull over to allow traffic to pass, a DO NOT PASS (R4-1) sign may be placed on the shadow vehicle.

Inspection and Documentation of Temporary Traffic Control

A. Documenting Inspections

Monitoring work zone traffic control should be a priority for all transportation agencies. Observations cannot be substantiated unless properly recorded. Inspections and documentation should always be current and accurate. Entries should be brief and factual (no opinions). Never erase mistakes; always cross out errors and make corrections (eraser marks in a diary may raise credibility concerns). Consider taking a video or photographs of the traffic control immediately after it's installed. The TTC Zone Checklist below can be used to help with this documentation process.

Temporary Traffic Control (TTC) Zone Checklist

Project: _____ Inspector's Name: _____

Date: _____ Time of Day: _____

Overall appearance of TTC Zone: _____

A. DRIVE THRU

- Maneuvers easy to follow?
- Adequate warnings of hazards?
- Signing clear?
- Traffic control devices sufficiently visible?
- Consistent with traffic control plan?
- Comments: _____

B. SIGNS

- Need to be removed/repositioned/covered?
- Need to be cleaned/replaced?
- Need additional signs?
- Existing signs need to be covered?
- Sign supports crashworthy?
- Adequate retroreflectivity?
- Correct size?
- Correct spacing?
- Consistent with traffic control plan?
- Comments: _____

C. CHANNELIZING DEVICES

- Adequate taper length?
- Device spacing?
- Need for additional devices?
- In need of repair/cleaning/replacement?
- Adequate retroreflectivity?
- Consistent with traffic control plan?
- Comments: _____

D. ARROW BOARDS

- All elements burning?
- Placement?
- Alignment?
- Capable of dimming?
- Consistent with traffic control plan?
- Comments: _____

E. PAVEMENT MARKINGS

- Conflicting markings?
- Retroreflective?
- Proper width and length?
- Comments: _____

F. FLAGGING

- High visibility clothing?
- Positioned appropriately?
- Proper equipment?
- Professional behavior?
- Comments: _____
- Corrective action required? _____
- Urgent? _____
- Within 3 days? _____
- Within _____ days?

Comments: _____

Signed: _____

B. Documenting Crashes in the Work Zone

When establishing any documentation procedure for work zone crashes, ensure supervisory and legal staff are aware of these records. Special documentation for work zone crashes should consider using this guidance:

- Develop and follow standard procedures.
- Establish and maintain a relationship with local law enforcement.
- Record all pertinent information, but only facts - not opinions.
- Use standard forms, if available.
- Supplement with photos and police reports.
- Describe any resultant revisions in temporary traffic control.
- Analyze any crash data at the completion of the project.

Other Work Zone Considerations

A. Flagging in Work Zones

Flagging is commonly considered one of the most dangerous jobs in temporary traffic control. Visibility and recognition by drivers are very important for safe and efficient flagger operations. Iowa has adopted even more stringent standards for flagging activities; these are described in the [Iowa DOT's *Flagger's Handbook*](#) and should be carefully reviewed before beginning any flagging activities.

B. High-Visibility Safety Apparel

All workers within the right-of-way who are exposed either to traffic (vehicles using the road/street for purposes of travel) or to work vehicles and construction equipment within the TTC zone shall wear high-visibility safety apparel that meets the Performance Class 2 or 3 requirements of the ANSI/ISEA 107 publication entitled "American National Standards for High-Visibility Safety Apparel and Headwear" or equivalent revisions.

C. Nighttime Operations

MUTCD Section 6G.19 offers guidance and advice for temporary traffic control measures for nighttime operations. Traffic volumes are reduced at night, but the number of impaired drivers may increase. Impaired drivers and reduced visibility mean that additional steps need to be taken to ensure safe and efficient working conditions. Work areas should be lighted to provide adequate visibility for work tasks and road users. Lighting shall not produce a disabling glare condition for approaching road users, flaggers, or workers. MUTCD Section 6F.82 describes specific requirements for lighting during night hours. Size and type of luminaries, mounting height, pole location, and positioning are all specified. The performance of the lighting should be observed immediately after implementation and then periodically during use. For flagging at night, comply with the [Iowa DOT's *Flagger's Handbook*](#).

D. Accommodation of Pedestrians and Bicyclists

The MUTCD requires all road users to be controlled throughout work zones, including motorists, bicyclists, and pedestrians. When urban streets are being improved, needs of pedestrians and bicyclists should receive as much attention as the needs of motorists.

- 1. Pedestrians:** The Americans with Disabilities Act of 1990 requires suitable access for persons with disabilities, even in work areas. Temporary traffic control for pedestrians should consider the special needs of disabled pedestrians, including those with visual disabilities. MUTCD Sections 6D.01 and 6D.02 provides guidance for planning temporary traffic control for pedestrians:
 - Pedestrians should not be led into conflicts with vehicles or work zone equipment.
 - A safe and convenient path should be provided for pedestrians, closely replicating existing sidewalks.

Pedestrians shall be notified in advance if sidewalks will be closed. The MUTCD requires standard signs to be supplemented with alternative warnings such as audible messages or instructions to aid visually impaired pedestrians, if such a need is identified. In addition, a firm, stable, and slip resistant surface should be provided throughout the entire length of any temporary pedestrian facility. There should be no curbs or abrupt changes in grade or terrain that could cause tripping or be an obstacle to wheelchair use.

To avoid conflicts with work zone activities, pedestrian travel may need to be diverted. Moving work equipment across designated pedestrian paths should be avoided or at least minimized. Temporary traffic barriers should be considered for safe separation when vehicular and pedestrian paths are relocated close together in long-term work areas. Mesh fencing, caution tape, rope, or chain strung between traffic control devices will not comply with standards in PROWAG and should not be used.

For additional guidance, refer to MUTCD Chapter 6D, [SUDAS Design Manual Chapter 12](#), and the Field Guide for Pedestrian Accommodation in Work Zones (FHWA Grant DTFH61-13-H-00025).

2. **Bicyclists:** Proper planning for bicyclists through and along work zones is as important as planning for motor vehicle traffic, especially in urban and suburban areas. According to the MUTCD, if the TTC zone affects the movement of bicyclists, adequate access to the roadway or shared use path shall be provided. On low volume roads or short work zones, standard traffic control practices are usually adequate. It is important to remove temporary signing, debris, and other obstructions from the edge of the roadway, bike lane, or shared use path after each day's work.

If a bike facility detour involves significant out of direction or distance travel, bicyclists will prefer to ride through the work zone. It is preferable to allow bicyclists to proceed as close to their original route as possible. On longer projects, a temporary bike lane or a wide travel lane may be needed. Advance work zone signs should not obstruct the bicyclist's path. Signs should be placed on the shoulder or planting strip rather than in the bike lane or on the shared use path. For additional guidance, refer to the AASHTO Guide for the Development of Bicycle Facilities, 4th Edition.

E. Road and Street Closures

Roadway improvements can generally be accomplished more efficiently and safely when vehicular traffic is detoured from the work area. However, access for local property owners and commercial interests must be maintained in many situations. Even though a street or road section is closed by official action, the agency must still consider appropriate temporary traffic control measures in that area even if only for local public traffic. Properly using specific regulatory signs is required.

Traffic control for closures can be considered in two different applications: outside the work area and inside the actual closed street or road section. MUTCD Part 6 includes specific requirements and guidance for temporary traffic control associated with closures.

When safety fence is needed, provide orange plastic mesh containing ultraviolet stabilizers with a height of 48 inches \pm 2 inches. Maximum aperture opening of a nominal 4.5 square inches. Connect to posts or drums to keep the safety fence upright and tight. In lieu of safety fence, Type III barricades may be placed continuously across the pavement, including shoulders if present.

While the messages on the following signs may seem similar, each must be used appropriately:

- ROAD (STREET) CLOSED (R11-2),
- LOCAL TRAFFIC ONLY signs (R11-3a), and
- ROAD CLOSED TO THRU TRAFFIC (R11-4).

MUTCD Section 6F.08 states that the ROAD (STREET) CLOSED (R11-2) sign shall not be used where road users are allowed to pass. When local access (vehicular or pedestrian) is allowed in closed street or road sections, be sure to maintain an appropriate level of temporary traffic control, including

- warning signs
- barricades and other channelizing devices at drop-offs, and
- fencing of excavations

F. Business Access

Providing clearly defined, continuous access to businesses along the construction area is critical to the success of a long duration traffic control setup. The only time a business access should be closed is when it falls within the activity area. When that situation occurs, consideration should be given to cross easements between properties and temporary access connecting adjacent properties. Signage indicating alternate business access points should be added to the temporary traffic control setup.

Work Zone Traffic Control References

American Road and Transportation Builders Association. *Pedestrian Accommodation in Work Zones: A Field Guide*. Based on FHWA Grant Agreement DTFH61-13-H-00025. February 2018.

International Safety Equipment Association. American National Standard for High-Visibility Safety Apparel and Accessories.

Iowa Department of Transportation. *Flagger's Handbook*. October 2015.

U.S. Access Board. *Proposed Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way*. Also known as the public Right-of-Way Accessibility Guidelines or PROWAG.

U.S. Department of Transportation. Federal Highway Administration. *Manual on Uniform Traffic Control Devices for Streets and Highways*. 2009 Edition.

U.S. Department of Transportation. Federal Highway Administration. *Standard Highway Signs (Including Pavement Markings and Standard Alphabets)*. 2004 Edition.

Wiegand, P., Richards, B. *Temporary Traffic Control Handbook*. 2016 Edition.

